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The Relationship of Pre-pubertal BMI Status to Post-pubertal BMI Status: An 8 Year Cohort Study

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Abstract

Objective: To investigate body mass index (BMI) percentile trends in a longitudinal cohort through puberty and to identify factors associated with post-pubertal overweight/obese BMI percentile status.

Methods: A retrospective cohort study of 760 children over eight years in a large academic healthcare system. Each child had at least one pre-puberty visit during 1999-2000 while aged 6-11 and at least one post-puberty visit during 2006-2007. Demographic and BMI data was collected on all subjects. For pre-pubertal overweight/obese subjects (BMI ≥ 85th percentile), additional data was reviewed.

Results: Overall, rates of overweight/obesity increased from 39% to 46% from pre to post puberty, respectively. Neither race/ethnicity nor gender was associated with increased post-pubertal BMI percentile. Twenty percent of children with normal pre-puberty BMI percentile progressed to being overweight/obese. A high normal pre-pubertal BMI (72nd-84th percentile) was predictive of post-pubertal overweight/obese status. Having a post-puberty overweight/obese BMI percentile was 20.4 times more likely if the pre-puberty BMI was ≥ 85th percentile. Pre-puberty overweight/obese subjects were less likely to be obese post-puberty if they met with a nutritionist/dietician. Few overweight/obese subjects had a provider-documented diagnosis of overweight/obese pre-puberty and weight related co-morbidities doubled through puberty, but neither influenced post-pubertal BMI percentile status.

Conclusions: A pre-pubertal BMI at high normal (72nd-84th percentile), or a BMI ≥ 85th percentile, but not race/ethnicity or gender, are risk factors for an overweight/obese BMI status post-puberty. Most children do not out grow their overweight/obese status through puberty, signifying the need for improved, earlier identification of and intervention for the pre-pubertal overweight/obese children and those near overweight (BMI ≥ 72nd percentile).

Keywords: Puberty; Body Mass Index-BMI; Adolescents; Overweight; Obesity; Electronic Health Records

Abbreviations: BMI: Body Mass Index; OR: Odds Ratio; CI: Confidence Interval; EHR: Electronic Health Records

Introduction

In the United States, prevalence rates of childhood overweight and obesity have more than doubled over the past two decades [1-4]. According to recent studies, 14.8% of children and adolescents aged 2 through 19 years classify as overweight (body mass index (BMI) ≥ 85th percentile and <95th percentile) while 16.9% classify as obese (BMI ≥ 95th percentile) [4]. Research has also demonstrated that minority populations have higher rates of overweight and obesity and are disproportionately affected by this growing epidemic [3-7].

High rates of weight problems among youth are troubling because obese children often become obese adults [8,9] and obesity in adulthood is a health risk [10]. Childhood obesity also predicts adult metabolic syndrome [11] and there is a well established correlation between high childhood BMI and coronary heart disease in adulthood [12-15], Several immediate consequences of childhood obesity include psychosocial stigma, asthma [16], non-alcoholic fatty liver disease and cardiovascular risk factors (hypertension, dyslipidemia, insulin resistance and diabetes) [17-20].

Much of our current knowledge about pediatric overweight/obesity comes from cross-sectional studies which do not examine the progression of BMI status in the same individuals over a period of time. Some longitudinal studies involving pediatric subjects have focused on the progression of weight and BMI from adolescence or childhood to adulthood. For example, one study found that the prevalence of obesity from adolescents (13-20 year olds) to young adults (19-26 years old) increased from 10.9% to 22.1% [21] while a different study found that a high BMI during childhood is associated with a higher risk of coronary heart disease as an adult [12]. Focusing on an earlier period of life, another study found that overweight status in elementary school-aged children was associated with an overweight status at age twelve [22]. No studies, however, have focused on the dynamic period of growth occurring from pre- to post-puberty.

While much is known about the effects that pediatric obesity can have on later adult life, there is a paucity of data regarding how pre-puberty BMI status affects post-puberty BMI status. To date, there have been no longitudinal studies that follow BMI percentile trends in a single cohort of children through the pre- and post-pubertal growth period. This study presents a longitudinal, culturally diverse cohort of urban children from pre- to post-puberty, identifying factors associated with the abnormal progression of BMI percentile and the subgroups at highest risk of retaining or developing post-pubertal overweight or obese status.

