ORIGINAL

Weight and height growth velocities of Japanese boys and girls between age 7 and 14 years : a critical window for early adolescent overweight risk

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Abstract : Childhood overweight is an important worldwide problem of public health concern, with metabolic, physical and psychosocial complications. More and more evidence is accumulating that children who gain weight rapidly earlier in life are at higher risk of becoming overweight later in adulthood life. Therefore, in a seven-year longitudinal study, we studied mid-childhood and early adolescence weight and height growth velocities among 5,024 Japanese 2nd grade primary school boys and girls along with its effect on the likelihood of being overweight adolescents by the age of 14 y. Our findings showed that weight growth velocity of both sexes was associated with being overweight at the end of longitudinal study. Boys' risk of accelerated weight growth velocity and becoming overweight adolescents was almost doubled during ages 7~11 y and become reduced afterward. Otherwise, odds ratios of girls' weight growth velocity peaks were found only at ages from 9~10 and 10~11 y. Thus, we suggest a critical window of mid-childhood period associated with adolescence risk of overweight, and we recommend that studying weight growth determinants during 7~11 y of boys and 9~11 y of girls may help in developing and applying proper programs for prevention and intervention of overweight problem. J. Med. Invest. 57 : 124-132, February, 2010

Keywords **:** *growth velocity, overweight, Japanese, school children, longitudinal study*

INTRODUCTION

Worldwide, the prevalence of overweight and obesity has become a problem of major public health concern. For instance, in developed countries and in Japan, overweight/obesity is gaining much attention for its increasingly reported associations with morbidity and mortality. More and more, evidence is accumulating that childhood overweight/obesity increases the risk of adulthood obesity which strongly correlated with cardiovascular diseases, metabolic syndrome, type 2 diabetes and other complications including cancers (1-16).

In children as well as adolescents, calculating the body mass index (BMI, kg/m^2) from body weight and height is a simple and acceptable screening method for detecting overweight and obesity. However, during childhood and early adolescence the BMI changes substantially with age, which makes setting BMI cut-off points for deciding overweight/obesity a bit difficult. The pattern of weight and height growth during childhood period makes it

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difficult to have a definite prediction for the development of overweight/obesity later in life (17-21).

Assessment of weight and height growth in children may help to understand the potential periods of switching from being a normal weight and becoming an overweight/obese individual. Such understanding of the growth velocities is supposed to be helpful in developing preventive or therapeutic intervention programs.

In this research, we aimed at studying the weight and height growth velocities among Japanese school boys and girls. Therefore, we recruited a cohort of 5,024 school children from primary schools of Tokushima prefecture, Japan ; and followed up their weight and height growth velocities, annually, between the ages of 7 and 14 years.

For calculating overweight percentages among children of this study we used age and gender-specific BMI cut-off points starting from early childhood based on international data from different countries, which is linked to adults' cut-off points of BMI > 25 for overweight and > 30 for obese subjects (age adjusted BMI based on International Obesity Task Force (IOTF) standards) (22). Thus, in this study, children's weight, height and BMI were examined annually, and weight and height growth velocities were calculated during a 7-year longitudinal study and implications of these growth velocities to the subjects' current and future overweigh will be discussed.

SUBJECTS AND METHODS

Subjects

This study was designed to investigate the anthropometric growth velocities among school children at Tokushima prefecture. Further we aimed at comparing the anthropometric growth velocities of boys and girls as well as among normal, overweight and obese children to find out the age at which these Japanese children start to gain weight and develop overweight or obesity. For these purposes, we designed a longitudinal prospective cohort study that started on April, 2001 ; with a cohort of 2nd grade primary school children i.e., 7 years old, who belonged to 232 primary schools in Tokushima prefecture, Shikoku Island, Japan.

Throughout the seven years cohort study, every year on the month of April, we assessed the anthropometric measurements (i.e., body weight and height) and calculated the BMI of every child in the study cohort. Then after the baseline study and from the consecutive annual anthropometric measurements weight and height growth velocities were calculated on 7 points of time throughout the longitudinal study (i.e., annual anthropometric weight and height growth velocities measurements).

Anthropometric measurements (weight and height) were conducted for the cohort school children by the school nurses. Children were allowed to wear only the underclothing during the measurements. Body weight was measured and recorded to the nearest 0.1 kg, and height was measured and recorded to the nearest 0.1 cm using a manual height board. BMI was then computed for all the children using the formula ; BMI equals weight (kg)/height (m^2).

