The Turkish Journal of Pediatrics 2020; 62: 994-1001
https://doi.org/10.24953/turkjped.2020.06.011

Original Article

Life-stage factors associated with overweight severity in adolescents

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ABSTRACT

Background. Investigating life-stage factors associated with overweight may be useful in the prevention of excessive BMI increase. The main aim of this study was to investigate the influence of the route of delivery, birth weight and overweight onset on overweight severity in a sample of overweight adolescents followed at a Pediatric Obesity Clinic.

Methods. Clinical data from 412 adolescents with overweight (BMI ≥ p85), aged 10-18 were retrospectively collected and analyzed.

Results. Adolescents born by cesarean section (CS) showed a lower age of overweight onset, compared to other methods of delivery (d= 0.33, p= .009). Birth weight was positively associated with BMI z-score (r=.164, p= 002) and waist circumference (WC) (r=.191, p=.001). The overweight onset was negatively associated with BMI z-score (r= -.277, p <.001), WC (r= -.270, p <.001) and body fat mass (r= -.199, p=.001). Overweight duration was the best predictor of BMI z-score, explaining in 75% its variation (F=1,317)=26.94, p <.001), which increased to 99% when birth weight was included in the model (F(2,316)=18.47, p <.001).

Conclusions. This study suggests that lifestyle may interrupt the burden of CS on BMI z-score throughout growth. Moreover, increased birth weight may anticipate overweight onset, and consequently overweight duration in the presence of inadequate lifestyle behaviors.

Key words: adolescent, birth weight, way of delivery, overweight, overweight severity.

Obesity is a major chronic disease and public health concern around the world. Over a third of the world population has obesity.[1] A secular trend of the increasing prevalence of obesity has been estimated with 38% of the world's adult population developing overweight and another 20% obesity, by 2030.[2]

Besides the way of delivery, with an acknowledged association between cesarean section (CS) and obesity, the three critical periods for the development of childhood obesity include fetal life, the period of adiposity rebound (4-6 years old), and adolescence.[3-5]

According to the developmental origins of health and disease hypothesis, adverse conditions throughout early development, either in the uterus or during the early postnatal years or both, may lead to metabolic changes that increase obesity risk later on.[6] In that line, the prenatal period is referred to as a 'critical period' where adverse events may have a lifelong effect on body composition and contribute to the development of obesity.[7] Based on the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) which covered urban and sub-urban regions in twelve countries, high birth weight (defined as birth weight ≥3500 g) was associated with increased

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Received 25th November 2019, revised 5th January 2020, accepted 18th February 2020.

odds of obesity.[8] Gillman et al.[9] showed that high birth weight was a risk for overweight in adolescence. Other studies have shown that birth weight is linear and proportionally correlated to body mass index (BMI).[10] Frisancho et al.[11] showed that the relative risk for high BMI in adolescence was 1.9-times higher for children who were born as small for gestational age (SGA), 2.2-times for appropriate weight for gestational age (AGA), and 5.7-fold for large for gestational age (LGA). On the other hand, other authors have reported a relationship between SGA and adulthood obesity.[12] The supporting evidence explaining these results is based on the "J-shaped" (association of low birth weight with increased body fat mass (BFM)) as well as on the "U-shaped" curve hypothesis (association of both low and high birth weight with BFM).[13]

The lack of consensus suggests further more complex associations between birth weight and obesity. The period of adiposity rebound corresponds to the second rise in the BMI curve occurring between the ages of 4 and 6, when the BMI begins to increase again, after a rise in infancy and a subsequent decline.[14] This is another critical period for the development of childhood obesity that can track to early adulthood.[15] According to Geserick et al.[16] children who become overweight during this period have higher odds of being obese at adolescence. Adolescence may be considered as the last critical period for the development of obesity.[17]

Although the prevalence of obesity has come to a plateau in many European countries, the severity of obesity seems to increase, especially among adolescents.[18] Due to the increased obesity severity and its related comorbidities, several authors have suggested that waist circumference (WC) and waist-height ratio (WHtR) should be routinely assessed and used as measures of central adiposity.[19,20]

It is crucial to identify early life-stage factors associated with overweight in order to prevent excessive BMI increase till reaching adulthood. In fact, it has been shown that adolescent obesity is associated with increased risk of obesity during adulthood with 70.5% of severely obese adolescents remaining obese as adults.[21]

Although several studies have analyzed the relationship between some perinatal factors, such as the way of delivery, birth weight or overweight onset and BMI in children, to the best of our knowledge, the interaction between these factors in adolescents with overweight has never been investigated so far.

