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Trends in adolescent obesity in the Arab ethnic minority in Israel: an age-period-cohort analysis

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Abstract

Background The goals of the study were to analyze trends, age, period and cohort effects on overweight/obesity among Arab adolescents in Israel.

Methods A retrospective cohort study of 345,852 Arab adolescents aged 14–19 years between the years 2007–2022, and 283,420 Jewish adolescents' comparison group. Age effect was assessed by examining the effect of the age group (each year between 14 and 19 years), period effect by evaluation of the impact of the time period (two-year periods between 2007 and 2022), and birth cohort effect by estimating the effect of birth cohort (four/five-year birth cohorts between 1988 and 1991 and 2000–2003) on the prevalence of overweight and obesity.

Results There was an increase in the crude prevalence of obesity, and severe obesity (from 13.4% to 22.2%, and from 5.1% to 11.9%, respectively) among Arab adolescents. These numbers exceeded those in the matched Jewish group. The age effect was expressed by the constant decline in the adjusted Odds ratio (aOR) for obesity between the ages 14 (reference age) to 19 years (aOR = 0.30 (95% CI – 0.28–0.31)). The period effect was manifested by an increase in the aOR for obesity, reaching 1.88 (95% CI – 1.76–2.02) in 2021–2022. The cohort effect showed a steep increase in obesity prevalence from the cohort born in 1988–1991 (reference age) to the cohort born from 2000 to 2003 (aOR = 1.67 (95% CI – 1.57–1.77)).

Conclusion The combination of an increasing risk for obesity over time in the younger birth cohorts poses an increasing threat to future generations of adolescents. The findings could help focus future policy for vulnerable adolescent groups.

Keywords Adolescents, Obesity, Overweight, Trends, Age, period and cohort effects

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Background

Childhood obesity is strongly associated with both concurrent and long-term morbidity [1–9]. In the United States the prevalence of adolescent obesity has increased from 10.5% to 20.5% between 1990 and 2015 [10]. Many other countries manifest similar increasing trends in adolescent obesity, including China, in which the rate of obesity during the same period tripled from 3.3% to 10.2% [11], and Spain, in which it doubled from 2.2% to 4.3% [12]. A continuous increase has also been reported from Saudi Arabia and New Zealand, with increases up to 15.2% and 8.9%, respectively, in 2013 [13, 14]. Of note, several countries have succeeded in mitigating the prevalence of obesity in the last decade, among them Italy, Ireland, and the Czech Republic [15–17].

The prevalence of obesity varies among different ethnic groups from the same country. For example, in the United States, the prevalence of obesity among non-Hispanic blacks and Hispanic adolescents was higher than among both non-Hispanic whites and non-Hispanic Asian youth [18, 19]. Moreover, ethnic differences in trends of overweight and obesity rates were also reported, with a decline in these rates between 2007 and 2015 for Dutch children, compared to stable rates for Turkish, Moroccan, and South Asian children in the Netherlands [20].

In Israel, the prevalence and trends of adolescent obesity have been studied almost exclusively in the Jewish population, because they were based on height and weight measurements taken from adolescents before joining mandatory military service, from which the Arab population is exempted. These studies showed that the prevalence of adolescent obesity among Jewish males increased from 1.2% to 8.2% between the years 1967 to 2020 [21–24]. Sporadic reports on the prevalence of adolescent obesity in the Israeli Arab population showed higher rates than in the Jewish population, especially among 14–15 years old [25, 26]. There are no studies on trends in adolescent obesity in the Israeli Arab population, nor have adolescent obesity and associated factors been assessed at a nationwide level.

In this study we conducted a comprehensive analysis of trends in overweight/obesity among Arab adolescents in Israel between the years 2007–2022, including age, period, and cohort (APC) analysis to assess the effects of these factors on the prevalence of overweight/obesity, and assessment of socio-demographic factors that might be associated with overweight/obesity in this population. Similar analyses were conducted on a matched comparison group from the Israeli Jewish population to highlight unique overweight/obesity trends for Arab adolescents.

Methods

The Ethics Committee of Clalit Health Services approved the study (approval #0102-22-COM2) and exempted it from the requirement to obtain informed consents.

This was a retrospective cohort study, based on the centralized computerized database of Clalit Health Services (CHS), the largest HMO in Israel. CHS provides health services to approximately half of the Israeli population.

Study population

The study population was comprised of all Arab adolescents aged 14–19 years who are CHS members and whose medical records contained measurements of height and weight during the study period between January 1, 2007, to December 31, 2022. We included a Jewish comparison group matched by sex and socio-economic level to the study population using a 0.8:1 ratio.

Data collection

The study database consisted of data obtained from the computerized centralized database of CHS. It included height and weight, BMI (and BMI percentile), socio-demographic data (age, sex, ethnic sector, district of residence), and three levels of socio-economic status, based on participant's residential zip code.

Definitions of variables

BMI was defined as weight in kilograms divided by height squared in meters. Adolescent weight categories were defined as percentiles determined by the U.S. Center for Disease Control and Prevention (CDC), which were validated for Israeli adolescents [27], as 'underweight', 'normal', 'overweight', and 'obese' (BMI < 5th percentile, 5th-84.9th percentile, 85th-94.9th percentile, and ≥ 95th percentile, respectively) [28]. For this study, we defined 'severe obesity' as BMI ≥ 99th percentile [29].

