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Original Article

Overweight and Obesity Between Adolescence and Young Adulthood: A 10-year Prospective Cohort Study

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A B S T R A C T

Objectives: To assess changes in overweight and obesity between adolescence and young adulthood.
Design: Prospective 8-wave cohort study in Victoria, Australia, with 1,520 adolescents tracked from the age of 14 for a period of 10 years.
Main outcome measures: Participants aged <18 years were classified as non-overweight, overweight, or obese according to International Obesity Taskforce cutoff points. In those aged >18 years overweight was defined as a body mass index (BMI) ≥25; and obesity as a BMI ≥30.
Results: The proportion of overweight individuals increased from 20% in mid-adolescence to 33% at the age of 24 years. Obesity increased from 3.6% to 6.7%. Approximately 40% of young adults with a BMI ≥25 had been persistently at normal weights during adolescence and approximately 80% had been at a normal weight at some point. Around half of obese young adults had never been classified as obese as adolescents. No individual with persistent obesity in adolescence had a BMI <25 at 24 years. A total of 31% of females and 59% of males who had been overweight for only one or two waves of adolescent data collection had a BMI ≥25 at 24 years.
Conclusions: Substantial shifts in overweight and obesity occur between adolescence and young adulthood; the extent of continuity depends on both the severity and persistence of adiposity in adolescence. Few adolescents who peak into obesity or are persistently overweight achieve a normal weight in young adulthood. Resolution is more common in those who are less persistently overweight as teenagers, suggesting scope for lifestyle interventions in this subgroup.

There are good reasons to consider the years after puberty as important for understanding body mass [1–3]. Puberty brings physiological, behavioral, and emotional shifts with direct and indirect implications for weight [4]. The growth spurt brings about an increase in fat-free mass in boys and an increase in both fat and fat-free mass in girls [5]. For both males and females, early adolescent changes in body fat distribution elicit emotional and behavioral responses that commonly include efforts to control weight [6]. Other changes in adolescent lifestyle, such as decreasing physical activity across adolescence as well as increased alcohol and other drug use have the potential to affect weight [7,8].

There is good evidence that if obesity becomes established in adolescence, later spontaneous reversal is uncommon [3,9,10].

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Yet, before the recent increase in childhood obesity, more than 80% of obesity cases at the age of 35 years had an onset after the age of 17 years [3]. This suggests that there were marked changes taking place in body weight between adolescence and young adulthood with many young people making incident transitions into obesity during this period. For this reason, intervention in young people, particularly those with lower levels of adiposity, might be a valuable strategy in achieving lower rates of adult obesity. The risks associated with different levels and persistence of adolescent adiposity have not been quantified yet. The recent developments of standard definitions for childhood overweight and obesity not only allows comparisons between populations but also offers the scope to quantify changes within individuals over time [11].

Rapid changes in the epidemiology of obesity over the last 20 years may have also altered the previously documented patterns of continuity in obesity within individuals between adolescence and young adulthood [12]. In the present study, we drew on a large population cohort of adolescents with repeated measures of height and weight, who were followed up into early adulthood. The cohort was assembled in the mid-1990s, after a period when overweight and obesity had increased sharply in many countries including Australia [13,14]. In Australia, rates of overweight among children had doubled and obesity had tripled between the late 60s and mid-90s when more than one in five children were overweight or obese [13,15]. We set out to determine which patterns of adolescent weight predict overweight and obesity at the age of 24 years in a large, contemporary cohort. Specifically, we aimed to assess the following:

1. Adolescent weight patterns, defined using the International Obesity Taskforce (IOTF) criteria, predictive of overweight and obese status in young adulthood.
2. Extent of continuity of overweight and obese status between adolescence and young adulthood.