The main aim of this study was to investigate the influence of the way of delivery, birth weight for gestational age and overweight onset on adolescent overweight severity. We have hypothesized that: (i) CS is a predictor of increased BMI and waist circumference during adolescence; (ii) birth weight for gestational age is positively associated with BMI and WC during adolescence; (iii) overweight onset during the period of adiposity rebound is a predictor of BMI and WC severity during adolescence.

Material and Methods

Participants

Clinical files from adolescents with overweight (BMI ≥ p85), aged 10-18, with a first appointment between October 2014 and December 2018 at the Pediatric Obesity Clinic, Hospital de Santa Maria, Lisbon, Portugal, were searched and data collected retrospectively.

This study was approved by the research ethics committee of the Faculty of Medicine of the University of Lisbon, Portugal (271/2016), and is in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Signed informed assent/consent was signed by all the participants and respective caregivers.

Measures and instruments

Birth weight, gestational age and way of delivery

Birth weight, gestational age and way of delivery were collected using the individual health booklet, and birth weight for gestational age was categorized according to INTERGROWTH 21st.[22]

Birth weights ranging from percentile 11 to 89 for gestational age were considered as AGA, at percentile 10 or under as SGA and at percentile 90 or above as LGA. The z-score of birth weight for gestational age was also computed according to INTERGROWTH 21st.[22]

Overweight onset and overweight duration

Overweight onset, considered as the time where BMI started to exceeded percentile 85 based on the World Health Organization charts, was assessed using the individual health booklet.

Overweight duration was calculated as the difference between current age and overweight onset. Both variables were registered in years.

Anthropometric and body composition assessment

Height was assessed with a height stadiometer (SECA 217, Hamburg, Germany) in the Frankfurt plan, without shoes, with the participants back to the stadiometer, and after an expiratory phase. Height was registered to the nearest 0.1 cm.

Bodyweight and body composition were measured with a bioelectrical impedance scale (InBody 230, Seoul, Korea) to the nearest 0.1 kg, with the subjects wearing as few clothes as possible, and without shoes or socks. % of BFM and % of skeletal muscle mass (SMM) were calculated dividing the total BFM and SMM (kg) by body weight, respectively.

BMI was calculated dividing the body weight in kilograms by the square of height in meters [BMI= weight (kg)/height^2 (m)]. The BMI z-score was calculated according to World Health Organization [BMI z-score= $[(BMI/M(t))^{L(t)}-1]/L(t)S(t)$].

WC was assessed using a flexible anthropometric tape (SECA 203, Hamburg, Germany). WC was measured at the iliac crest level, with the subjects standing and at the end of a regular expiration (Cameron method).

WHtR was calculated dividing the WC in centimeters by the height in centimeters [WHtR= WC (cm)/Height (cm)].

Clinical assessments

Pubertal status was assessed and categorized according to Tanner stages.

Statistical analysis

Data was analyzed using the IBM SPSS statistics (IBM SPSS statistics, version 21.0, IBM, New York, USA).

Chi-square and Independent sample t-test were used in order to analyze gender differences. Because statistically significant differences between girls and boys were found, all the analyses were performed controlling for sex.

The associations between gestational age, birth weight, overweight onset, and all the anthropometric and body composition variables were analyzed using partial correlations, controlling for age, sex and way of delivery. BMI z-score prediction (dependent variable) was computed using multiple linear regressions (stepwise method). A *p* value of <.05 was considered statistically significant.

Results

Clinical data from 412 overweight adolescents (87.1% Caucasian) were analyzed.

Boys (*n*=192, mean age 13.9 ± 2.0) showed higher height (*d*= 0.53, *p* <.001), BMI z-score (*d*= 0.21, *p*=.040), WC (*d*= 0.21, *p*=.048) and SMM (*d*= 0.40, *p* <.001), compared to girls (*n*= 220, mean age 14.4 ± 2.2). On the other hand, girls showed higher BFM (*d*= 0.53, *p* <.001) compared to boys (Table I).

