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Prevalence and determinants of overweight/obesity among school-aged adolescents in the United Arab Emirates: a cross-sectional study of private and public schools

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ABSTRACT

Objectives To estimate the prevalence and predictors of obesity among adolescents in the United Arab Emirates.
Design Cross-sectional study.
Setting Private and public secondary schools.
Participants Adolescents aged 13–19 years; 434 (46.6%) from private schools and 498 (53.4%) from public schools.
Measures Self-report questionnaires were used to assess adolescents' sociodemographic factors, fruit/vegetable (F/V) intake and physical activity. Participants' weight, height, waist circumference (WC), hip circumference and body fat percentage (%BF) were measured, and waist-to-height ratio (WHtR), waist-to-hip ratio (WHR) and body mass index (BMI) were calculated. Overweight/obesity was determined by BMI ≥85th percentile for age, abdominal obesity (AO) (WC, WHtR and WHR) and %BF.
Results A total of 34.7% of participants were overweight/ obese (BMI ≥85th percentile) and 378 (40.6%) had high %BF. AO was noted in 47.3%, 22.7% and 27.1% of participants, based on WC, WHR and WHtR, respectively. Significantly more participants from public schools were overweight/obese (37.8% vs 31.1%) and had greater AO (based on WC, WHR, WHtR) compared with those from private schools. Predictors of obesity based on BMI were: consuming less than five servings of F/V (adjusted OR (AOR) 2.41, 95% CI: 1.73 to 3.36), being physically inactive (AOR 2.09, CI: 1.36 to 3.22) and being men (AOR 3.35, 95% CI: 2.20 to 5.10). Predictors of AO were being men (WC: AOR 1.42, 95% CI: 1.01 to 2.00; WHtR: AOR 2.72, 95% CI: 1.81 to 4.08); studying at public school (WHR: AOR 1.67, 95% CI: 1.06 to 2.66); being Emirati (WHR: AOR 0.62, 95% CI: 0.43 to 0.90); consuming less than five servings of F/V (WC: AOR 1.71, 95% CI: 1.27 to 2.30; WHtR: AOR 1.46, 95% CI: 1.05 to 2.03), and being physically inactive (WC: AOR 1.63; 95% CI: 1.13 to 2.35).
Conclusions Focused interventions are needed to combat obesity while considering AO indicators and BMI to diagnose obesity in adolescents.

INTRODUCTION

Adolescence is a transitional developmental period characterised by changes in physical, intellectual, social and emotional

Strengths and limitations of this study

► This study examined prevalence and determinants of obesity using different obesity indices (body mass index, abdominal obesity and body fat percentage) in a representative sample of adolescents from private and public schools.
► This study used a cross-sectional design; therefore, causality cannot be assumed.
► In addition, we cannot rule out the potential effect of confounding factors that may influence obesity outcomes, such as participants' genetic composition, school dietary practices/policies, social factors and participants' full dietary intake.

health. Optimal growth during adolescence is important for maintaining good health throughout the life course. Obesity among adolescents is a serious health problem and public health issue that demands urgent attention.[1] Globally, the prevalence of overweight/ obesity has increased among children and adolescents. For example, the global prevalence was 4% in 1975, whereas the 2016 estimate was over 18%; this increase was similar among boys and girls (19% and 18%, respectively).[2] Increasing overweight and obesity rates are important public health issues for Middle Eastern and North African countries, especially as rapid increases in obesity have been observed among children and adolescents.[3] A large-scale epidemiological study (n=44 942) conducted in Ras Al Khaimah, United Arab Emirates (UAE), confirmed obesity was steadily increasing in those aged 3–18 years; each year an additional 2.36% were classified as obese and 0.28% as extremely obese.[4] In 2014, a global action plan that aimed to prevent and control non-communicable

diseases was adopted by the World Health Assembly.[1] This action plan highlighted the importance of measures to address obesity rates globally, including among children and adolescents. Many countries have reflected the need to focus on reducing and preventing obesity among young people in national policies and strategies; for example, the UAE included obesity among children as an indicator in the Vision 2021 National Agenda.[5]

In addition to causing health problems in childhood and adolescence, overweight and obesity among young people can have long-term health impacts into adulthood (eg, cardiovascular disease, insulin resistance, type 2 diabetes mellitus, psychosocial complications).[6] Childhood obesity can also predict obesity in adulthood. A long-term follow-up study indicated efforts to influence body mass index (BMI) over the life course should begin early (eg, before age 6 years), and noted the progression toward a high BMI begins in adolescence for boys and young adulthood for girls.[7 8] These studies highlighted that early intervention is important to prevent increased BMI and associated health risks, which also contribute to increased healthcare expenditure.[7 8]

Various external factors that influence obesity have changed in recent years, such as rapid changes in dietary practices (eg, fast food, processed foods), extensive use of technology (eg, the internet and mobile devices) and increasingly sedentary lifestyles. Such developments have been associated with high obesity rates among adolescents, especially in developing countries.[9] In particular, the rapid socioeconomic transition in Middle Eastern and North African countries has resulted in increased urbanisation and drastic lifestyle changes, manifested in low physical activity and unhealthy dietary practices.[3] These factors combined with the growing fast food industry have led to various nutritional-related chronic conditions among adolescents, including obesity.[9]