For the APC analysis, eight consecutive 2-years study periods, from 2007 to 2008 to 2021–2022, and five consecutive four-years birth cohorts from 1988 to 1991 to 2004–2008, were defined, with the last birth cohort (2004–2008) encompassing five years.

Statistical analyses

Data cleaning and deletion of outlying BMI values were carried out. Statistical analyses, including the APC analysis, were conducted using the R software (version 4.3.1). First, we assessed the rate of missing BMI data using the total number of insured Arab adolescents aged 14–19 years during the study period. Then, we compared basic socio-demographic characteristics to examine the possibility of selection bias. Statistical differences were tested by the chi-square test/two proportions z- test and t-test/Mann-Whitney test for categorical and continuous variables, respectively.

APC analysis

We applied APC analysis to our data to assess the independent effect of age, period, and birth cohort on overweight/obesity/severe obesity among the study adolescents. APC is an accepted, valuable tool for disentangling the impact of three related factors: age (a stage in life), period (historical timeline), and cohort (a group born in the same time period), on health-related phenomenon, including obesity. To assess the period effect, we calculated the crude rates of overweight/obesity/severe obesity in each of the study periods, by dividing the number of cases by the total number of insured individuals aged 14–19 years, who had BMI measurements in the same period. For adolescents who had several measurements during the same study period, the mean BMI and BMI percentile measures for this period were calculated. We graphically presented the period effect separately for males and females. The crude age and cohort effects were analyzed and graphically presented for different cohorts and ages. To assess the adjusted APC effects, we built three APC models with age, period, and cohort effect as the main independent variables, and overweight/obesity as dependent variables. Since some of the participants had several measurements during the study period, we used mixed models with fixed effect for each of the APC components, and sex, district of residence, socio-economic status as covariates, and random effects to account for within person correlation. These APC models were applied separately to Arab and Jewish adolescents and the effects of the main variables were compared between these populations.

Results

Socio-demographic characteristics

Of 636,109 eligible Arab adolescents aged 14–19 during the study period, 345,852 (54.4%) had BMI measurements in their medical records. Comparison of the baseline characteristics of the adolescents with and without BMI measurements revealed no major differences between the groups, except for a slightly lower percentage of males (49.7% vs. 52.0%, respectively) (Additional File 1). The baseline characteristics of Arab adolescents with BMI measurements across the different study periods are presented in Table 1. The mean age of the participants varied between 16.5 and 16.8 years, males constituted 47.7–49.6% of the participants, and 60.9–65.2% of the participants were in the lower socio-economic class. Most participants, in almost all study periods, except for the first one, resided in the Jerusalem districts (above 20% each), while a low percent resided in the Central and Dan-Petah-Tikva districts.

Crude period effect

Table 2 presents the mean BMI, BMI percentile, and weight categories of the Arab participants throughout the study periods. The mean BMI and BMI percentile increased from 22.5 to 23.6 and 57.2 to 62.2, respectively over the 16-year study period. The mean BMI percentile increased steadily by 0.3 per study period between 2007 and 2008 and 2013–2014, after which the changes fluctuated. In addition, the crude prevalence of obesity and severe obesity in this population increased from 13.4% to 22.2% and from 5.1% to 11.9%, respectively, during

Table 1 Socio-demographic characteristics of Arab adolescents over the study periods

Characteristic	Study periods							
	2007-2008	2009-2010	2011-2012	2013-2014	2015-2016	2017-2018	2019-2020	2021-2022
Number of participants	65,718	81,783	63,614	62,614	64,055	75,340	65,431	39,746
Age at measurement								
Mean (SD)	16.5 (1.6)	16.5 (1.7)	16.5 (1.7)	16.5 (1.7)	16.6 (1.7)	16.6 (1.6)	16.8(1.6)	16.8 (1.6)
Median (range)	16 (14-19)	16 (14-19)	16 (14-19)	16 (14-19)	16 (14-19)	17 (14-19)	17(14-19)	17 (14-19)
Sex (Male), *N* (%)	32,026 (48.7)	40,368 (49.4)	31,291 (49.2)	30,713 (49.1)	31,233 (48.8)	37,333 (49.6)	32,284 (49.3)	18,955 (47.7)
Socio-economic status, *N* (%):								
Low	39,997 (60.9)	51,042 (62.4)	39,672 (62.4)	39,968 (63.8)	41,598 (64.9)	49,146 (65.2)	42,157 (64.4)	25,569 (64.3)
Middle	18,436 (28.1)	20,237 (24.7)	15,917 (25.0)	14,958 (23.9)	14,518 (22.7)	16,885 (22.4)	14,844 (22.7)	8,757 (22.0)
High	469 (0.7)	564 (0.7)	444 (0.7)	454 (0.7)	391(0.6)	385 (0.5)	356 (0.5)	209 (0.5)
No data	6,816 (10.4)	9,940 (12.2)	7,581 (11.9)	7,234 (11.6)	7,548 (11.8)	8,924 (11.8)	8,074 (12.3)	5,211 (13.1)
District of residency, *N* (%):								
Northern	16,439 (25.0)	14,348 (17.5)	12,029 (18.9)	12,108 (19.3)	12,203 (19.1)	12,699 (16.9)	11,085 (16.9)	6,916 (17.4)
Haifa	15,822 (24.1)	20,077 (24.5)	16,397 (24.8)	15,171 (24.2)	15,016 (23.4)	18,939 (25.1)	15,389 (23.5)	8,071 (20.3)
Sharon-Shomron	13,220 (20.1)	12,176 (14.9)	8,853 (13.9)	9,410 (15.0)	9,561 (14.9)	10,884 (14.4)	9,487 (14.5)	6,002 (15.1)
Central	1,004 (1.5)	1,582 (1.9)	1,155 (1.8)	1,297 (2.1)	1,386 (2.2)	1,237 (1.6)	983 (1.5)	544 (1.4)
Dan-Petah-Tikva	1,976 (3.0)	2,579 (3.2)	2197 (3.5)	1,864 (3.0)	1,786 (2.8)	2,209 (2.9)	1,886 (2.9)	1,229 (3.1)
Jerusalem	7,293 (11.1)	17,763 (21.7)	13,062 (20.5)	13,045 (20.8)	13,063 (20.4)	16,779 (22.3)	15,145 (23.1)	10,069 (25.3)
Southern	9,964 (15.2)	13,258 (16.2)	9,921 (15.6)	9,719 (15.5)	11,040 (17.2)	12,593 (16.7)	11,456 (17.5)	6,915 (17.4)