Statistically significant differences between girls and boys were also found in the number of CS, with a higher number of CS among boys (46.6% vs. 29.5%, *p*=.001) (Table I). Adolescents born by CS showed a lower age of overweight onset, compared to those born with other methods of delivery (*d*= 0.33, *p*=.009).

Table I. Sample characteristics.

	Girls		Boys			Total	
	n	Mean±SD	*n*	Mean ±SD	*p*	*n*	Mean ±SD
Age (years)	220	14.4 ± 2.2	192	13.9 ± 2.0	.017	412	14.2 ± 2.1
Height (cm)	220	158.9 ± 7.5	192	163.7 ± 10.6	<.001	412	161.1 ± 9.4
Weight (kg)	220	82.9 ± 18.6	192	86.5 ± 24.2	.098	412	84.5 ± 21.5
BMI (kg/m^2)	220	32.59 ± 6.02	192	31.78 ± 6.36	.186	412	32.21 ± 6.19
BMI z-score	220	2.68 ± 1.02	192	2.89 ± 0.99	.040	412	2.78 ± 1.01
WC (cm)	189	101.5 ± 12.9	152	104.4 ± 14.5	.048	341	102.8 ± 13.7
WHtR	189	0.63 ± 0.07	152	0.63 ± 0.07	.681	341	0.63 ± 0.07
BFM (%)	193	44.1 ± 5.7	180	40.7 ± 7.2	<.001	373	42.5 ± 6.7
SMM (%)	175	31.8 ± 6.1	158	34.5 ± 7.2	<.001	333	33.1 ± 6.8
Overweight onset (years)	163	6.2 ± 4.3	161	5.3 ± 3.65	.042	324	5.7 ± 4.03
Birth weight (g)	214	3261 ± 554	191	3287 ± 659	.664	405	3273 ± 605
Gestational age (weeks)	220	38.8 ± 1.8	192	38.1 ± 2.6	.001	412	38.4 ± 2.2
Birth weight z-score	214	0.40 ± 1.29	191	0.51 ± 1.24	.365	405	0.45 ± 1.27
Race	*n*	%	*n*	%	*p*	*n*	%
Caucasian	192	87.3	167	87.0		359	87.1
Black	27	12.3	24	12.5	.993*	51	12.4
Asian	1	0.5	1	0.5		2	0.5
Delivery							
Eutocic	114	60.0	84	47.2		198	53.8
Cesarian section	56	29.5	83	46.6	.001*	139	37.8
Other	20	10.5	11	6.2		31	8.4
Birth weight category							
SGA	28	13.1	9	4.7		37	9.1
AGA	131	61.2	137	71.7	.008*	268	66.2
LGA	55	25.7	45	23.4		100	24.7
Tanners' stage							
1	1	12.5	7	87.5		8	2.2
2	25	31.6	54	68.4		79	21.4
3	18	39.1	28	60.9	<.001*	46	12.4
4	29	43.3	38	56.7		67	18.1
5	124	72.9	46	27.1		170	45.9

AGA: appropriate weight for gestational age, BFM: body fat mass, BMI: body mass index, CS: cesarean section, LGA: large for gestational age, SGA: small for gestational age, SMM: skeletal muscle mass, WC: waist circumference, WHtR: waist-to-height ratio.
* Chi-square test.

From the 412 adolescents, 37 were born SGA and 100 LGA. According to birth weight for gestational age, LGA participants showed a higher BMI z-score during adolescence compared to AGA (*d*= 0.32, *p*=.023). No statistically significant differences were found between SGA and AGA or between SGA and LGA.

No associations were found between birth weight for gestational age and overweight onset.

When controlling for sex, age and way of delivery, birth weight showed to be positively correlated with BMI z-score (*r*=.164, *p*=.002), WC (*r*=.191, *p*=.001) and WHtR (*r*=.126, *p*=.028); birth weight z-score was positively correlated with BMI z-score (*r*=.144, *p*=.006) and WC (*r*=.153, *p*=.007); overweight onset was negatively correlated with BMI z-score (*r*= -.277, *p* <.001), WC (*r*= -.270, *p* <.001), WHtR (*r*= -.227, *p* <.001), and BFM (*r*= -.199, *p*=.001); overweight duration showed to be positively correlated with BMI z-score (*r*= -.261, *p* <.001), WC (*r*= -.260, *p* <.001), WHtR (*r*= -.213, *p* <.001), and BFM (*r*= -.176, *p*=.003). Gestational age was positively correlated with birth weight (*r*= .472, *p* <.001), and negatively correlated with birth weight z-score (*r*= -.234, *p* <.001) (Table II).