The UAE has also witnessed rapid economic development and corresponding changes in lifestyles, leading to a marked increase in obesity in children/adolescents. Recently, the Global School-based Student Health Survey reported the obesity prevalence in the UAE youth population (aged 13–15 years) was 16.2%.[10] Previous cross-sectional studies from different cities across the UAE have also shown increased rates of obesity in adolescents, with the reported prevalence ranging from 18.9% in Abu Dhabi[11] to 35% in Dubai.[12]

Given the increased prevalence of obesity, it is important to clarify factors that contribute to obesity. School type (eg, public, private) may be a key determinant of obesity, as students spend much of their day in school. Previous studies investigated differences in obesity rates between public and private schools. For example, one study found that many students attending public schools were obese and had low physical activity, low fruit and vegetable (F/V) consumption, and low intakes of water, fibre, vitamins and minerals.[13] Another study found that children attending public schools had a high BMI and a greater likelihood of being overweight compared with children attending

private schools.[14] However, other studies have reported opposite trends. Studies conducted in different countries such as Pakistan, Kenya and India, all reported private school students had higher rates of obesity compared with those attending public schools.[15–17] Another study conducted in Shanghai also reported more students at private schools were overweight compared with those at public schools.[18] That study noted that this difference may be explained by diet, socioeconomic status, school environment and factors related to infancy.

Most previous studies that investigated the prevalence of obesity in the UAE did not consider school type and other potentially associated factors. The majority of available studies[4 11 12] only used BMI as indicator of obesity in school-aged adolescents and did not include other parameters such as abdominal obesity (AO) indicators and body fat percentage (%BF). Relying on BMI only does not provide a realistic and comprehensive picture of obesity in adolescents.[1 2] By mapping and rigorously assessing adolescents' obesity-related health status, healthcare providers, policymakers, schools and families will be able to collaborate to develop appropriate evidence-based approaches to promote adolescent health.

This study explored the epidemiology of overweight and obesity in the adolescent population and compared obesity figures between private and public schools. We also aimed to determine factors that contributed to overweight and obesity in participants, using BMI, AO and %BF indicators. Factors measured included sociodemographic data for age, gender, nationality, parents' level of education, employment (employed/unemployed), self-reported income (below average/average/above average), school type (public vs private) and lifestyle factors (F/V intake, physical activity levels).

SUBJECTS AND METHODS
Study design and setting
We adopted a quantitative correlational design. The sample was drawn from intermediate and high schools (secondary education) that were randomly selected from lists obtained from the Ministry of Education and other private/public school governing bodies in the UAE's seven emirates (Sharjah, Dubai, Abu Dhabi, Ajman, Ras Al Khaimah, Fujairah and Umm Al Quwain). Recent statistics from the Ministry of Education (2018)[19] showed the UAE has fewer public schools than private schools (619 public vs 643 private schools). Similarly, in terms of secondary schools (study population), the UAE has more private (n=257) than public schools (128).[19] This study was reported according to the Strengthening the Reporting of Observational Studies in Epidemiology checklist for reports of cross-sectional studies (see online supplemental file 1).

Participants and sampling
This study used one-stage cluster sampling of private and public schools. To obtain a representative sample,

a simple random sampling technique was used to select 10 schools from the public cluster and 15 schools from the private cluster. Cluster sampling is cost-effective and recommended when it is difficult to compile a sampling frame that includes all elements of the study population.[20]

A convenience sample of classes from grades 9–12 was chosen by the principals of the selected schools based on students' availability. All students in those classes were invited to participate in this study. Convenience sampling was justifiable in our situation as it increased the cooperation of school principals and staff in data collection. The principal of each school provided access to classes depending on the class schedules, students' availability and willingness of school personnel to facilitate data collection. Furthermore, selected schools requested that data collection procedures did not interrupt the planned educational activities which were set at the beginning of the academic year (eg, examinations' schedules, physical activity classes and other extracurricular activities).

The sample included male and female students from grades 9–12 in private and public schools (aged 13–19 years) of any nationality whose parents provided consent for them to participate. We excluded students with chronic diseases (eg, type 2 diabetes, cancer and mental health conditions) based on information from students' school records. This was because management of chronic diseases requires following special lifestyles and dietary practices that may affect the study's anthropometric measurements.

We used a standard sample size estimation method to obtain the sample size for a proportion data.[21] Based on an overweight/obesity prevalence of 40% among UAE adolescents,[4] a 3% margin of error, 95% CI and a significance level of 0.05 (two tailed),[21] a total of 1024 participants were needed. The 40% obesity prevalence rate used for this calculation was based on recent evidence of an increased prevalence of obesity in adolescents and rates reported in similar studies that included large populations of UAE school-aged adolescents from all nationalities, which was similar to our population.[4 11 12] An additional 100 participants were included to allow for non-responses and control for the design effect associated with cluster sampling, where less precise information is anticipated because people in a cluster tend to be more alike.[20] The larger sample size also increased precision during multiple comparisons in the statistical analyses and aided in controlling for possible confounding variables.[21]

Data collection

Figure 1 presents a flowchart of the data collection process. Participating students completed a self-report questionnaire that included questions about sociodemographic characteristics, F/V intake and physical activity. This was followed by collection of anthropometric measurements. Trained research assistants administered the questionnaire in the selected classrooms. Participating students were then directed to the on-site school clinic where anthropometric measurements were taken by the research team using

standardised techniques. The same research team administered the questionnaire and took the anthropometric measurements to maintain consistency and uniformity in the data collection process across different sites. Data were collected from September 2018 to May 2019, which was a regular school period excluding the summer holiday. In the UAE, there are no large seasonal variations during this part of the year and the temperature falls within an acceptable range; therefore, we anticipated no seasonal differences in anthropometric measurements.