Table 2 Mean BMI, BMI percentile, and weight category of Arab adolescents, by study period

Study periods	2007-2008	2009-2010	2011-2012	2013-2014	2015-2016	2017-2018	2019-2020	2021-2022	*p*-value
Both sexes									
BMI, kg/m^{2}Mean (SD)	22.5 (4.4)	22.5 (4.3)	22.7 (4.7)	22.8 (4.8)	22.9 (4.9)	23.1 (4.8)	23.2 (5.0)	23.6 (5.6)	<0.001
BMI percentile Mean (SD)	57.2 (30.5)	57.5 (30.4)	57.8 (31.1)	58.1 (31.4)	58.5 (31.5)	61.3 (30.8)	60.8 (31.4)	62.2 (32.1)	<0.001
Weight categories *N* (%)									<0.001
Underweight[a]	2,683 (4,1)	3,282 (4.0)	2,652 (4.2)	2,721 (4.3)	2,928 (4.6)	3,125(4.1)	2,935 (4.5)	1,884 (4.7)	
Normal[b]	46,249 (70.4)	57,155 (69.9)	43,448 (68.3)	41,849 (66.8)	42,224 (65.9)	49,502 (65.7)	42,288 (64.6)	24,204 (60.9)	
Overweight[c]	7,973 (12.1)	10,378 (12.7)	7,939 (12.5)	7,972 (12.7)	8,173 (12.8)	9,381(12.5)	7,815 (11.9)	4,840 (12.2)	
Obese[d]	8,813 (13.4)	10,968 (13.4)	9,575 (15.1)	10,072 (16.1)	10,730 (16.8)	13,332 (17.7)	12,393 (18.9)	8,818 (22.2)	
Severely obese[e]	3,352 (5.1)	4,089 (5.0)	3,753 (5.9)	4,007 (6.4)	4,420 (6.9)	6,178 (8.2)	6,085 (9.3)	4,730 (11.9)	
Males									
BMI, kg/m^{2}Mean (SD)	22.6 (4.6)	22.7 (4.6)	23.0 (4.7)	23.1 (4.5)	23.2 (4.8)	23.5 (4.7)	23.6 (5.0)	23.9 (5.4)	<0.001
BMI percentile Mean (SD)	58.0 (31.0)	58.1 (31.2)	58.3 (31.4)	59.0 (30.4)	59.3 (30.3)	62.1 (32.4)	61.5 (31.7)	62.9 (32.6)	<0.001
Weight categories *N* (%)									<0.001
Underweight[a]	1542 (4.8)	1,918 (4.8)	1,522 (4.9)	1,505 (4.9)	1,639 (5.2)	1,831 (4.9)	1,104 (5.6)	386 (6.0)	
Normal[b]	21577 (67.4)	27,058 (67.0)	20,480 (65.5)	19,659 (64.0)	19,656 (62.9)	23,380 (62.6)	12,890 (65.5)	4,076 (63.6)	
Overweight[c]	3980 (12.4)	5,190 (12.9)	3,949 (12.6)	3,884 (12.6)	3,977 (12.7)	4,685 (12.5)	2,132 (10.8)	736 (11.5)	
Obese[d]	4927 (15.4)	6,202 (15.4)	5,340 (17.1)	5,665 (18.4)	5,961 (19.1)	7,437 (19.9)	3,566 (18.1)	1,211 (18.9)	
Severely obese[e]	2,018 (6.3)	2,503 (6.2)	2,222 (7.1)	2,396 (7.8)	2,592 (8.3)	3,659 (9.8)	3,616 (11.2)	2,654 (14.0)	
Females									
BMI, kg/m^{2}Mean (SD)	22.3 (4.3)	22.4 (4.4)	22.5 (4.7)	22.6 (4.6)	22.7 (4.9)	22.8 (4.8)	22.9 (4.9)	23.3 (5.4)	<0.001
BMI percentile Mean (SD)	56.5 (30.8)	57.0 (31.3)	57.3 (30.4)	57.3 (30.4)	57.8 (31.2)	60.5 (32.1)	60.1 (31.8)	61.6 (32.5)	<0.001
Weight categories *N* (%)									<0.001
Underweight[a]	1,141 (3.4)	1,364 (3.3)	1,130 (3.5)	1,216 (3.8)	1,289 (3.9)	1,300 (3.4)	809 (4.0)	276 (3.9)	
Normal[b]	24,672 (73.2)	30,097 (72.7)	22,968 (71.1)	22,190 (69.6)	22,568 (68.8)	26,065 (68.6)	14,558 (71.8)	4,956 (70.3)	
Overweight[c]	3,993 (11.9)	5,188 (12.5)	3,990 (12.3)	4,088 (12.8)	4,196 (12.8)	4,735 (12.5)	2,172 (10.7)	810 (11.5)	
Obese[d]	3,886 (11.5)	4,766 (11.5)	4,235 (13.1)	4,407 (13.8)	4,769 (14.5)	5,907 (15.5)	2,739 (13.5)	1,006 (14.3)	
Severely obese[e]	1,348 (4.0)	1,615 (3.9)	1,519 (4.7)	1,627 (5.1)	1,805 (5.5)	2,546 (6.7)	2,453 (7.4)	2,099 (10.1)	