Method

Sample

Between August 1992 and March 2003, we conducted an 8-wave cohort study of adolescent and young adult health in the state of Victoria, Australia. Data collection protocols were approved by The Royal Children's Hospital's Ethics in Human Research Committee. Informed consent was obtained from participating school organizations and parents. Further participant consent was obtained from those in the young adult waves. The cohort was initially defined with a two-stage cluster sample in which we selected two Grade 9 classes at random from each of the 44 schools drawn from a stratified frame of all secondary schools (government, Catholic, and independent) in the state (total number of Year 9 students was 60,905 in 1993). School retention rates were 98% across the state to year 9 in the year of sampling. One class from each school entered the cohort in the latter part of the ninth school year (wave 1) and the second class 6 months later, early in the 10th school year (wave 2). Participants were subsequently reviewed at a further four 6-month intervals during the teens (waves 3–6) with two follow-up waves in young adulthood aged 20–21 years (wave 7) and 24–25 years (wave 8). In waves 1 to 6, participants self-administered the questionnaire on laptop computers [16], with telephone follow-up of those who were absent from school. The seventh and eighth waves of data collection were undertaken with computer-assisted telephone interviews.

From a total sample of 2,032 students, 1,943 (95.6%) participated at least once during the first six (adolescent) waves. In wave 8, 1,520 (78% of teenage participants) were interviewed between April 2002 and June 2003. Response rates are shown in Figure 1. Reasons for noncompletion at wave 8 follow-up were refusal ($n = 269$), loss of contact ($n = 150$), and death ($n = 4$). The mean age (standard deviation) at waves 1 and 8 were 14.5 (.5) and 24.1 (.6) years, respectively. Using the highest weight category during waves 1 to 6, neither overweight status (Odds ratio [OR] 1.0; 95% confidence interval [CI]: .74–1.4) nor obese status (OR = 1.0, CI .63–1.6) predicted differential participation at wave 8.

Measures

Weight and height

The same two research assistants conducted assessments of height and weight across each of the waves of data collection in the adolescent period. After training at baseline they measured weight to the nearest .1 kg with subjects in minimal school uniform with portable digital scales. A weight of 1 kg was deducted from the measure to account for the weight of the residual clothing. Height was measured with shoes removed using a rigid stadiometer and recorded to the nearest centimeter. Self-reported weights and heights were used for those who had left school in the later teenage waves. In the adult phase (waves 7 and 8), weight and height were assessed using self-report, after postal prenotification that these two questions would be asked at interview in the forthcoming week. At each wave, body mass index (BMI) was calculated (kg/m^2) and participants <18 years of age were classified as non-overweight, overweight, or obese

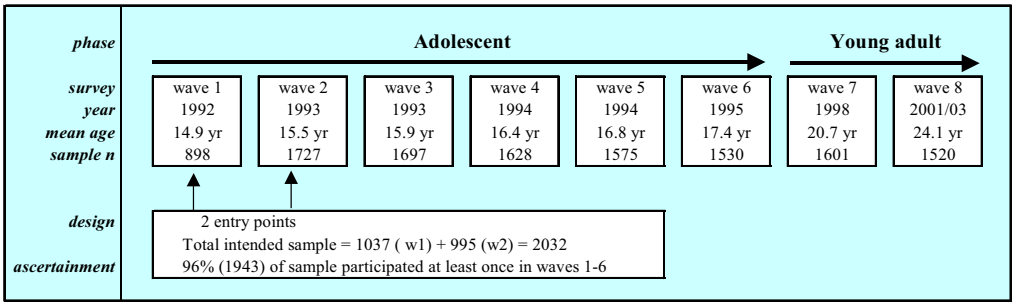

Figure 1. Sampling and ascertainment in the Victorian Adolescent Health Cohort, 1992–2003.

Table 1
Prevalence estimates of overweight and obesity across 10 years in 1943 participants initially aged 14 years