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Methods

Sample

A retrospective longitudinal data extract was conducted on electronic health record (EHR) data from pediatric patients seen in an academic, urban, hospital-based outpatient pediatric setting. Included were all children in the EHR that had been seen at least twice (once while 6-11 years old, during 1999-2000, and once while 13-18 years old, during 2006-2007) and had BMI data recorded at both visits. These criteria identified 942 potential study subjects, of which 19% (182) were ineligible due to either having entered puberty, defined as a Sexual Maturity Rating>1 [23,24] (as documented in the EHR documentation) at the first visit while aged 6-11 (27%, n=149), or having a BMI <5th percentile (6%, n=33). The criterion for being post-pubertal in 2006-2007 was strictly age-based and Sexual Maturity Data were not collected for this time period. For children with more than one visit during either time period, data from the earliest and latest visits from pre- and post-puberty, respectively, were used.

For the 760 qualifying subjects, we gathered additional information including gender, age, race/ethnicity, height, weight, BMI and BMI percentile. For subjects classified as overweight or obese pre-puberty, we gathered the following information: provider documentation of pre-puberty diagnosis of overweight or obesity; provider documentation of weight-related co-morbid ICD diagnoses (asthma, depression, hypertension, hyperlipidemia, non-alcoholic steatohepatitis, obstructive sleep apnea, slipped capital femoral epiphysis, polycystic ovarian syndrome, attention-deficit hyperactivity disorder, and acanthosis nigricans) diagnosed at either the pre-puberty or post-puberty visits; and nutrition/dietician visits. All data was extracted by a single chart reviewer. Data regarding weight related co-morbid diagnoses was taken from the structured data entry sections of the EHR and not from the actual text of a physician's note.

Definitions

In accordance with the most recent guidelines [25], we used the following definitions: normal (BMI ≥ 5th and <85th percentile), overweight (BMI ≥ 85th and <95th percentile) and obese (BMI ≥ 95th percentile). Overweight/obese is defined as the combined overweight and obese groups (BMI ≥ 85th percentile).

Statistical methods

Statistical Analysis Software (SAS, version 9.3) was used for frequency counts, univariate analyses and regression analysis. Logistic regression was used to evaluate the role that gender, race/ethnicity and pre-pubertal BMI percentile have on post-pubertal BMI percentile. For subjects with pre-puberty overweight/obesity, logistic regression was used to evaluate the role that nutritionist/dietician visits, having at least one pre-pubertal weight-related co-morbidity and a pre-pubertal provider-documented diagnosis of overweight or obesity had on post-pubertal BMI percentile. A p-value of <0.05 was considered statistically significant for all analyses.

This study was approved by the Institutional Review Board of the home institution.

Results

Of the 760 subjects, 45% were female, 43% Caucasian, 35% African-American, 19% Hispanic, and 3% other/unknown. The mean pre-puberty and post-puberty ages were 7.8 ± 1.5 and 15.2 ± 1.4 years, respectively. The average amount of time between pre-puberty and post-puberty visits was 7.3 ± 0.5 years. Of note, 48% of males and 44% of females qualified as overweight or obese post-puberty, with Caucasian males (50%) and African-American females (48%) topping the lists for their respective genders (Table 1). From the pre-puberty to the post-puberty visits, the percent of children qualifying as overweight/obese increased from 39% to 46%, respectively, with a higher percentage of children being obese rather than overweight (Table 1). Pre-puberty, there were no statistically significant differences between the normal group and the overweight/obese group for gender, race/ethnicity and age. In regression analysis, neither race/ethnicity nor gender was associated with an elevated post-pubertal BMI percentile.

Normal pre-puberty BMI group

Twenty-one percent (99) of the subjects with normal pre-pubertal BMI percentiles progressed to overweight (14%, n=67) or obese (7%, n=32) post-puberty. Subjects with normal pre-pubertal BMI percentiles were divided into quartiles according to their pre-pubertal BMI percentiles. Each quartile was analyzed to determine if there was a relationship between pre-pubertal BMI percentile quartile and an overweight/obese post-pubertal BMI status (Table 2). Pre-pubertal subjects with BMIs in the highest quartile (72nd-84th percentiles) were 4.8 (CI 2.9-7.8) times more likely to be overweight or obese post-puberty than those subjects with a pre-pubertal BMI in the lower three quartiles (Table 3).