[a]BMI <5th percentile, [b]BMI 5th-84.9th percentile, [c]BMI 85th-94.9 percentile, [d]BMI ≥95th percentile, [e]BMI ≥99th percentile

the study period, while the prevalence of overweight remained relatively stable.

A more moderate increase in obesity and severe obesity categories rates during the study period was observed in the Jewish comparison group (from 16.5% to 20.5% and from 7.4% to 11.1%, respectively; Additional File 2). This increase started in 2011–2012, after an initial decrease in prevalence between the years 2007–2008 and 2009–2010.

Figure 1 presents the mean BMI percentile, and the rates of overweight, obesity, and severe obesity among males and females across the study periods. In Arab adolescents the mean BMI percentile and the prevalence of obesity and severe obesity increased across the study periods in both sexes and was consistently higher among males than among females (Fig. 1A, C and D). For overweight there was no clear sex preponderance or increase in prevalence (Fig. 1B).

In the Jewish adolescent group, the mean BMI percentile was higher among males than females until 2015–2016, after which the mean BMI percentile became higher among females (Fig. 1A). The male preponderance in the prevalence of obesity and severe obesity seen in the Jewish group, was like that among Arab adolescents (Fig. 1C and D), but the difference between the sexes became negligible towards the end of the study period. In the comparison group, the prevalence of overweight was consistently higher for females (Fig. 1B).

Crude age and cohort effects

Figure 2 depicts the crude prevalence of overweight and obesity across ages and cohorts during the study period. In Arab adolescents the crude prevalence of overweight decreased continuously between the ages 14–18 years and increased sharply at the age 19, for all birth cohorts (Fig. 2A). The crude prevalence of obesity among Arab adolescents was relatively stable between the ages 14–16 or 14–17 for different birth cohorts but decreased at ages 17–19 or 18–19 (Fig. 2B), with the exception of the cohort born in 2000–2003, for which the increase was seen between ages 18–19. There was no cohort effect of note on overweight with a stable prevalence or mild increase through the birth cohorts for most ages, apart from the age 19, for which the prevalence of overweight had a sharp decrease between the cohorts born in 1996–1999 and 2000–2003 (Fig. 2C). In contrast, the prevalence of obesity in Arab adolescents was higher in the later birth cohorts than among the earlier ones (Fig. 2D).