Measurements

The self-reported questionnaire included sociodemographic data (age, gender, nationality and type of school (private vs public), parents' level of education, employment (employed/unemployed) and self-reported income (below average/average/above average)).

Physical activity

Participants' physical activity was recorded using the Physical Activity Questionnaire for Adolescents (PAQ-A). This tool is a 7-day recall self-report questionnaire with 9 items.[22] The PAQ-A was originally developed to evaluate physical activity levels among high school students (aged 14–19 years). Responses are on a 5-point Likert scale, and the 9 items are summed to give a total physical activity score. A high mean score indicates a high level of physical activity, and a cut-off score <2.75 is considered inactive. The English version of the PAQ-A has high reliability (Cronbach's alpha: 0.77–0.88) and high concurrent validity.[23] The Arabic version of the scale demonstrated good reliability and validity parameters when used in Arabic children and adolescents.[24] The estimated completion time for the PAQ-A is 20 min.[23]

F/V intake

F/V intake was assessed using the National Cancer Institute (NCI) Fruit and Vegetable Screener.[25] This instrument covers the frequency/amount consumed of specific items. These include: 100% fruit juice, fruit (eg, fresh, canned, frozen), fried potatoes (eg, French fries), other potatoes, dried beans, other vegetables and tomato-based sauces (eg, pasta, pizza). The instrument also evaluates the frequency of consumption of vegetable combinations (eg, sandwiches, salads, casseroles/stews, stir-fries). We calculated servings per day using NCI standard scoring algorithms.[26] The English version of the NCI has been reported to have excellent reliability and validity in both adults and adolescents.[27] The scale also had acceptable reliability (Cronbach's alpha: 0.82) and predictive validity among Saudi young adults.[27] An F/V intake of less than five servings was considered a low intake.

Obesity-related anthropometric measurements and indices

Anthropometric indices included height (cm), weight (kg), waist and hip circumferences (WC and HC, respectively), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) and %BF. For these measurements, students removed their shoes and wore minimal lightweight clothing as per WHO guidelines.[28] Participants' height (to the nearest 0.1 cm)

Phase I:
Participant selection and sampling
Ethical approval by concerned parties
Random selection of schools through cluster sampling (private and public schools)
Inviting selected schools to participate by the Ministry of Education
Inviting 1124 students (grades 9 -12) from the selected schools to participate via
convenient sampling

Phase II:

Data collection

Administering the surveys: General demographics, physical activity questionnaire
for adolescents, fruit and vegetables intake questionnaire
Measuring anthropometric indicators of obesity: height, weight, waist
circumference, hip circumference & body fat percentages through body
composition analyzer (TANITA)

Phase III:

Statistical analysis

Generating descriptive statistics (prevalence of obesity-body mass index,

abdominal obesity, and body fat percentage)

Exploring the associations between study variables

Exploring the independent determinants of obesity indices through multivariate
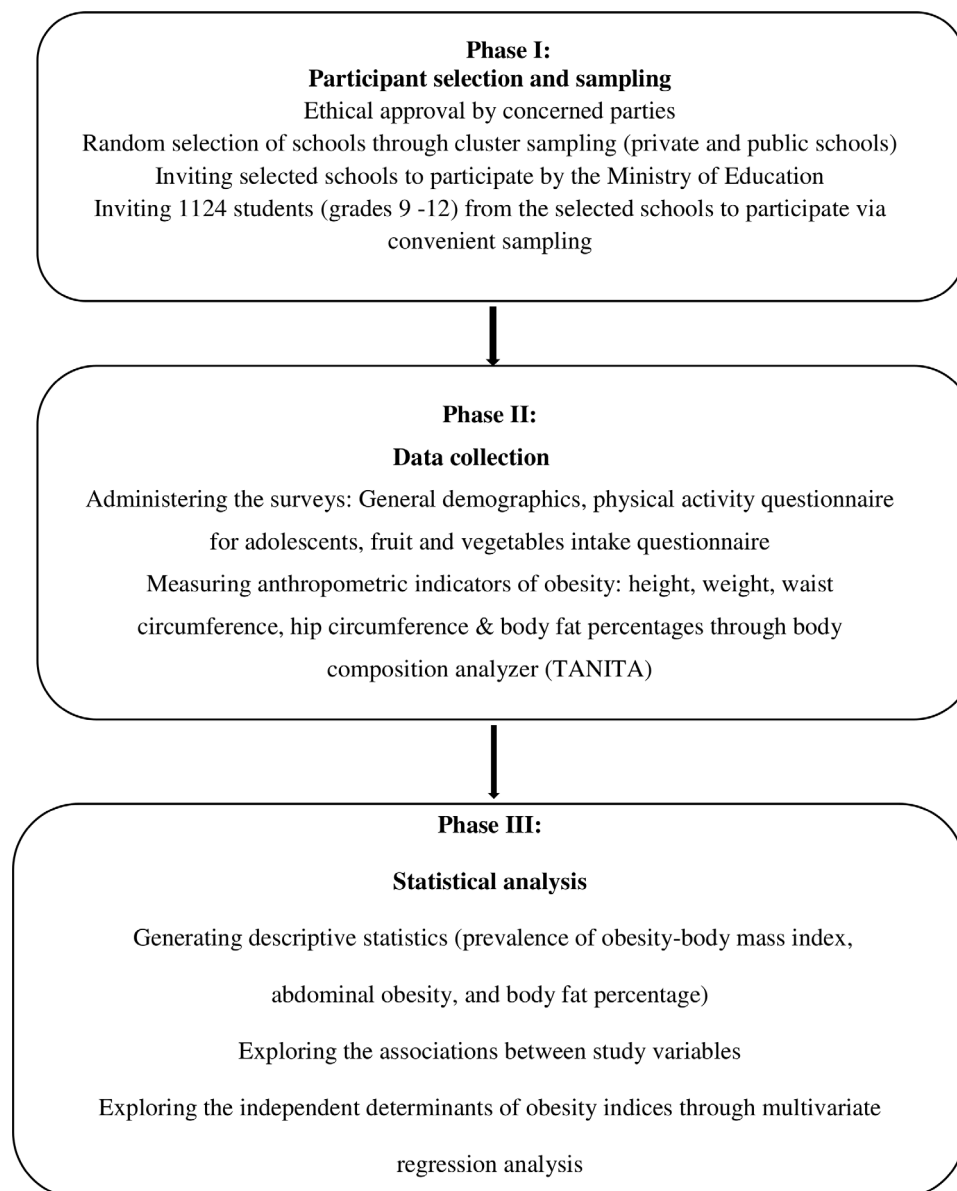
regression analysis