Phase Measure	Overweight and/or obese						Obese					
	Total (n = 1,943)		Male (n = 943)		Female (n = 1,000)		Total (n = 1,943)		Male (n = 943)		Female (n = 1,000)	
	%[a]	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)	%	(95% CI)
Adolescent phase												
In BMI category at least once[b]	32	(30–35)	31	(28–34)	33	(30–37)	7	(5–8)	5	(3–7)	8	(6–10)
Persistently in BMI category[c]	11	(9–12)	9	(7–11)	13	(10–15)	2	(1.1–2)	1	(.4–2)	2	(1–3)
Persistence (No. of waves)												
None	68	(65–70)	69	(66–72)	67	(63–70)	93	(92–95)	95	(93–97)	92	(90–94)
1 or 2	12	(10–13)	12	(10–15)	11	(8–14)	3	(2–4)	2	(1–3)	4	(2–5)
3–6	20	(18–22)	18	(16–21	22	(19–25)	3	(3–4)	3	(2–4)	4	(3–5)
Average across 6 waves			18	(16–20)	22	(19–24)			3	(2–4)	4	(3–5)
Young adult phase												
20 yrs (wave 7)	24	(22–26)	28	(25–31)	20	(18–23)	4	(3–5)	3	(2–4)	5	(3–6)
24 yrs (wave 8)	33	(31–35)	39	(36–43)	27	(24–30)	7	(5–8)	6	(4–8)	7	(5–9)

[a] Prevalences were obtained by averaging across the 5 imputed datasets.
[b] Refers to being in the BMI category in at least one wave.
[c] Refers to being in this category at every wave of assessment during the adolescent phase.

according to IOTF cutpoints [11]. Those who were aged 18 years or more were classified as non-overweight (<25 kg/m^2), overweight (≥25 and <30 kg/m^2), or obese (≥30 kg/m^2) [11].

Analysis

Summary measures of adolescent exposures were created by considering all six waves of data collection in the adolescent period. We estimated both the period and mean prevalence rates of different patterns of adolescent overweight and obesity. Persistence of adiposity in the teens was defined for overweight and obesity, respectively. For each, a distinction was made between less persistent (1–2 waves) and more persistent states (3+ waves). Data analysis was undertaken using Stata 10 (Stata Corporation, College Station Texas).

Because of the computer-based data collection, there were few missing data for individuals within the waves. However, 36% of respondents missed at least one wave of data collection in the adolescent phase (waves 1–6), leading to a potential bias in summary measures calculated from these data. To address this, we used the method of multiple imputation with five complete datasets created by imputation under a multivariate normal model that incorporated all the outcome variables of interest measured at all waves of data collection, along with the fixed covariates of gender, age, rural or urban residence, and parental divorce or separation, using adaptive rounding for binary measures [17]. However, the analysis of outcomes at wave 8 only included the 1,520 participants who completed data collection at that point. Estimates of prevalence and (log) odds ratios were obtained within the multiple imputation framework by averaging across the imputed datasets with Wald-type confidence intervals obtained using Rubin's combination rules [17,18].

Results

The sex ratio of the cohort (males, 46%) was similar to that in Victorian schools at the time of sampling [19]. A total of 22% of the sample had parents who were separated or divorced, 24% grew up in a household speaking a language other than English, 12% were not born in Australia, and 74% attended a metropolitan school at study commencement. The highest level of parental education was incomplete secondary schooling (32%), complete secondary schooling, vocational diploma, or certificate (34%), and university degree (34%).

Table 1 shows the estimated prevalence of overweight and obesity across the eight waves of data collection. The average prevalence of overweight and/or obesity over the six adolescent waves was 20% (95% CI: 18–21). For obesity alone, it was 4% (CI: 3–4). Almost one in three participants were overweight or obese for at least one adolescent wave (period prevalence: overweight and/or obesity 32%, 95% CI: 30–35). The odds of ever being overweight or obese were similar in males and females (OR = 1.1, CI: .9–1.4). One in five participants was overweight or obese for most of the adolescent waves.

Seven percent (CI: 5–8) of participants were categorized as obese on at least one occasion during the adolescent waves. Adolescent girls were more likely to have ever been in the obese range (OR = 1.6, CI: 1.1–2.4). Just under 2% of the sample was never less than obese during the teen waves with girls more likely to be in this unremitting group (OR = 2.1, CI: 1.0–4.6). There was a similar trend across all waves for more adolescent girls to have had a BMI in the obese range (OR = 1.6, CI: 1.0–2.5).