The collected data were encoded according to the children's municipality, school, birth date and gender. The children identities were kept anonymous for ethical considerations ; therefore, we combined their anthropometric data during the seven years cohort study with their age, sex, birth date, municipality and school code.

Originally, this 7 years longitudinal study included a cohort of 7,506 children (3,855 boys and 3,651 girls), however, after omitting children with incomplete data and others from schools for children with special needs and those who remained unidentified after data combination trials, we could have full confirmed data of 5,024 children (2,601 boys and 2,423 girls). The omitted data have not biased the analyzed children data. Before starting this study we got the consent of Tokushima board of education as well as schools' administrations ; and the ethical committee of Tokushima University Hospital approved the study.

Statistical methods

Using BMI cut-off values according to the International Obesity Task Force by Cole et al. 2000, the children were classified as normal, overweight/obese (22). At the baseline study and after the annual cross-sectional anthropometric measurements, the number of normal, overweight and obese children was calculated and prevalence of overweight/obesity was determined. All analyses were done for the boys and girls, separately. Statistical analyses were performed using the software of statistical package for social sciences, SPSS ver11 (SPSS Inc.). Differences between boys and girls' measurements' means were analyzed by Student t-test. Weight and height growth velocities in four sub-groups at seven

point of time were compared by Bonferroni's test if the one-way analysis of variance (ANOVA) test was significant. P values less than 0.05 were considered significant.

Tracking of overweight or obesity was defined as being overweight from the baseline and throughout the longitudinal study till its final-year. In each age category the number of subjects who first met the criteria of overweight during the follow-up was analyzed. We also analyzed children weight and height at each year and subtracted it from the data of the previous year to calculate the growth velocity of weight and height of the Japanese school boys and girls.

For boys and girls, separately, and at different ages between 7 and 14 y, the children's weight and height growth velocities were investigated.

Then the likelihood of becoming overweight at the final year of the longitudinal study was investigated for the boys and girls who were initially non overweight. For this purpose we used a logistic regression model. The resulted odds ratios were used to draw a figure for boys and another figure for girls' odds ratios for becoming overweight at different ages between 7 and 14 y.

In all the statistical comparisons, p-values less than 0.05 were considered significant.

RESULTS

In this 7-year longitudinal study we started with a baseline study (on April, 2001) by measuring body weight, height and BMI for a cohort of school children whose ages were 7 y old and belong to the 2nd grade of primary schools at Tokushima prefecture, Japan. We followed up the 5,024 children (2,601 boys and 2,423 girls) whose data was full and confirmed. During the seven-year longitudinal study, we followed up body weight and height growth and monitored the growth velocity, separately for boys and girls.

Table 1 presents the means and standard deviations of the anthropometric measurements of the Japanese boys and girls including mainly body weight, height and BMI at every year starting from the baseline measurements on the year 2001 onwards for seven consecutive years i.e., from age 7 till the age of 14 y. Results indicate that at the age of 7 and 8 y, boys have significantly higher body weight, height and BMI than girls. Then, at the age of 9 y height and BMI of boys and girls become almost comparable. However, on the age of 10 and 11 y girls show accelerated height growth and become significantly taller but not heavier than boys, which makes the boys seem fatter having significantly higher BMI. This can be simply explained by the physiological trends for girls to start reaching maturity earlier than boys. This phenomenon was reversed completely by the age of 13~14 y where boys weights and heights are significantly increased while their BMI was significantly reduced than girls.

Table 2 shows tracking status of overweight

Table 1 Mean BMI values of Japanese school boys and girls as measured in the baseline (2001) and the following annual cross-sectional survey studies (2002-2008).