Figure 1 Flow diagram of data collection process and analysis.

and weight (to the nearest 0.1 kg) were measured using a telescopic measuring rod (Seca 220) for column scales. Two measurements for WC and HC were recorded for each participant using an inextensible anthropometric tape (Seca 201). These measurements were taken while participants stood erect with their arms by their sides and feet close together.

AO indices included: WC, WHtR and WHR. For WC, a cut-off of above the 90th percentile for age indicated AO.[28] Participants' WHtR was calculated by dividing their WC by height, and a cut-off value of 0.5 was used to define AO.[28 29] WHR was calculated by dividing the WC by HC (WHO, 2008), with a cut-off value of 0.85 used to define AO.[28] BMI (weight in kg divided by height in m^2) was calculated and classified according to WHO criteria: underweight=BMI <3rd percentile; normal weight=BMI between the 3rd and 85th percentiles; overweight=BMI between the 85th and 97th percentiles; and obesity=BMI >97th percentile.[30]

A BMI at or above the 85th percentile for adolescents was adopted to classify participants as either overweight/obese or underweight/normal, as this was widely used in similar epidemiological studies[4 11 12] and recommended by international organisations (eg, WHO, Centers for Disease Control and International Obesity Taskforce) to define obesity.[30–32] However, because there are clinical limitations in using BMI to estimate obesity in adolescent populations and the lack of a gold standard to define obesity,[33] we also reported other obesity indices including AO indicators (WC, WHtR, WHR) and %BF. This combination was critical to provide valid and reliable obesity estimates in our adolescent population.

Participants' %BF was measured using the body composition analyser (TANITA MC 780 multi-frequency segmental body composition analyser). This device measured participants' body composition parameters by evaluating differences in impedance of body components (eg, muscle and lean tissue).[34] Various body composition parameters are

automatically calculated, including total body muscle and fat mass, total body water, total body fat and water ratios, muscle mass of the arms/legs, BMI and basal metabolic rate. This technology has been shown to be valid and reliable.[34][35] Standardised %BF cut-off ratios were used with 25% for boys and 30% for girls.[36]

Data analysis

We used RStudio Desktop V.1.3.1093 for all statistical analyses, including mixed-effects logistic regression. Descriptive characteristics were calculated (frequency, percentage, mean and SD). Next, we compared differences in categorical sociodemographic variables by school type (private vs public) using X^2 tests.

To address the clustering within schools, simple and multiple mixed-effects logistic regression analyses were conducted. The model included the random effect of schools using R package 'lme4'[37] to determine the factors that predict obesity indicators (BMI, AO and %BF). The factors that were assessed were sociodemographic variables, school type, physical activity and F/V intake. Variables with a p value of ≤0.20 in the simple regression analysis were included in the multivariate regression model (gender, nationality, school type, F/V intake and physical activity). Results of the mixed-effects multiple logistic regression models were expressed as ORs with 95% CIs, and p values less than 0.05 (two sided) were considered statistically significant.

RESULTS

Participants' characteristics and obesity-related indices

Table 1 presents participants' characteristics. Of the 1124 adolescents who were recruited and met the inclusion criteria, 932 participants had complete data (82.9% response rate): 434 (46.6%) attended private schools and 498 (53.4%) attended public schools. Participants who had missing and incomplete data were eliminated from the analyses. The most common reason for not participating was lack of interest in this study.

Participants' average age was 15.8±1.43 years; 311 (33.4%) were men and 621 (66.6%) were women. The majority of the participants were UAE nationals (61.1%). More than two-thirds of participants' mothers were not employed (n=682, 73.2%) and the majority (60%) had an average family income (based on participants' self-report). Participants' mean F/V score was 3.1±1.83, with 504 (54.1%) reported having less than five F/V servings. The mean physical activity score was 2.3±0.71; 79.7% of participants were classified as inactive.