By the age of 20 years, the prevalence of overweight and/or obesity had increased, particularly in males. At 24 years, prevalence rates for overweight and/or obesity were 33% (CI: 31–35) compared with an average prevalence of 20% (CI: 18–21) across the adolescent waves. Females at 24 years had lower odds (.55, CI: .44.68) of being in the overweight and/or obese category compared with males. By 24 years, the prevalence of obesity was 7% (CI: 6–8), a rate that was 87% higher than the average across waves 1 to 6. No difference in the prevalence of obesity among both the genders was evident at 24 years (OR = 1.1, CI: .76–1.7).

Predicting BMI ≥25 (overweight/obesity) at 24 years

Table 2 shows the associations between adolescent weight categories (summarized over waves 1–6) and having a BMI ≥25 at 24 years (wave 8). Of those 480 participants with a BMI ≥25 at 24 years, 33% had never been overweight during adolescence, with this proportion being higher in males (39%) than females (27%). A total of 269 males (39% of wave 8 male participants) had a BMI ≥25 of which 13% (n = 34) had been obese on at least one

Table 2
Prediction of a BMI ≥25 at 24 years of age (wave 8) in 1,520 cohort participants from weight categories measured during adolescence (waves 1–6)

Phase Measure	BMI ≥25 (overweight and/or obese) at 24 yrs											
		Total (n = 480)				Male (n = 269)				Female (n = 211)		
	N[a]	n[b]	%	(95% CI)	N	n	%	(95% CI)	N	n	%	(95% CI)
Adolescence (waves 1–6)												
No overweight or obesity	1,034	163	16	(13–19)	478	105	22	(18–26)	556	58	10	(8–13)
Any overweight or obesity[c]												
Overweight	387	228	59	(52–65)	182	130	71	(64–78)	205	98	48	(39–56)
Obese	99	89	90	(83–98)	36	34	94	(86–100)	63	55	88	(77–99)
Persistence of overweight and obesity[c]												
Overweight 1 or 2 waves	176	79	45	(34–56)	86	51	59	(47–71)	89	28	31	(17–45)
Overweight 3+ waves	212	149	70	(64–77)	96	79	82	(74–90)	116	70	60	(50–71)
Obese 1 or 2 wave	47	41	87	(74–100)	15	15	99	(91–100)	32	25	81	(63–98)
Obese 3+ waves	52	49	93	(87–100)	21	19	90	(77–100)	31	30	96	(87–100)
Young adult: 20 yrs												
Not overweight or obese	1,158	187	16	(14–18)	497	108	22	(18–26)	661	79	12	(9–14)
Overweight	300	233	78	(72–83)	176	138	78	(71–85)	124	95	77	(69–84)
Obese	62	60	96	(92–100)	24	24	99	(93–100)	39	37	95	(88–100)

[a] Frequencies (N) refer to the adolescent phase (waves 1–6) and were obtained by averaging across the imputed datasets. Rounding errors account for inexact total Ns.
[b] Frequencies (n) and percents are those of the exposed who were overweight or obese by 24 yrs and were obtained by averaging across the imputed datasets.
[c] Mutually exclusive adolescent weight categories.

occasion during the adolescent waves, 48% (n = 130) had been overweight on at least one occasion, and 39% (n = 105) had never been overweight. A total of 211 females (27% of wave 8 female participants) had a BMI ≥25 of which 26% (n = 55) had been obese at least once during the adolescent waves, 47% (n = 98) had been overweight on at least one occasion, and 28% (n = 58) had never been overweight or obese.

Of those who were ever overweight as adolescents, 59% had a BMI ≥25 at wave 8. There was a gender difference in continuity in that just under half the females who had been overweight during the adolescent waves had a BMI ≥25 by 24 years compared with over 70% of males (OR = .44, .30–.66). Persistence of adolescent overweight status later predicted a BMI >25. In all, 70% of those who were overweight on three or more adolescent waves were still overweight at 24 years compared with 45% of those who were overweight on one or two waves. Females showed less continuity in both categories. For all adolescent obesity categories, the rate of BMI ≥25 at 24 years was very high. Continuity between obesity at 20 years and BMI ≥25 at 24 years was similarly very high.