Overweight/Obese pre-puberty BMI Group

The majority (84%) of subjects who qualified as overweight or obese pre-puberty had BMI ≥ 85th percentile post-puberty. The odds ratio of qualifying as overweight or obese post-puberty was 20.4 times greater (CI 13.9-30.1) if the pre-puberty BMI was ≥ 85th percentile (Table 3). For the 16% (46) of subjects who improved from being overweight/obese pre-puberty to a normal post-puberty BMI percentile, 70% (33) were male, 40% African- American, 42% Caucasian, and 18% Hispanic. A statistically significant relationship existed between male gender and improving to a normal post-puberty BMI percentile (p=0.01), race/

	Pre-puberty, Ages 6-11y – % (n)			Post-puberty, Ages 13-18 y – % (n)		
	Normal	Overweight	Obese	Normal	Overweight	Obese
Male (n=414)	58.7 (243)	17.2 (71)	24.2 (100)	52.4 (217)	17.4 (72)	30.2 (125)
Caucasian (n=174)	60.9 (106)	17.2 (30)	21.8 (38)	50.6 (88)	21.3 (37)	28.2 (49)
African-Am. (n=148)	55.4 (82)	18.9 (28)	25.7 (38)	52.7 (78)	16.2 (24)	31.1 (46)
Hispanic (n=78)	57.7 (45)	15.4 (12)	26.9 (21)	56.4 (44)	12.8 (10)	30.8 (24)
Female (n=346)	63.9 (221)	15.9 (55)	20.2 (70)	56.1 (194)	20.2 (70)	23.7 (82)
Caucasian (n=151)	65.6 (99)	15.9 (24)	18.5 (28)	58.9 (89)	21.2 (32)	19.9 (30)
African-Am. (n=114)	62.3 (71)	16.7 (19)	21.1 (24)	51.8 (59)	19.3 (22)	29.0 (33)
Hispanic (n=67)	59.7 (40)	16.4 (11)	23.9 (16)	53.7 (36)	20.9 (14)	25.4 (17)
Total	61.1 (464)	16.6 (126)	22.4 (170)	52.8 (401)	18.9 (142)	27.2 (207)

Table 1: Pre-pubertal to post-pubertal progression of BMI status by gender and race/ethnicity

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ethnicity however, was not associated with improving to a normal post-puberty BMI percentile (p=0.74).

Eighty-two percent (242) of overweight/obese subjects did not have a provider-documented diagnosis of pre-puberty overweight or obesity. Only 1 of the 54 subjects who had a provider-documented pre-puberty weight related co-morbid diagnosis improved to a normal BMI post-puberty. Overweight/obese subjects diagnosed with at least one weight related co-morbid diagnosis increased from 31% pre-puberty to 65% post-puberty (p<0.0001) and there were several statistically significant increases in individual weight related co-morbidities (Table 4). Furthermore, obese subjects were disproportionately affected by weight related co-morbidities, compared to overweight subjects, in almost all categories both pre-puberty and post-puberty. In a regression analysis, neither having a weight-related co-morbidity diagnoses nor having a pre-puberty diagnosis of overweight or obesity affected post-pubertal BMI trends [OR 1.2 (CI 0.7-2.0) and OR 0.4 (CI 0.2-1.1), respectively] (Table 3).

Between the pre-puberty and post-puberty visits, 31% of overweight/obese subjects were seen at least once by a nutritionist/dietician. In a regression analysis, overweight/obese subjects without a nutritionist/dietician visit during this interim were 0.4 (CI 0.2-0.7) times more likely to be obese post-puberty when compared to overweight/obese subjects with at least one nutritionist/dietician visit (Table 3).

Discussion

This retrospective cohort study is the first to look at the association of pre-puberty BMI status to post-puberty status in a large cohort of racially and ethnically diverse children. Our analysis demonstrates that children do not outgrow weight problems during puberty and, in fact, weight problems tend to worsen during this time. More children had higher abnormal BMI percentiles post-puberty, compared to pre-puberty. The single biggest predictor of post-pubertal BMI percentile is pre-pubertal BMI percentile, across all categories.