The prevalence rate of overweight/obesity was 34.7% (n=323) (BMI ≥85th percentile), and rates for AO were 47.3%, 22.7% and 27.1% as evaluated by WC, WHR and WHtR, respectively. Moreover, 378 (40.6%) participants had excess body fat as estimated by %BF using TANITA (M=27.6%, 12.0%) (table 1).

Private versus public schools

Table 2 shows the associations between sociodemographic factors, lifestyle variables and obesity-related indices by

Table 1 Characteristics of participating adolescents (n=932)	
Characteristics	**Frequency (%) or mean±SD**
Gender	
Male	311 (33.4)
Female	621 (66.6)
Age (years)	15.8±1.4
Nationality	
UAE National	569 (61.1)
Non-UAE National	363 (38.9)
Type of school	
Public	498 (53.4)
Private	434 (46.6)
Mother's employment	
Employed	250 (26.8)
Unemployed	682 (73.2)
Economic status	
Below average	32 (3.4)
Average	559 (60)
Above average	341 (36.6)
F/V score	3.1±1.8
≥5 servings	428 (45.9)
<5 servings	504 (54.1)
PAQ-A	2.3±0.7
Active (mean score ≥2.75)	189 (20.3)
Inactive (mean score <2.75)	743 (79.7)
BMI (kg/m²)	61.8±33.0
Underweight	79 (8. 4)
Normal	530 (56.9)
Overweight	158 (17.0)
Obese	165 (17.7)
WC (cm)	76.8±13.3
Normal	491 (52.7)
Abdominal obesity	441 (47. 3)
WHR (cm)	0.83±0.07
Normal	720 (77.3)
Abdominal obesity	212 (22.7)
WHtR (cm)	0.47±0.08
Normal	679 (72.9)
Abdominal obesity	253 (27.1)
%BF	27.6±12.0
Normal	554 (59.4)
Above normal (excess body fat)	378 (40.6)

%BF, body fat percentage; BMI, body mass index; F/V, fruits and vegetables; PAQ-A, Physical Activity Questionnaire-Adolescents; UAE, United Arab Emirates; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

Table 2 Comparisons between private and public schools (n=932)

	Public schools n (%), mean±SD (n=498, 53.4%)	Private schools n (%), mean±SD (n=434, 46.6%)	P value*
Gender			0.694
Male	169 (33.9)	142 (32.7)	
Female	329 (66.1)	292 (67.3)	
Nationality			<0.001
UAE National	407 (81.7)	162 (37.3)	
Non-UAE National	91 (18.3)	272 (62.7)	
Mother's employment			0.123
Employed	144 (28.9)	106 (24.4)	
Unemployed	354 (71.1)	328 (75.6)	
Economic status			<0.001
Below average	30 (6.0)	2 (0.5)	
Average	374 (75.1)	167 (38.5)	
Above average	94 (18.9)	265 (61.0)	
F/V score	3.0±1.7	3.1±1.9	
≥5 servings	197 (45.4)	231 (46.4)	0.761
<5 servings	237 (54.6)	267 (53.6)	
PAQ-A score	2.2±0.70	2.2±0.6	
Active	403 (81)	340 (78.3)	0.320
Inactive	95 (19)	94 (21.7)	
BMI (kg/m^2)			0.001
Underweight	44 (8.8)	35 (8.1)	
Normal	266 (53.4)	264 (60.8)	
Overweight	77 (15.5)	81 (18.7)	
Obese	111 (22.3)	54 (12.4)	
WC (cm)	78.5±15.0	74.80±11.0	0.028
Normal	247 (49.6)	247 (57.0)	
Abdominal obesity	251 (50.4)	187 (43.0)	
WHR (cm)	0.83±0.07	0.83±0.06	
Normal	372 (74.7)	348 (80.2)	0.040
Abdominal obesity	126 (25.3)	86 (19.8)	
WHtR (cm)	0.48±0.08	0.46±0.06	
Normal	333 (66.9)	346 (79.7)	0.001
Abdominal obesity	165 (33.1)	88 (20.3)	
%BF	27.6±10.4	25.3±8.9	0.510
Normal	301 (60.4)	253 (58.3)	
Above normal (excess fat)	197 (39.6)	181 (41.7)	

*P values significant at <0.05 based on X^2 tests.

%BF, body fat percentage; BMI, body mass index; F/V, fruits and vegetables; PAQ-A, Physical Activity Questionnaire-Adolescents; UAE, United Arab Emirates; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

school type. Public schools had significantly more Emirati students compared with private schools that had more expatriate students (p=0.001). In addition, significantly more participants from public schools had an average family income as compared with private schools (75.1% vs 38.5%). However, above average income was significantly more prevalent in private school (61%) as compared with public school (18.9%) (p=0.001). There was no statistically significant difference in F/V score between participants from public and private schools, with more than half of the participants in each school group consuming less than five F/V servings per day (54.6% vs 53.6%).

With regards to obesity indicators, significantly more participants attending public schools were overweight/obese (BMI ≥85th percentile) compared with those from private schools (37.8% vs 31.1%) (p=0.001). Moreover, participants from public schools had significantly higher AO indicators than their counterparts from private schools, as estimated by WHtR (p=0.001), WC (p=0.028) and WHR (p=0.040) (table 2).