Predicting BMI ≥30 (obesity) at 24 years

Table 3 illustrates the prediction of obesity (BMI ≥30) at 24 years (wave 8) by adolescent weight categories. Of the 98 participants who were obese at 24 years, 49% (n = 48) had been obese on at least one occasion during the adolescent waves, 39% (n = 38) had been overweight on at least one occasion but had never been obese, and 12% (n = 12) had been at a normal weight throughout the adolescent waves. Only 1% of those who had been consistently at a normal weight during the teens had a BMI ≥30 at wave 8. Of those who were ever overweight as adolescents, 10% had a BMI ≥30 at 24 years with little difference between males and females. Although persistence of overweight during the adolescent waves increased the risk of obesity at wave 8, less

Table 3
Prediction of a BMI ≥30 at 24 years of age (wave 8) in 1,520 cohort participants from weight categories measured adolescence (waves 1–6)

Phase Measure	BMI ≥30 (obese) at 24 yrs											
		Total (n = 98)				Male (n =43)				Female (n = 55)		
	N[a]	n[b]	%[b]	(95% CI)	N	n	%	(95% CI)	N	n	%	(95% CI)
Adolescence (waves 1–6)												
No overweight/obesity	1,034	12	1	(.4–2)	478	5	1	(.1–2)	478	6	1	(.2–2)
Any overweight or obesity[c]												
Overweight	387	38	10	(6–13)	182	20	11	(6–16)	182	16	9	(4–13)
Obese	99	48	49	(38–60)	36	18	49	(30–68)	36	18	49	(35–63)
Persistence of overweight and obesity[c]												
Overweight 1 or 2 waves	176	9	5	(1–9)	86	6	6	(0–14)	86	3	4	(0–11)
Overweight 3+ waves	212	29	14	(9–18)	96	15	15	(7–23)	96	12	12	(6–19)
Obese 1 or 2 wave	47	16	34	(20–48)	15	5	32	(4–59)	15	5	35	(18–53)
Obese 3+ waves	52	32	62	(48–77)	21	13	61	(38–84)	21	13	63	(43–83)
Young adult: 20 yrs												
Not overweight or obese	1,158	7	1	(.1–1)	497	3	1	(0–1)	497	3	1	(.01–1)
Overweight	300	44	15	(10–19)	176	22	13	(8–18)	176	31	18	(11–25)
Obese	62	47	75	(64–86)	24	17	72	(53–91)	24	18	76	(62–90)

[a] Frequencies (N) refer to the adolescent phase (waves 1–6) and were obtained by averaging across the imputed datasets. Rounding errors account for inexact total Ns.
[b] Frequencies (n) and percents are those of the exposed who were obese by 24 yrs and were obtained by averaging across the imputed datasets.
[c] Mutually exclusive adolescent weight categories.

than one in seven with more persisting overweight were obese at wave 8. Only one in twenty who were overweight on only one or two adolescent waves had a BMI ≥30 at 24 years.

For any adolescent who had been obese at any point, the rate of BMI ≥30 at 24 years was high. Almost half of those who had at some point been obese during adolescence had a BMI ≥30 at 24 years. Almost two-third of those with obesity on three or more adolescent waves had a BMI ≥30 compared with approximately one-third for those who were obese on only one or two waves.

Discussion

Even in the context of rising obesity rates in childhood, there is a substantial change in the weight status between adolescence and young adulthood. The prevalence of overweight status (BMI ≥25) increased by 65% between mid-adolescence and the age of 24 years, and the prevalence of obesity (BMI ≥30) has almost doubled. Approximately two in five young adults with a BMI ≥25 had been persistently at normal weights during adolescence and four in five had been in the normal weight range at some point. Similarly, 80% of obese young adults had been in a lower weight category at some point during the teens, and half of them had never been obese during that time. Yet for most obese 24-year-olds, some weight disturbance was already evident in adolescence.

The majority of earlier studies tracking the early course of overweight and obesity have done so from childhood to adulthood rather than from adolescence to adulthood and are thus not really comparable with the present report [20]. In their recent systematic review, Singh et al [20] found only six studies tracking weight from adolescence to young adulthood that they deemed to be of "high quality." Four of these reported on older birth cohorts (i.e., born before 1970) and thus did not cover the question of continuities between adolescence and young adulthood since the emergence of the obesity epidemic. One of the two remaining relevant studies was a small cohort of 155 participants born between 1975 and 1976 and is thus not comparable with the present study in terms of size [21]. The other was a New Zealand cohort of 924 participants which broadly reported risks associated with a higher percentile of BMI at different ages but did not use the increasingly accepted IOTF cutoff points [22].