			Boys (n=2,601)			Girls (n=2,423)		
Year	Grade	Age(y)	Height	Weight	BMI	Height	Weight	BMI
2001	2nd	7	122.5± 5.2 **	24.9± 5.0 **	16.5± 2.4 **	121.8± 5.2	24.2± 4.5	16.3± 2.2
2002	3rd	8	128.1± 5.4 **	28.3± 6.1 **	17.1± 2.8 **	127.6± 5.6	27.5± 5.6	16.8± 2.5
2003	4th	9	133.4± 5.8	31.8± 7.3 **	17.4± 3.1	133.7± 6.3	31.1± 6.6	17.3± 2.7
2004	5th	10	139.0± 6.2 **	35.6± 8.5	18.3± 3.3 **	140.4± 6.3	35.8± 7.5	17.9± 2.8
2005	6th	11	145.1± 7.3 **	40.1± 9.7	18.9± 3.4 **	147.1± 6.7	40.5± 8.7	18.6± 3.0
2006	7th	12	152.5± 8.1 *	45.8± 10.7 *	19.5± 3.4	152.0± 6.0	45.1± 8.9	19.5± 3.2
2007	8th	13	159.7± 7.8 **	50.6± 10.8 **	19.7± 3.3 **	154.9± 5.5	48.5± 8.7	20.2± 3.2
2008	9th	14	165.1± 6.7 **	56.0± 11.0 **	20.4± 3.4 **	156.4± 5.4	51.4± 8.6	21.0± 3.2

Data are expressed as the Mean± SD.
P values were calculated by using Student's t-test.
* $p < 0.05$
** $p < 0.01$

Table 2 Tracking overweight status of Japanese school boys and girls from the baseline (2001) till the final year cross-sectional cohort study (2008).

Tracking status	Boys (n (%))	Girls (n (%))
NOW-NOW	1962 (75.9)	1885 (77.8)
NOW-OW	192 (7.4)	164 (6.8)
OW-OW	259 (10.0)	199 (8.2)
OW-NOW	188 (7.2)	175 (7.2)
Total	2601	2423

among the children cohorts throughout the 7-years study. Tracking the BMI status of the children was performed by comparing their BMI at the baseline study with that of the final year measurements of the cohort study. Tracking BMI status resulted in having four sub-groups in each cohort of school boys and girls : children who were non-overweight at the baseline survey and were non-overweight at the end of the longitudinal study (NOW-NOW) ; children who were initially non-overweight but became overweight at the end of the study (NOW-OW) ; children who were initially overweight and ended the study as overweight (OW-OW) ; and children who started as overweight at the baseline survey but ended up as non-overweight (OW-NOW) at the end of the 7-years longitudinal study i.e., at age of 14 y.

Among boys, 10.0% were tracked as overweight (OW-OW) from the baseline survey till the final year, while for girls OW-OW group was 8.2%.

There were 7.4% boys and 6.8% girls having normal weight at the baseline survey and have become overweight at the final year i.e., (NOW-OW).

A 7.2% of boys and a similar percent of girls who were initially overweight returned back to their normal BMI (OW-NOW) by the end of the longitudinal study. Deciding BMI tracking status was used in further studies on body weight and height growth velocities in normal (NOW-NOW) and overweight boys and girls, independently.

We compared height and weight growth velocities among the four sub-groups at seven point of time in each sex. By ANOVA test, significant differences were found in the height and weight growth velocities in almost all the checked time points for both sexes. In boys, we found that the height growth velocity of the four sub-groups started nearly the same at the baseline study. However, in the following years, all groups started to show their different peaks and patterns of height growth. At age of 12~13 y NOW-NOW boys showed their peak of height growth, which appeared a bit later than other sub-groups and significantly higher than OW-OW ($p<0.01$) and OW-NOW boys ($p<0.01$) (Fig. 1A). Unlike height, boys' weight growth velocity of NOW-NOW boys was significantly lower than other groups till the points of 10~11 y. The weight of the boys who started as normal and ended as overweight (NOW-OW) was rapidly growing after 11~12 y (Fig. 1B).