This study identified two risk factors for a post-pubertal BMI ≥ 85th percentile: 1) a pre-pubertal BMI at the high end of the normal range (72nd-84th percentile) and 2) a pre-pubertal BMI ≥ 85th percentile. One in five children with a normal pre-puberty BMI percentile progressed to an overweight/obese post-puberty BMI percentile. The majority (52%) of those who progressed had a pre-puberty BMI percentile in the highest normal quartile (72nd-84th percentile). Eighty-four percent of the pre-puberty overweight/obese group remained overweight/obese post-puberty. These findings are similar to another longitudinal study that followed BMIs in children over a 10 year period from ages 2 to 12. Nader et al. [22] reported that preschool and early elementary school children with BMIs ≥ 85th percentile or BMIs >50th percentile were more likely than children with BMIs <50th percentile to reach overweight status at age 12. Our study is consistent with these findings

	Pre-pubertal	Post-pubertal	
BMI Percentile Range*	**Percentage with Normal BMI - % (n)**	**Percentage with Normal BMI - % (n)**	**Percentage with Overweight/Obese BMI - % (n)**
5th-33rd	25.4 (118)	92.4 (109)	7.6 (9)
34th-54th	25.4 (118)	89.0 (105)	11.0 (13)
55th-71st	24.1 (112)	76.8 (86)	23.2 (26)
72nd- 84th	25.0 (116)	56.0 (65)	44.0 (51)

Table 2: Pre-pubertal to post-pubertal progression of BMI status within normal pre-pubertal quartiles

*Each range contains one-quarter of all the Normal Pre-pubertal BMI percentile subjects, i.e. quartiles.

Factor	Odds Ratio (Confidence Interval)
Pre-puberty BMI ≥ 85th percentile	20.4 (13.9-30.1)
Pre-puberty BMI in highest normal quartile (72nd-84th percentile)	4.8 (2.9 – 7.8)
At least one provider-documented, weight-related co-morbidity	2.0 (0.7 – 2.0)
A provider-documented diagnosis of pre-puberty overweight or obesity	0.4 (0.2 – 1.1)
At least one nutritionist/dietician visit during puberty	0.4 (0.2 – 0.7)

Table 3: Regression analysis of factors that predict post-puberty BMI ≥ 85th percentile

	Pre-Puberty	Post-Puberty	P-value**
	Total – % (n) Overweight vs. Obese - % of Total (n)	**Total – % (n)* Overweight vs. Obese - % of Total (n)**	
Subjects with at least one provider-documented, weight related co-morbidity	31.1 (92) 44.6 (41) vs. 55.4 (51)	64.5 (191) 23.6 (45) vs. 63.4 (121)¥	<0.0001
Asthma	21.6 (64) 43.8 (28) vs. 56.2 (36)	35.5 (105) 26.7 (28) vs. 60.0 (63)	<0.0001
Depression	0.3 (1) 100 (1) vs. 0	10.1 (30) 26.7 (8) vs. 63.3 (19)	0.10
Diabetes Mellitus Type II	0.3 (1) 100 (1) vs. 0	1.4 (4) 0 vs. 100 (4)	0.91
Hyperlipidemia	0.7 (2) 0 vs. 100 (2)	15.5 (46) 13.0 (6) vs. 82.6 (38)¥	0.02
Hypertension	0.7 (2) 0 vs. 100 (2)	12.5 (37) 8.1 (3) vs. 83.8 (31)¥	0.02
Non-Alcoholic Steatohepatitis	0 0 vs. 0	1.4 (4) 0 vs. 100 (4)	n/a
Obstructive Sleep Apnea	3.0 (9) 33.3 (3) vs. 66.7 (6)¥	13.5 (40) 10.0 (4) vs. 85.0 (34)¥	<0.0001
Slipped Capital Femoral Epiphysis	0 0 vs. 0	0.3 (1) 0 vs. 100 (1)	n/a
Polycystic Ovarian Syndrome	0 0 vs. 0	2.0 (6) 50.0 (3) vs. 50.0 (3)	n/a
Attention-Deficit Hyperactivity Disorder	7.1 (21) 42.9 (9) vs. 57.2 (12)	15.2 (45) 22.2 (10) vs. 60.0 (27)	<0.0001
Acanthosis Nigricans	0.3 (1) 0 vs. 100 (1)	6.8 (20) 20.0 (4) vs. 75.0 (15)¥	n/a

In this column, "Total" values include the 46 subjects who had pre-puberty overweight/obesity, but improved to a normal BMI post-puberty. The "Overweight vs. Obese" values do not include these same 46 subjects.
** *p-values* in this column correlate with the Pre- and Post-Puberty "Total" values.
¥ *p-value <0.05*

Table 4: *Progression of provider-documented, weight-related co-morbidities from pre-puberty to post-puberty in the pre-puberty overweight/obese BMI group (n=296)

and demonstrates that an elevated pre-pubertal BMI persists through puberty. Future research is needed to look at young children with BMI percentiles at this high end of the normal reference range to identify modifiable risk factors that contribute to their impending overweight/obese status.