Consistent with earlier findings, established adolescent obesity status conferred markedly heightened risks for later overweight and obesity [20,23]. No individual with persistent and unremitting obesity during the teen waves was at a normal weight at 24 years indicating even higher rates of continuity than those found in earlier work [24]. For those persistently overweight (but not obese) during adolescence, recovery to a normal weight was also uncommon, particularly in males in whom only one in five had a BMI <25 at the age of 24 years. Yet for those with less persistent and less severe adolescent weight problems, overweight and obesity were much less common later, particularly in females. Over two-thirds of all girls with less persistent overweight in adolescence were at a normal weight in young adulthood. The picture was less sanguine for males, with only 40% of those with less persistent overweight achieving a normal weight at 24 years.

This study had good response rates at all the waves and has the strength of having measured weight at multiple points during the teens and using the IOTF cutoffs for overweight and obesity for children and adolescents. The IOTF cutoffs have been widely adopted in many countries over the past decade, although some countries, including the United States, have continued to use country-specific definitions [14,25]. These IOTF cutoffs have the further advantage of intersecting exactly with the definitions of the World Health Organization for overweight and obesity from the age of 18 years, an important feature for tracking overweight and obesity into adulthood in this study. There were however missing data because of some participants missing data collection during some waves. The use of multiple imputation should have reduced measurement biases arising from missing data in the adolescent waves, but it does not address a possibility of biases related to differential response at wave 8 of those who had greater weight gains between adolescence and young adulthood. Weight was measured in a standard way during the first six waves of data collection. At waves 7 and 8, as follow-up was conducted by telephone interview, we relied on self-report of weight and height after written notification that this question would be asked at an interview in a week's time. Previous studies in young adults have used self-report and found high levels of agreement ($\kappa > .80$) between self-reported data and measured BMI categories [26,27]. Where error occurs it tends to be toward an overestimation of height and underestimation of weight with a resultant underestimation of the prevalence of overweight and obesity [28–30] Our procedure should have optimized the accuracy of self-report, but it is likely that we have somewhat underestimated rates of young adult obesity and the increases that take place between adolescence and young adulthood.

Females had better weight outcomes in young adulthood. Despite higher rates of obesity in adolescent girls, rates had become similar to males by the age of 24 years. By this point in young adulthood, twice as many males were in the overweight category. This picture is consistent with another recent Australian cross-sectional study of young adults [26]. Reasons for these gender differences are not immediately clear. One contributing factor may be the absence of gender standardization of the BMI cutoffs in adults so that males may have a higher BMI at a given level of adiposity. It is also possible the higher rates of overweight and obesity in female adolescents may in part, be a result of the earlier growth spurt in females compared with males and the alterations in body fat that follow puberty [4]. Other possibilities are that adolescent and young adult females are more likely to successfully engage in weight control strategies compared with males [6].

Spontaneous resolution by young adulthood is unlikely for those adolescents who peak into obesity or are persistently overweight. For these groups, clinical intervention appears warranted even though there is still much to learn about the safety and longer term efficacy of available approaches [31–33] Yet the high rates of incident overweight and obesity between adolescence and young adulthood, as well as the degree of recovery from less persisting overweight in adolescence, suggest that the transition from adolescence to young adulthood is an important phase for prevention. Understanding the factors that predict resolution of adolescent overweight is an important area for further research. It is possible that screening to detect the recent onset of overweight status tied to lifestyle interventions around physical activity, reduced screen-time, and promoting a balanced diet may promote return to normal weight in young adults [34]. Notwithstanding these clinical opportunities, the most important preventive strategies will be population-based and focused on reversing risks related to low physical activity and high energy intake that typically become prominent during the adolescent years [7,35].

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All the authors declare that the answer to the questions on your competing interest are all no.

Ethic approval by Ethics in Human Research Committee of the Royal Children's Hospital, Melbourne Australia.

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