Predictors of overweight/obesity: BMI, AO and %BF

Table 3 presents the results of the mixed-effects multiple logistic regression analysis with the random effect of schools. Predictors of being overweight/obese (based on BMI) were: being men (adjusted OR (AOR) 3.35, 95% CI: 2.20 to 5.10), consuming less than five servings of F/V (AOR 2.41, 95% CI: 1.73 to 3.36), and being physically inactive (AOR 2.09, CI: 1.36 to 3.22).

Students in public schools had significantly higher odds of AO based on WHR than those in private schools (AOR 1.67, 95% CI: 1.06 to 2.66). However, compared with expatriates, Emirati students were significantly less likely to have AO (WHR: AOR 0.62, 95% CI: 0.43 to 0.90) and a high %BF (AOR 0.54, 95% CI: 0.30 to 0.98). Male participants had a significantly higher odds of AO based on WC (AOR 1.42, 95% CI: 1.01 to 2.00) and WHtR (AOR 2.72, 95% CI: 1.81 to 4.08) compared with female participants. However, men had significantly lower odds of high %BF than women

(AOR 0.19, 95% CI: 0.12 to 0.33). Compared with ≥five F/V servings per day, less than five F/V servings was associated with significantly higher odds of AO based on WC (AOR 1.71, 95% CI: 1.27 to 2.30) and WHtR (AOR 1.46, 95% CI: 1.05 to 2.03). Furthermore, participants who were physically inactive had a significantly higher odds of AO based on WC (AOR 1.63, 95% CI: 1.33 to 2.35) compared with those who were physically active (table 3).

DISCUSSION

This study presents new information regarding the epidemiology and determinants of overweight/obesity among UAE school-aged adolescents. We found a considerably high prevalence of overweight/obesity among participants (34.7%), which supported previous UAE-based epidemiological studies that used BMI to define obesity.[4 11 12] The prevalence rates of overweight/obesity observed in our study were also consistent with studies from other Arab countries that used BMI to classify obesity, including Saudi Arabia (39%),[38] Kuwait (44.3%),[39] Lebanon (32.2%)[40] and Egypt (35%).[41] Conversely, studies conducted in Western countries reported lower obesity rates compared with our study. For example, the obesity rate among adolescents in European countries was between 22% and 25%, with the rate for Italy[42] being 23.3% (either overweight or obese) and rates

Table 3 Determinants of overweight/obesity based on BMI, abdominal obesity indicators and total %BF using mixed-effects* multiple logistic regression (n=932)

Dependent variable ⇒	BMI overweight/obese	Elevated WC	Elevated WHR	Elevated WHtR	High %BF
Independent variable ⇓	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Gender					
Female†					
Male	**3.35 (2.20 to 5.10)**	**1.42 (1.01 to 2.00)**	1.20 (0.85 to 1.71)	**2.72 (1.81 to 4.08)**	**0.19 (0.12 to 0.33)**
School					
Private†					
Public	0.60 (0.19 to 1.91)	1.07 (0.51 to 2.26)	**1.67 (1.06 to 2.66)**	1.34 (0.58 to 3.09)	0.52 (0.01 to 26.91)
Nationality					
Expatriate†					
Emirati	1.19 (0.81 to 1.75)	0.74 (0.52 to 1.04)	**0.62 (0.43 to 0.90)**	0.85 (0.57 to 1.26)	**0.54 (0.30 to 0.98)**
F/V serving					
≥5†					
<5	**2.41 (1.73 to 3.36)**	**1.71 (1.27 to 2.30)**	1.09 (0.79 to 1.50)	**1.46 (1.05 to 2.03)**	1.27 (0.78 to 2.09)
PAQ-A					
Active†					
Inactive	**2.09 (1.36 to 3.22)**	**1.63 (1.13 to 2.35)**	0.99 (0.67 to 1.48)	1.41 (0.92 to 2.17)	1.31 (0.76 to 2.27)

Numbers in bold are statistically significant (p<0.05).
*With the random effect of schools in the mixed-effects logistic regression.
†Reference category.
AOR, adjusted OR; %BF, body fat percentage ; BMI, body mass index; F/V, fruits and vegetables; PAQ-A, Physical Activity Questionnaire-Adolescents; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

for Greece being 19.1% (overweight) and 3.2% (obesity).[43] In the USA, 30% of adolescents were overweight/obese.[44]

In the present study, we also investigated other obesity indicators using AO indices. A concerning finding in our study was that AO indicators were high (WC 47.4%, WHR 22.8% and WHtR 27.2%). Visceral adiposity (as measured by WC, WHR and WHtR) is associated with an increased risk for earlier onset of metabolic disorders, and obesity-related morbidity and mortality.[3 8] There are variations in the literature on indices and values used to define AO in adolescents. For example, El-Kassas and Ziade[40] reported central obesity rates as evaluated by WC (41.8%) and WHtR (38.3%), whereas Al-Hazzaa et al[38] reported abdominal obesity using WHtR (35.9% for adolescent men and 30.3% for women). Abolfotouh et al[41] reported lower AO rates among Egyptian adolescents using WHR (16.1%), WC (4.5%) and WHtR (16.7%). These variations may be attributable to geographical location, genetic compositions and differing lifestyles, along with different cut-off values for interpreting AO results.