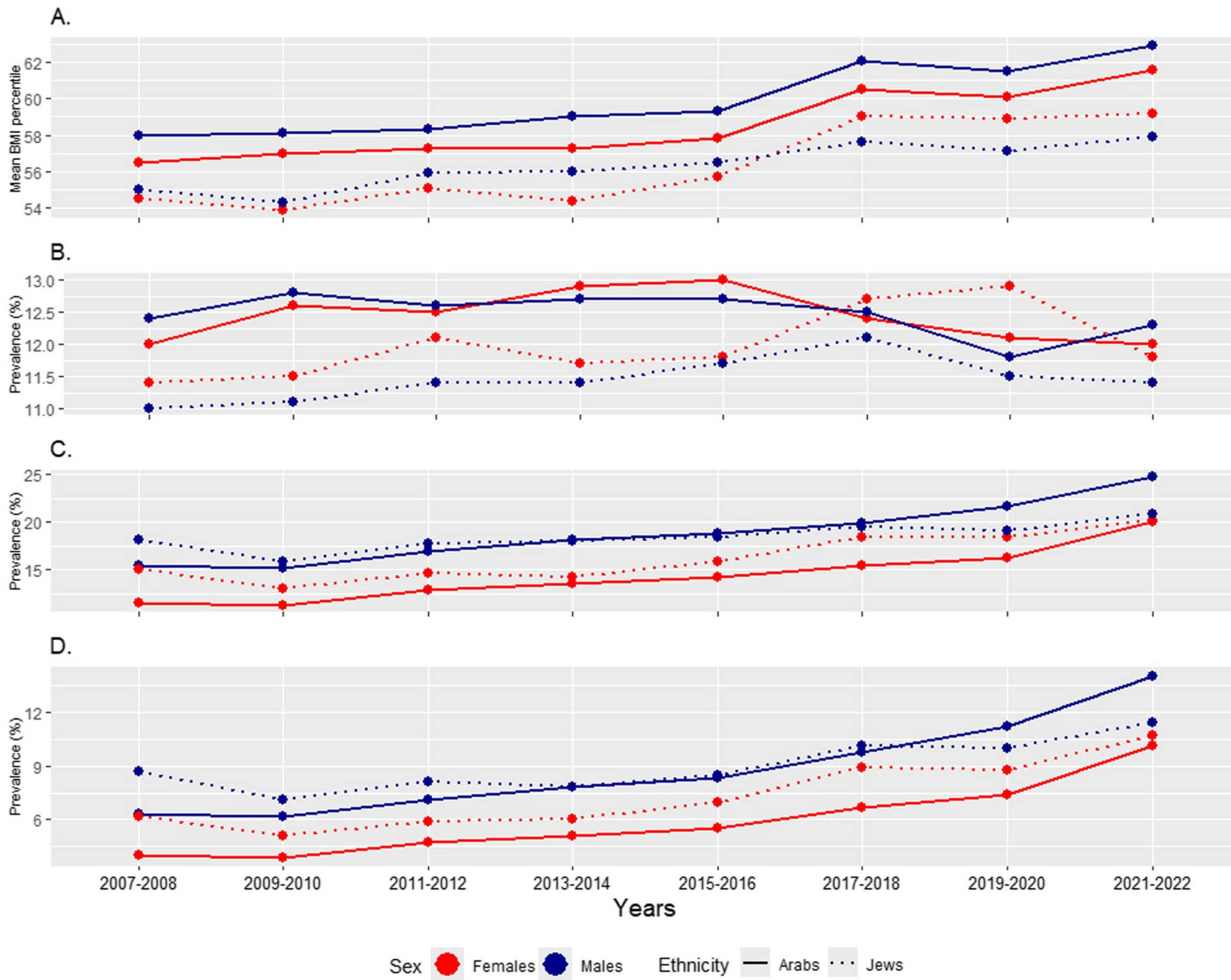

Fig. 1 Change in mean BMI percentile and in the prevalence excessive weight categories among sexes during the study periods **A** -change in mean BMI percentile; **B** -change in the prevalence of overweight; **C** -change in the prevalence of obesity; **D** -change in the prevalence of severe obesity. Overweight: BMI ≥ 85th-94.9 percentile, obesity: BMI ≥ 95th percentile, severe obesity: BMI ≥ 99th percentile

Jewish adolescents demonstrated similar age and cohort effects, apart from a slightly different age effect on obesity, resulting in a steep decrease in its prevalence between the ages 14–16 years, a stable period between the ages 16–17 years, and further decrease between the ages 17–19 years (Fig. 2D). The sharp decrease in the prevalence of overweight in the birth cohort of 2000–2003 at age 19 that was observed in Arab adolescents was not seen in the Jewish comparison group.

Adjusted APC effects

Figure 3 displays the aORs for age, period, and cohort effects on obesity, obtained from mixed logistic regression models. This was done after adjusting for sex, district of residency, and socio-economic status, and taking within-person correlations into consideration. A constant decline in aOR for obesity was observed in Arab adolescents between the ages 14 (reference) and 19, followed by a steep decrease between the ages 18 (aOR = 0.71 (95% CI – 0.69–0.74)) and 19 (aOR = 0.30 (95% CI – 0.28–0.31)) (Fig. 3A). In contrast, a period effect manifested by a gradual increase to aOR 1.88 (95% CI – 1.76–2.02) in 2021–2022, compared to the reference 2007–2008 period. The cohort effect in Arab adolescents showed a constant steep increase in the odds for obesity from the cohort born in 1988–1991 (reference) to the cohort born in 2000–2003 (aOR = 1.67 (95% CI – 1.57–1.77)), with a slight decline in the 2004–2008 birth cohort (aOR = 1.57 (95% CI – 1.51–1.62)).

In the Jewish comparison group, there was a steeper decrease in the prevalence of obesity between the ages 14–18 years (aOR = 0.57 (95% CI – 0.54–0.60) at the age of 18). The period effect in this group was manifested in lower odds for obesity between 2009 and 2016 (compared to the reference 2007–2008 period), and then moderately higher odds between 2017 and 2022 reaching aOR 1.25