In contrast, there was a small group of subjects (16%, n=46) who demonstrated an improvement from pre-puberty BMI ≥ 85th percentile to a normal post-puberty BMI percentile. Male gender was associated with this improving progression while ethnicity was not. This observation needs further research. Our study points to the observation that even one nutritionist/dietician appointment during puberty among overweight/obese patients can statistically improve post-pubertal weight status. This emphasizes that early diagnosis, along with a seemingly simple intervention such as a nutritionist/dietician visit, could have a significant impact.

Overall, there was an increase in the prevalence of overweight/obese status in our population over time (46% overweight/obese post-puberty compared to 39% overweight/obese pre-puberty). The prevalence in our study population is higher than recent national data which reports that 34% of children aged 12-19 and 33% of children aged 6-11 have a BMI ≥ 85^{th} percentile [4]. Gordon-Larsen et al. has reported on the increasing prevalence of obesity from the transition of adolescence to young adulthood [21]. Their longitudinal study reported that obesity (BMI ≥ 30) rates increased from 11% in adolescents (ages 13-20) to 22% in young adults (ages 19-26). In our study population, obesity (BMI ≥ 95^{th} percentile) rates increased from 22% pre-puberty to 27% post-puberty.

While the overall trend in all groups seems to be an increase over time in overweight and obesity prevalence, our cohort had higher prevalence rates than other published data. This is likely due to our data being collected from a public hospital system which provides service to a lower-income population, which has been shown to be associated with higher rates of obesity [26]. In addition, this cohort is a predominantly minority population, which is also associated with higher rates of overweight and obesity [3-7].

In our study we found few pre-pubertal overweight/obese children (18%) had a provider-documented diagnosis of overweight or obesity pre-puberty. In a regression analysis, having a charted diagnosis was not found to have an influence on post-pubertal BMI (OR 0.43, CI 0.17-1.06). It is important to note, however, that 31% of this group was seen during the interim period by a nutritionist/dietician, presumably for weight-issues. This suggests that for some subjects, overweight or obesity was identified, but not documented in the EHR, and an intervention (nutrition/dietician referral) was pursued. Benson et al. has also reported significant under-diagnosis of overweight/obesity and concluded that identifying the problem is the first step in fighting this growing epidemic [27].

For pre-pubertal overweight/obese subjects, weight related co-morbid diagnoses doubled from pre- to post-puberty. Having at least one weight-related, pre-pubertal co-morbidity identified and documented by a provider, however, did not have an effect on post-pubertal BMI status. While several papers have identified co-morbidities that are associated with pediatric obesity [9-20], to our knowledge our study is the first to follow and report the longitudinal development of co-morbidities over time. The significant increase in co-morbid diagnoses could be partially attributable to potential provider under-diagnosis in the pre-pubertal group. Despite this consideration, our data demonstrates that obese subjects suffer the highest rates of co-morbidities.

During the study period only one-third of the pre-puberty overweight/obese group met at least once with a nutritionist/dietician. Overweight/obese subjects without a nutritionist/dietician visit were 2.6 times more likely to be obese post-puberty, compared to overweight/obese subjects who had met at least once with a nutritionist/dietitian. The American Academy of Pediatrics recommends that the treatment of pediatric obesity should include a multidisciplinary approach; including a referral to a qualified nutritionist/dietitian [25]. Similar to findings from O'Brien et al. [28], our study showed that few (22%) obese children received a nutritionist/dietitian referral for treatment of pediatric obesity.

Limitations of this study include lack of information regarding the diet and exercise habits of the subjects; study population is at a single location and may not be representative of greater population; and it is not known if the subjects accessed additional health care, such as nutrition visits, at another health care facility.

Conclusion

A pre-pubertal BMI at high normal (72^{nd} to 84^{th} percentile), or BMI ≥ 85^{th} percentile, but not race/ethnicity or gender, appear to be risk factors for progression to overweight or obese BMI status post-puberty. The common belief that children will overcome their overweight or obese status, as they grow taller and pass through puberty, does not hold true in this study population. Pediatricians need to use these findings to identify pre-pubertal children who are at-risk for becoming or remaining overweight/obese post-puberty, and offer interventions, such as a nutrition/dietician referral, which may have a significant impact on the trajectory of the BMI status.

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