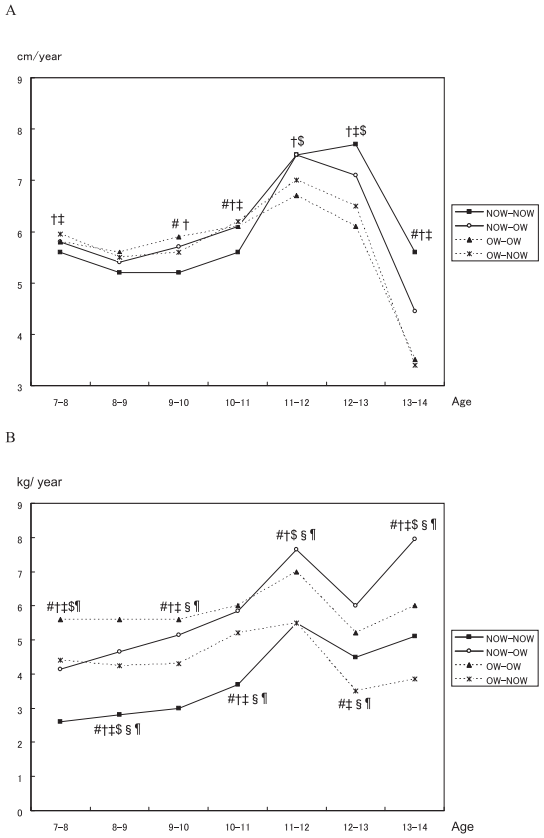

Fig. 1. A 7-years longitudinal follow up results of the studied Japanese boys' height (A) and weight (B) growth velocities among the four tracking sub-groups (2001~2008). # $p<0.05$, † $p<0.05$, ‡ $p<0.05$, $ $p<0.05$, § $p<0.05$, ¶ $p<0.05$ for differences between NOW-NOW and NOW-OW, NOW-NOW and OW-OW, NOW-NOW and OW-NOW, NOW-OW and OW-OW, NOW-OW and OW-NOW, OW-OW and OW-NOW, respectively.

For girls, the height growth velocity of the four sub-groups was closely comparable throughout the study (Fig. 2A), but the weight growth velocity of OW-OW girls was significantly higher than other sub-groups at baseline and reached its peak at the age of 10~11 y. By the age of 9~10 y the NOW-OW subgroups growth velocity significantly exceeded that of the OW-NOW and showed their peak at 10~11 y and 11~12 y while keeping significant increases than the other girls' sub-groups till the

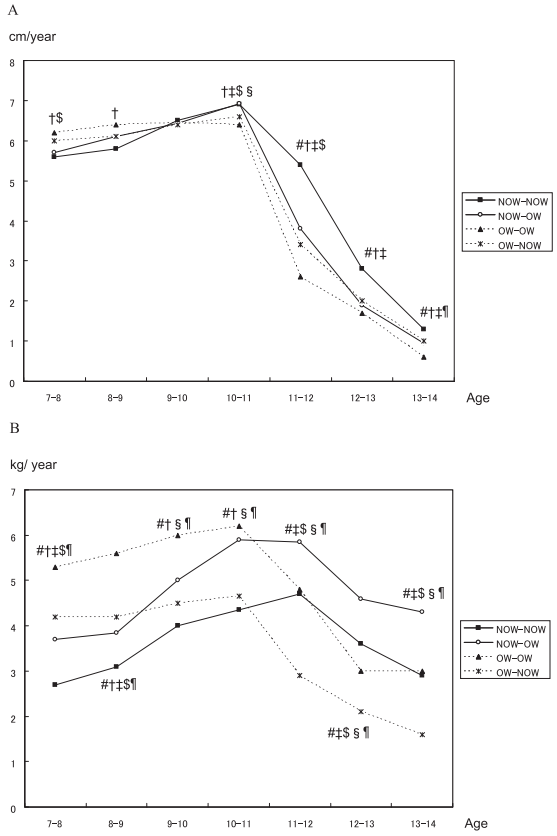

Fig. 2. A 7-years longitudinal follow up results of the studied Japanese girls' height (A) and weight (B) growth velocities among the four tracking sub-groups (2001~2008). # $p < 0.05$, † $p < 0.05$, ‡ $p < 0.05$, $ $p < 0.05$, § $p < 0.05$, ¶ $p < 0.05$ for differences between NOW-NOW and NOW-OW, NOW-NOW and OW-OW, NOW-NOW and OW-NOW, NOW-OW and OW-OW, NOW-OW and OW-NOW, OW-OW and OW-NOW, respectively.

end of the longitudinal study (Fig. 2B).

Table 3 shows odds ratio/1-SD increase in weight growth velocity of the initially non overweight boys and girls (NOW-NOW and NOW-OW tracking sub-groups), throughout the seven-year longitudinal study. It indicates the children's likelihood of becoming overweight at different points during their ages between 7~14 y. For boys, the "odds ratio" of gaining weight rapidly and becoming an overweight boy was almost doubled at each point throughout the period from ages 7~11 y, then the risk is relatively reduced through the early adolescence period. However, for girls, the pattern of weight growth velocity and the likelihood for being an overweight was different. The peak of the girls' likelihood of becoming overweight at the final year of the longitudinal study was found at ages from 9~10 y and 10~11 y. Odds ratio distribution patterns per each year from the age of 7~14 y for boys and girls are presented in figure 3A and 3B, respectively.