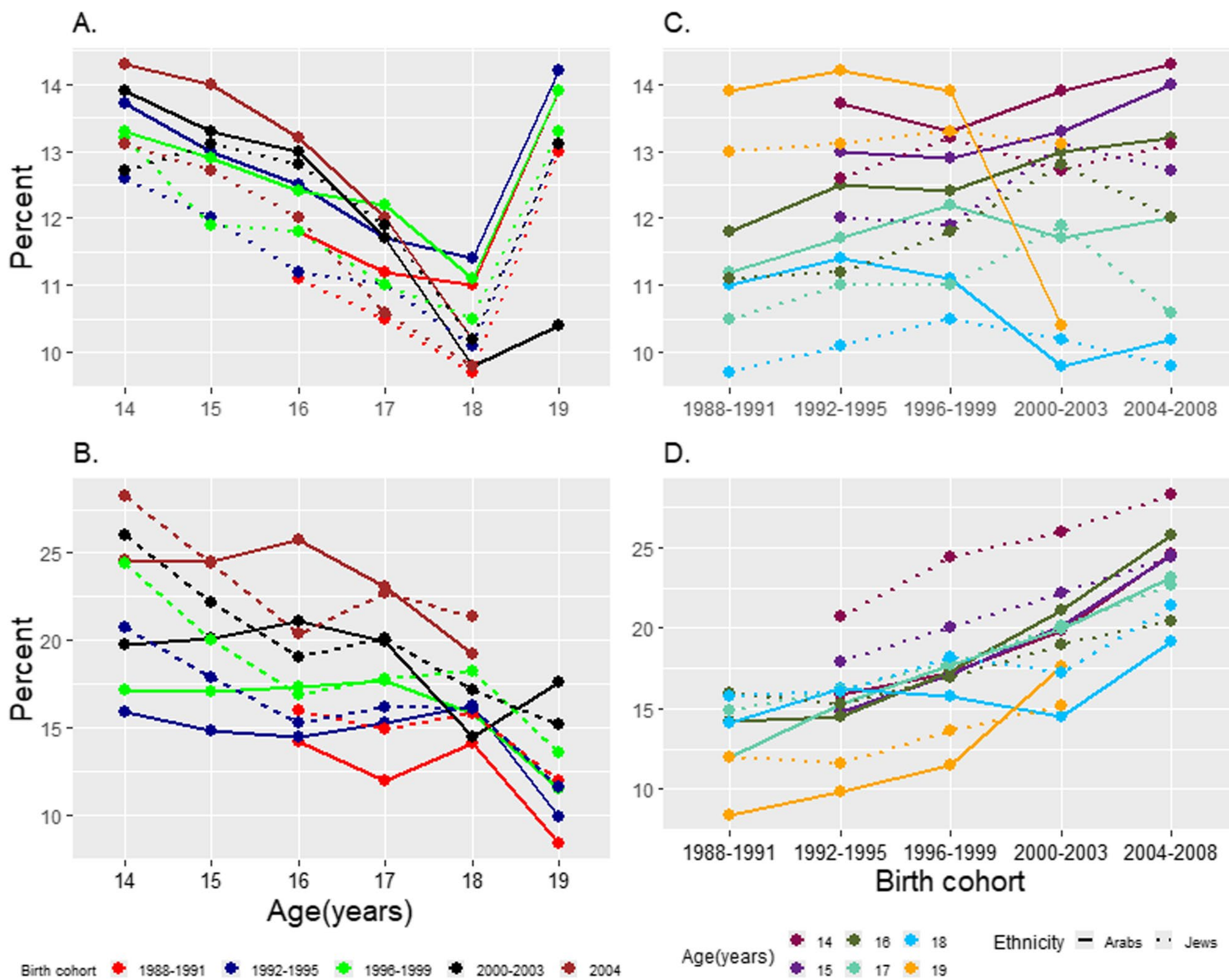

Fig. 2 Prevalence of overweight and obesity by age and birth cohort Prevalence of overweight (**A**) and obesity (**B**) by age for different birth cohorts. Prevalence of overweight (**C**) and obesity (**D**) by birth cohort for different ages. Overweight: BMI ≥ 85th-94.9 percentile, obesity: BMI ≥ 95th percentile

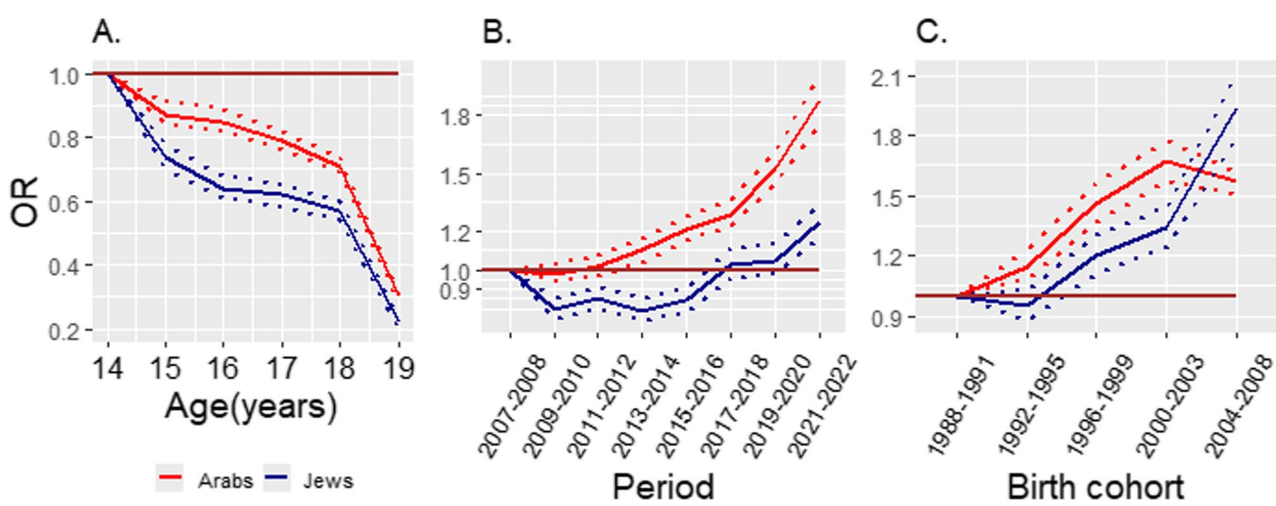

Fig. 3 Odds ratios of being obese Odds ratios (ORs) (solid lines) and 95% confidence intervals (dotted lines) of being obese by age (**A**.), study period (**B**.) and birth cohort (**C**.), adjusted for sex, district, socio-economic status, and within-person correlation. Reference category for age is 14 years, for period is 2007–2008, and for birth cohort is the birth cohort born between 1988–1991