We found that the majority of the participating adolescents showed low physical activity levels (79.7%) and more than half (54.1%) had low F/V consumption (less than five servings). A recent study in UAE reported that only around 28% of Emirati adolescents had the recommended daily F/V intake.[45] As for the low levels of physical activity, our finding was consistent with a global estimate from the WHO that 81% of those aged 11–17 years did not meet daily physical activity recommendations.[46] It is noteworthy that physical inactivity and low F/V consumption in adolescence may persist throughout adulthood, which will increase the risk for chronic lifelong diseases later in life.[45 46]

Obesity in public versus private schools

Interestingly, we found a higher prevalence of obesity in adolescents from public schools than among adolescents from private schools (as measured by BMI). Differences in obesity rates between private and public schools have been reported in different countries in studies that used BMI. Similar to our findings, a study examining obesity rates among students in Palermo reported more public school students were overweight/obese compared with private school students (age 13 years: 40.8% vs 34.5%; age 15 years: 36.7% vs 30.2%).[13] However, other studies have reported contrasting findings. For example, a study in Kenya found that overweight/obesity rates were significantly higher (29.0%) among private school children than those from public schools (11.5%).[16] Similar trends of higher obesity rates in private schools compared with public schools were also observed in studies from India,[17] Pakistan[15] and Saudi Arabia.[38] A possible explanation for the inconsistent findings related to obesity rates between private and public schools could be differences in sociodemographic, environmental and cultural factors of attending students. For example, in the UAE, public schools are mostly attended by Emirati/national students whereas private schools are mainly attended by expatriates.[19] Therefore, different eating habits among cultures could contribute to these

findings. Furthermore, offering unhealthy items in vending machines, poor communication between food suppliers and school personnel, and limited physical activity facilities at schools may be correlated with body weight in adolescents.[47]

Similarly, in our study, public school students had significantly higher AO indicators (WC, WHR, WHtR) than private school students, which were consistent with our results for BMI values. Most previous UAE-based studies reported BMI rates and did not examine these obesity indicators. Similarly, many other studies that compared private and public schools in various countries did not compare AO indicators.[13 16–18] Accordingly, our results align with the recommendation from several previous researches suggesting that in addition to BMI, other anthropometric measurements should be included as indicators of obesity when screening adolescents in schools (eg, WC, WHC and WHtR).[28 33]

Interestingly, we found no significant difference between private and public schools in F/V consumption, with participants from both schools consuming less than the recommended number of daily F/V servings. This finding was inconsistent with previous comparative studies in which participants from public schools were found to consume less F/V compared with participants from private schools. For example, a school-based study from Ethiopia reported private school adolescents consumed significantly more F/V compared with their public school counterparts.[48] Similarly, a Brazilian study among school children aged 10–12 years (151 from public schools, 55 from private schools) showed public school participants had less F/V consumption than those from private schools.[49] A recent mixed-methods study from the UAE in which the majority of the sample was from public schools (24 public, 10 private) reported that only 28% of participants (n=620) met the WHO recommended daily F/V intake.[45]

Low consumption of F/V among school-aged adolescents is a common problem in different regions around the world.[46] Despite governmental guidance regarding adoption of a unified school nutritional policy across all schools in the UAE, there is no mechanism to encourage students to increase F/V consumption, and no monitoring mechanism to control types of food offered at school canteens. Examining environmental factors in both private and public schools (eg, types of snacks, beverages and content of students' lunch boxes) is recommended to better understand factors that contribute to the low F/V consumption among adolescents.

In our study, variations were noted in sociodemographic factors, nationality, and economic status between participants from private and public schools. These personal factors could play an important role in determining obesity rates in adolescents,[42 45 50] and therefore warrant further attention. Understanding the differences between private and public schools and the sociodemographic structure among adolescents is essential to build focused interventions that overcome barriers to healthy choices, especially in public schools that demonstrated increased obesity rate.

Determinants of obesity in participants

Physical activity and F/V intake were significant determinants of overweight/obesity, and showed independent relationships with different obesity indicators including BMI and AO (WC) after adjustment for all other variables in the model. Other studies have also shown that low levels of physical activity and unhealthy dietary practices predicted obesity among adolescents.[5] Rapid urbanisation and lifestyle changes in the UAE have increased exposure to fast/processed foods, sedentary lifestyle along with reduced F/V consumption and less physical activity.[3 13 17] Adolescents tend to spend most of their time playing computer games, doing homework and similar activities instead of spending time on exercise and sports.[45] Therefore, promoting healthy lifestyles for adolescents is a public health priority as the WHO recommends at least 60 min of moderate-to-vigorous physical activity each day, and a dietary intake of at least 400 grams of F/V each day (roughly equivalent to five servings of F/V per day).[51] Therefore, there is a need to enforce school policies that motivate adolescents to consume the recommended intake of F/V and engage in physical activities for better health outcomes. In the school environment, guidelines for food consumption inside schools, canteen food menus, and diet and exercise self-efficacy must be explored in future studies.[5 45]

Considering gender differences should also be highlighted, as male participants in our study were more likely to have higher BMI and AO (above normal WC and WHtR) and less likely to have high %BF compared with female participants. These findings were consistent with previous studies.[52 53] For example, significantly higher AO (measured by WHR and WC) was reported in adolescent boys compared with girls in Poland.[52] A cross-sectional, school-based study from China involving 830 boys and 796 girls aged 7–16 years showed that more boys were obese (based on BMI: 15.2% vs 6.9%) and boys had more central obesity (based on WC: 27.4% vs 11.7%) compared with girls.[53] Similarly, a study from Brazil involving adolescents from private and public schools showed boys had significantly higher BMI and AO (measured by WC) than girls.[54] Focused nutritional and physical activity programmes that reflect differences in lifestyles and perceptions of overweight and obesity among male adolescents are needed to promote better health outcomes.[53] Addressing this issue should involve multiple approaches targeting behaviour change (eg, food labelling, planning 'exercise-friendly' cities).