Table 3 Seven-years risk of Japanese boys and girls for becoming overweight by the age of 14 y ; odds ratios for 1-SD increase in weight growth velocity and 95% CIs at different ages between 7 and 14 y.

Boys

Age	Odds ratio	95% CI	p value	1-SD (kg/year)
7-8	2.69	2.26-3.03	> 0.01	1.72
8-9	1.98	1.68-2.32	> 0.01	2.28
9-10	2.39	1.97-2.88	> 0.01	2.61
10-11	2.05	1.73-2.44	> 0.01	3.05
11-12	1.69	1.45-1.97	> 0.01	4.40
12-13	1.17	1.01-1.34	0.04	4.05
13-14	2.55	2.13-3.05	> 0.01	5.30

Girls

Age	Odds ratio	95% CI	p value	1-SD (kg/year)
7-8	1.87	1.57-2.22	> 0.01	1.74
8-9	1.89	1.55-2.31	> 0.01	1.87
9-10	2.69	2.34-3.23	> 0.01	2.70
10-11	2.87	2.37-3.37	> 0.01	3.56
11-12	1.51	1.30-1.85	> 0.01	3.79
12-13	1.44	1.21-1.72	> 0.01	3.10
13-14	1.95	1.67-2.29	> 0.01	2.07

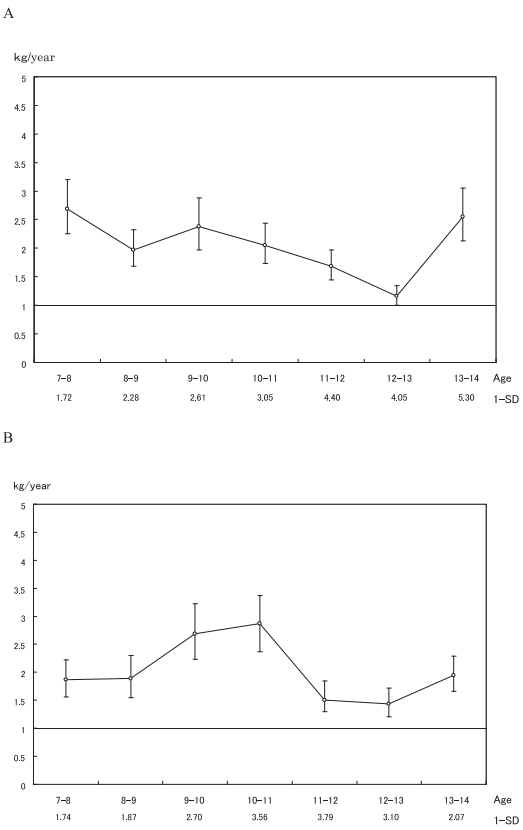

Fig. 3. Seven-years odds ratios for the initially non overweight boys (A) and girls (B) for becoming overweight by the end of the longitudinal study. Odds ratio/1-SD increase in weight growth velocity at any point of time between ages of 7 and 14 y indicates the risk of being overweight at the end of the 7-year longitudinal study.

DISCUSSION

Childhood overweight is an important worldwide problem of public health concern, with metabolic, physical and psychosocial consequences (23-25). It has also, become manifested from the accumulating data that overweight children are significantly more likely to become overweight or obese adults (26-30). Moreover, several studies are accumulating more evidence indicating that children who gain weight rapidly earlier in life are at higher risk of becoming overweight or obese later in adulthood life (31-37). Therefore, studies that focus on growth velocities are thought to be helpful for overweight and obesity researchers to find out the proper periods for applying prevention and intervention programs to control overweight problem. Some researchers have already focused on the postnatal and early childhood weight and height growth velocities among children and studied its relationship with adolescent body fatness. They concluded that there are two main critical periods of early childhood associated with the later risk of obesity : up to 6 months after birth and from 2 y onward till 5 years of age (38).

In our study, we aimed at studying mid-childhood and early adolescence weight and height growth velocities among Japanese school boys and girls along with its effect on the likelihood of being overweight adolescents.

Therefore, we studied body weight, height and BMI of 5,024 Japanese 2nd grade primary school children (2,601 boys and 2,423 girls) from Tokushima prefecture in a baseline study, on April, 2001, and followed up their anthropometric measurements in a seven-year longitudinal study. The boys and girls weight and height growth velocities were calculated and comparisons were performed among four tracking subgroups decided by following up their initial BMI status at the baseline survey and at the end of the longitudinal study.