(95% CI – 1.17–1.34), which was lower than among Arab adolescents. There was no statistically significant difference in the cohort effect in Jewish adolescents, in aOR for obesity between the cohorts born in 1988–1991 and 1992–1995, but after that period there was a constant increase in aOR, reaching an aOR of 1.94 (95% CI – 1.79–2.11) for the cohort born in 2004–2008.

Associations of socio-economic factors with overweight/obesity

Additional File 3 presents the full results of the mixed logistic regression model for the APC effect on overweight and obesity among Arab adolescents. In addition to the described adjusted APC effects on obesity and the less prominent period and cohort effects on overweight, interesting effects of other variables on overweight/obesity were observed. Compared to the central district, the lowest aOR for overweight and obesity was observed in the peripheral Southern and Northern districts. The aORs for obesity were higher in the central districts of Israel, increasing to 1.25 (95% CI – 1.09–1.43) in the Sharon-Shomron district. In the middle socio-economic class, the odds for overweight increased and in the middle and low socio-economic classes the odds for obesity increased.

Discussion

This is the first nationwide, systematic study on adolescent overweight and obesity in the Arab minority in Israel. The results showed an alarming rate and rapidly increasing trend for obesity among Arab adolescents over the last 16 years. The crude rate of adolescent obesity almost doubled and exceeded 22% in 2021–2022, with the aOR for obesity reaching 1.88 (95% CI – 1.76–2.02) in 2021–2022 compared to the reference period from 2007 to 2008. This rate is even higher than that reported in the United States [19], a country with one of the highest rates of obesity, and much higher than the rates reported in countries in Europe and Asia [11, 12, 15–17]. This rate surpassed reported rates among Muslim populations in other parts of the world, including Saudi Arabia (15.2% for adolescent obesity) [13], whose Human Development Index is the highest in the Muslim world, and approaches that of Israel. At the end of the study period the rates of both adolescent obesity and overweight in Arab adolescents exceeded those in their Jewish counterparts, although the rates for the latter were also strikingly high. Arab boys had higher rates of obesity than Arab girls. These sex differences in obesity patterns are similar to other published papers, where in most countries boys have higher prevalence of obesity than girls [12, 13, 17, 19], though in Ireland, the obesity rates were higher in girls compared to boys [16]. The prevalence of severe obesity, defined in our study as BMI ≥ 99th percentile, more than doubled during the study period, reaching 11.9% in 2021–2022 and exceeding that of the Jewish comparison group. A survey from the United States reported the prevalence of severe obesity as high as 8.4% in this age group [19], but a different definition for severe obesity was used, with a threshold of BMI ≥ 120% of the ≥ 95th percentile, according to the updated CDC definition. There is a good correlation between this definition and the one that was used in our study [30]. According to the same CDC definition, the prevalence of severe obesity among adolescents was much lower, around 2–5%, in most other countries [14, 31, 32]. Although the Jewish comparison group showed an initial decrease and relatively stable rates of severe obesity until 2015–2016, it manifested an alarming increase through the other study periods.

Notably, in 2022 the CDC developed new percentiles to monitor very high BMI values. The 2000 CDC BMI-for-age growth charts were based on data from 1963 to 1980 and did not extend beyond the 97th percentile. The updated charts are based on data for children and adolescents from 1988 to 2016, and extend up to the 99.99 percentile, thus expanding the reference population. These charts were published after the analysis for the present study began and were not used in it.

In this study the prevalence of obesity was highest at age 14 year for almost all birth cohorts (15.9% – 24.6% in the different cohorts) and decreased gradually until age 19 (8.4% – 17.6%). With age 14 serving a reference value, the ORs for obesity at age 19 decreased gradually to 0.3. In Spain, a similar effect of *age* was demonstrated, with higher prevalence of obesity and combined overweight and obesity among adolescents aged 14–15 than among those aged 16–17 [33]. A recent study from the United States, that examined APC effects on obesity in youth, showed the highest prevalence of obesity at age 14 during the earliest years of follow-up (1999–2007), while in 2017–2019 the prevalence of obesity was the lowest at this age [34]. An opposite effect of age was demonstrated in a study of youth in England, with the lowest OR for obesity at age 14, and the highest at 19 [35], although for overweight a changing effect of *age* was demonstrated in the same study. The Korean study, which did not evaluate separate adolescent age groups, did show that adolescents in high school had a higher prevalence of obesity than those in middle school [36]. In the present study, the age effect in the Jewish group was like that in the Arab group, with a steeper decline in OR through the ages 14 to 19. In terms of the overall cohort effect, obesity rates increased in the later birth cohorts compared to the earlier ones, reaching an aOR of 1.67 (95% CI 1.57–1.77) in the cohort born in 2001–2003, compared to the reference cohort, born in 1988–1991. Subsequently, there was a decrease in aOR for obesity in the 2004–2008 cohort. The study of the cohort effect in youth in England [35], showed a similar consistent rise in aOR for obesity in subsequent birth cohorts, with a decrease in aOR for obesity in the cohort born in 2004–2008. In contrast, in a study from the United States, the cohort effect was minimal, with no cohort deviating from the main trend [34]. In the Jewish comparison group, the increase in aOR was like in Arab adolescents, except for the absence of decline in the last birth cohort, born in 2004–2008.