Consistent with previous findings,[14] our study showed adolescents in public schools were more likely to have AO (based on WHR) compared with those in private schools. AO has been associated with visceral fat mass, higher blood pressure and cardiovascular risk factor clustering, and should be measured along with BMI.[53 54] Among adolescents in Poland (141 boys and 168 girls aged 16–18 years), AO (WC, WHR, WHtR) was associated with family environment and modifiable lifestyle factors.[52] In our study, school type predicted WHR but not other important obesity indicators (eg, BMI), AO indicators (WC, WHtR) and %BF.

Therefore, our results regarding the effect of school type on obesity should be interpreted with caution. It is necessary to further investigate school environmental factors that could affect obesity in adolescents that consider obesity indicators in addition to BMI (eg, AO and %BF). Unlike many other countries, adolescents in the UAE come from diverse ethnic backgrounds; therefore, it is essential to investigate the possible contributions of lifestyle factors and parental and cultural practices to obesity.

In our study, being Emirati was associated with lower odds of AO (based on WHR) and high %BF compared with expatriates after adjusting for all other factors. These results need further verification as we did not collect information on participants' genetic composition, which could explain the differences observed between Emirati and non-Emirati adolescents who have diverse ethnic backgrounds. Such an investigation could also include all obesity indicators that were considered in this study (BMI, AO, %BF). This comprehensive research could provide evidence to support policymakers in their efforts to develop targeted interventions to combat the impact of obesity and its sequelae on health and well-being among adolescents.

The results from the present study concerning the high obesity prevalence and its determinants confirm the need for a strong and unified policy that considers students' diverse sociodemographic characteristics, school type and environment, and educational policies when initiating campaigns to combat obesity. Government health campaign interventions and strategies must be established at the federal level to support schools to identify overweight and obese adolescents and increase their awareness about the negative impact of obesity on health outcomes in adolescents.[5 45] A unified and collaborative health promotion model is needed where UAE health officials, teachers, parents, students and social media are involved as early as possible.[5 46 51] Furthermore, it is recommended that a surveillance system for obesity indicators for UAE adolescents is implemented to monitor the effectiveness of policies aiming to counteract obesity in this population.

Strengths and limitations

Our study is among the first in the UAE to provide valid estimates of obesity by considering BMI, AO indicators and %BF. This study highlights the urgent need to screen for obesity in our schools and emphasises the importance of health promotion campaigns and practices, especially in public schools. Further, the present findings focus on the importance of considering F/V intake and physical activity among adolescents as important predictors of obesity, which can be used to inform the direction of public health policy geared toward improving lifestyle of adolescents.

Many men in higher secondary education move to vocational and technical schools to build their skills, meaning fewer men stay in secondary schools.[19] This trend was reflected in this study where there were fewer male participants than female participants. This limits the generalisability of the study findings. Furthermore, we expected to recruit more adolescents from private schools as we invited more

private schools to participate; however, fewer private school participants were recruited for this study. This might be attributable to limited access given by school administration to classes in the private school cluster. Additional genetic, family, dietary pattern, stress and social factors should be examined in future studies to provide a comprehensive picture of the determinants of obesity in adolescents.

Despite the use of multiple obesity indices in this study to provide a valid picture of obesity among the UAE adolescent population, we used international cut-off points to classify participants into overweight/obese and normal/underweight groups. Given the overwhelming health risks associated with obesity in adolescents, there is an urgent need for a standardised definition of obesity in adolescents so that trends can be monitored and comparisons made between adolescents of different ethnic groups. Subsequently, established gold standards can be used to determine obese adolescents in clinical practice as well as in relevant epidemiological studies.

CONCLUSIONS

Our study showed a high prevalence rate of overweight/obesity among school-aged adolescents in the UAE (as measured by BMI), which confirms that obesity remains a widespread problem in UAE schools. This study underscores the importance of early screening of AO indicators (WHtR, WC and %BF) in the routine assessment of adolescents in addition to BMI, because AO is associated with high blood pressure, metabolic syndrome and cardiometabolic risks. It is also necessary to promote healthier lifestyles (eg, healthy eating by increasing F/V intake and increased physical activity) among children and adolescents to help curb obesity trends and prevent the development of chronic diseases. Additional studies are needed to observe the changes in obesity rates necessary to achieve the UAE Vision 2021 National Agenda of a world-class healthcare system by reducing the prevalence of obesity among children to support a healthy population in our schools.

Finally, obesity in adolescents is multifactorial; therefore, further research is needed to examine the contributions of modifiable and non-modifiable risk factors to obesity among adolescents in different cultures. Future research should establish cut-off values for different obesity indicators to yield better screening and diagnosis of obesity among adolescents.

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