We found that at the ages of 7~8 years boys had more overweight than girls, but on the age of 9 years the differences disappear since in this age it is physiologically known that girls start to grow faster before puberty. However, on the age of 10~11 girls' height but not weight growth becomes accelerated than boys ; therefore the boys were fatter on this period. In the early adolescence period boys weight and height growth are significantly accelerated than girls. These periods of earlier girls puberty at the age of 9 and the boys pubertal age is a bit later than them is consistence with the known physiological trends (39-42).

Tracking the children's BMI status from the baseline to the end of the 7-year longitudinal study was performed by comparing their BMI at the baseline with that of the final year measurements. Tracking status investigation showed that 10% of 7 y overweight Japanese primary school boys tracked into overweight 14 y adolescents. This percentage was lower among girls, where, 8.2% of 7 y overweight primary school girls tracked into overweight 14 y adolescents. These results indicate that the prevalence of overweight is higher among Japanese boys, whose childhood overweight is more tracked to early adolescence than the Japanese girls of the same age (43).

The children tracking status resulted in having four sub-groups in each cohort of school boys and girls : NOW-NOW, NOW-OW, OW-OW and OW-NOW.

Further, we investigated height and weight growth velocities among boys and girls and compared the height and weight growth velocities among the BMI tracking four sub-groups.

For boys, the height and weight growth velocities were significantly different among the four sub-groups in almost points. It was obvious that the NOW-NOW boys had their height growth peak at 12~13 y which was later than boys of the other 3 sub-groups (Fig. 1A). For their body weight, OW-OW and OW-NOW groups showed parallel weight growth velocity, while from the initial measurements weight growth velocity of OW-OW was significantly higher than that of OW-NOW. A similar trend of weight growth velocity was observed for the two groups who were initially NOW. Thus, the curves of NOW-NOW and NOW-OW weight growth velocities were almost parallel in all the measurements points. The curve of NOW-OW weight growth velocity was differentially higher and the difference increases from the age of 11 y onward (Fig. 1B).

These results seem to be supported by other research finding from Japan, which reported that childhood obesity was increasing in Japanese boys, especially those who aged 9~11 y ; and those studies additionally, reported that approximately 32% of the obese boys and 41% of the obese girls grow into obese adults, and the degree of obesity is a predictive factor for adult obesity (44).

For girls' weight growth velocity, girls who were initially overweight (OW-OW and OW-NOW) had parallel weight growth velocities curves with their

peaks at age 10~11 y, while those who were initially non-overweight (NOW-NOW and NOW-OW) had parallel curves but their weight growth velocity peaks appeared later on ages 11~12 y (Fig. 2B). The girls' height growth velocity curves were significantly different, however these curves did not show noticeable differences among the four sub-groups (Fig. 2A).

For further understanding of the weight and height growth velocities and their effects on the likelihood of boys and girls overweight status at the end of the 7-year longitudinal study, we used a logistic regression model to calculate odds ratios in the NOW-NOW and NOW-OW sub-groups of boys and girls.

The logistic regression model showed that the boys' risk of gaining weight and becoming overweight adolescents was almost doubled at each point throughout the period from the age of 7 till 11 y, and then the risk is relatively reduced through the early adolescence period. However, for girls, the pattern of weight growth velocities and the likelihood for being overweight adolescents were different, whereas, their peaks of "odds ratio" of becoming overweight at the final year of the longitudinal study was found only at ages from 9~10 y and 10~11 y.

It must be clearly indicated here, that our study has a limitation of investigating weight and height growth velocities from children data between the ages of 7 and 14 years, which can not help in predicting the overweight status of those children beyond this age limit. Further studies with extended age ranges will follow to study the associations between height and weight growth velocities and adult BMI.

We can conclude that during the boys' age of 7 to 11 y and girls' age of 9 to 10 y body weight growth velocities seem to be associated with early adolescence overweight at the age of 14 y.

These results can suggest another critical window of mid-childhood period to be added to the current hypothesis of Button et al (2008) who hypothesized having two critical windows of early childhood associated with the later risk of overweight/obesity (38). We concluded that researches on overweight and obesity problems must take into considerations the periods of critical weight growth velocities to apply the proper preventive programs and plan for intervention strategies. This will be very helpful to concentrate the efforts to the target critical time windows of overweight problem.

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