While a clear age effect was observed in our study for both overweight and obesity, period and cohort effects were seen clearly only for obesity.

Along with the description of the APC effects on overweight and obesity among Arab adolescents in Israel, this study pinpointed important socio-demographic risk-factors for the problem. Living in peripheral areas of Israel, compared to the central, decreased the risk for obesity significantly, by about 20%. A possible explanation for this phenomenon is that Arabs living in peripheral areas may have healthier nutritional habits, with lower exposure to processed food. A study from Spain [33] reported higher obesity rates in urban compared to rural areas. In contrast, in the United States, a higher prevalence of obesity was found in non-metropolitan areas compared to metropolitan [19].

Compared to the high socio-economic classes, the risk for obesity increased by 25% in the middle and lower classes. As socio-economic status was defined in our study by zip code, this finding may be related to a lack of green space and less opportunity for physical activity in less prosperous neighborhoods. This association of lower socio-economic status with higher prevalence of adolescent obesity is in accord with previous global research [37–39]. It is even more noteworthy as more than 60% of the Arab adolescents in Israel belong to the low socio-economic class.

Adolescent obesity is a significant public health issue due to its association with both short-term and long-term health ramifications, leading to a high social and economic burden. Large studies from Israel, for the most part involving Jewish adolescents, demonstrated increased risks for several types of diabetes mellitus [40–42], cardio-vascular morbidity and mortality [43, 44], and cancer [45]. Recent studies featured associations of adolescent obesity with co-morbidity and future morbidity in Arab adolescents in Israel [46–48], and mortality risk in the general population of Israeli adolescents [49]. The present analysis of trends can help focus health policies and initiatives on adolescent obesity and more effectively mitigate its health consequences.

Limitations and strengths

The main limitation of our study is missing data on BMI, which may have led to under- or over-estimation of adolescent obesity rates. It is possible that adolescents with obesity were reluctant to undergo preventive screening measurements. However, it is also possible that given the demonstrated higher prevalence of DM2 in this group, they may have required more medical interventions and consequently more healthcare visits and more BMI measurements.

The recommendation to measure height and weight for BMI, which applies to all adolescents aged 14–19 years, has been an integral part of the Israel National program for quality indicators in the community since 2007, so the missing BMI measurements could be considered as randomly missing data. Furthermore, the demonstrated similarity in the socio-demographic characteristics between the adolescents with and without measurements in our study minimizes the risk of selection bias. The second limitation is that since registration of BMI as a part of Israel National program for quality indicators in community began in 2007, our research was limited to a 16-year period. A longer study period may have provided a broader perspective. In addition, the specific ethnic nature of the study population limits its generalizability and it may be primarily of local importance. Lastly, BMI has limitations as a useful measure of obesity, its utility differs in different ethnicities, and it cannot distinguish between muscle and fat tissue [50]. At the same time, BMI is still the most widely used measure in population-based epidemiological studies [14, 31–36] and has a good correlation with body fat percentage [50]. The main strength of this study is that it was based on a nationwide, representative, large and reliable database, with a high number of observations. Another strength is that the weight and height measurements were taken by health care professionals and not self-reported.

Conclusions

Our study demonstrated increasing trends for adolescent obesity and severe obesity rates in the Arab minority in Israel, especially among younger birth cohorts. This rate exceeded the rate among their Jewish counterparts. Additional risk factors for adolescent overweight and obesity were younger age (within the 14–19 age group), lower socio-economic level, and residence in central, compared to peripheral areas in Israel. Understanding the upward trends of obesity, and the impact of age, and cohort effects is crucial to the goal of targeting health initiatives to a specific age group and birth cohort. Moreover, the combination of increasing risk for obesity over time and in the younger birth cohorts poses an increasing threat to the health of future generations of adolescents. The results of the present study indicate that interventions should begin at a younger age, especially in the more recent cohorts. These findings necessitate urgent intervention and can help determine the focus of future policy steps in vulnerable adolescent groups.

Abbreviations

APC age, period, and cohort
CHS Clalit Health Services
CDC Center for Disease Control and Prevention

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

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None.

Authors' contributions

YTG took part in the conception and design of the study, contributed substantially to data acquisition, analysis and interpretation, and drafted the work. DN took part in the conception and design of the study, contributed substantially to data interpretation and revised the written manuscript. IM took part in the conception and design of the study, contributed substantially to data analysis and interpretation and revised the written manuscript. All authors read and approved the final manuscript.

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Data availability

Availability of data and materials: The data that support the findings of this study are available from Clalit Health Services. Restrictions apply to the availability of these data, which were used under license for this study.

Declarations

Ethics approval and consent to participate

We confirm that all methods were performed in accordance with the ethical standards as laid down in the Declaration of Helsinki and its later amendments or comparable ethical standards. The Ethics Committee of Clalit Health Services approved the study (approval #0102-22-COM2), and exempted it from the requirement to obtain informed consents.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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