According to multiple linear regressions (stepwise method), overweight duration was the best predictor of BMI z-score during adolescence, explaining in 75% its variation (F(1,317)= 26.94, *p* <.001). Including birth weight in the model, the interaction between these variables was able to explain 99% of BMI z-score variation (F(2,316)= 18.47, *p* <.001).

Overweight onset during the period of adiposity rebound was not associated with BMI and WC severity.

Discussion

Adolescent overweight dramatically progresses into adulthood. It is crucial to investigate life-stage factors associated with overweight in order to prevent excessive BMI increase throughout this critical period for the development of obesity.[17,23,24]

The main aim of this study was to investigate the influence of perinatal factors (i.e. way of delivery, birth weight) and overweight onset on overweight severity in a sample of overweight adolescents followed at a Pediatric Obesity Clinic, in order to identify the factors associated with BMI severity in this population. Identifying these factors may allow the improvement of both preventive and timely weight management interventions.

Literature shows a strong association between CS and increased BMI and WC, in the offspring

Table II. Partial correlations between life-stage factors and adolescent anthropometric/body composition measures.

	Gestational age	Born weight	Born weight zs	Overweight onset	Overweight duration	WC	WHtR	%BFM	%SMM	BMI zs
Gestational age	1									
Born weight	.472†	1								
Born weight zs	-.234†	.731†	1							
Overweight onset	-.026	-.014	.007	1						
Overweight duration	.019	.005	-.013	-1†	1					
WC	.057	.191†	.153$^{\$}$	-.271†	.260†	1				
WHtR	.027	.126*	.098	-.227†	.213†	.926†	1			
%BFM	.073	.086	.028	-.199†	.176$^{\$}$	.597†	.673†	1		
%SMM	-.045	-.008	.038	.013	-.005	-.316†	-.369†	-.465†	1	
BMI zs	.022	.164$^{\$}$	.144$^{\$}$	-.277†	.261†	.812†	.822†	.673†	-.349†	1

*p<0.05; $^{\$}$p<0.01; †p<0.001

BFM: body fat mass, BMI: body mass index, SMM: skeletal muscle mass, WC: waist circumference, WHtR: waist-to-height ratio, ZS: – z-score.

* Partial correlations controlling for sex, age and way of delivery.

and later in life.[25,26] According to our findings, CS was not associated with BMI z-score during adolescence. One possible explanation for the lack of association may be the specific characteristics of the sample studied. In fact, the majority of the studies that reported an association between CS and BMI z-score studied the general population.[25] The absence in our sample of other weight categories, besides overweight, most probably impaired this association. Another possible explanation could be the adoption of healthy lifestyle behaviors at a certain point in time. Although the way of delivery may influence overweight onset, dietary and physical activity behaviors are concurrent and modifiable factors that may influence BMI z-score at any time.[27] Indeed, in this study, CS showed to be only associated with overweight onset. Adolescents born by CS have shown decreased age (-1.4 ± 0.47 years) of overweight onset, compared to other ways of delivery. According to the literature, the link between CS and increased BMI relies on the *hygiene hypothesis*. In other words, infants born by CS are mainly exposed to maternal skin microbiota and to external environmental bacterial communities at birth. CS impairs the exposure of the newborn to maternal vaginal bacteria, which is known to be the major source of the newborn's intestinal bacteria. The decreased intestinal bifidobacteria and bacteroids (known to be negatively associated with dietary nutrient absorption) in the newborn delivered by CS compared to vaginal, may lead to early overweight onset. Although data on intrapartum indications for CS is missing, it should be noted that the main intrapartum indications for this procedure are not known as risk factors for obesity.[28]

In line with several other studies, our findings show a positive association between birth weight/birth weight z-score and BMI z-score, WC and WHtR. Interestingly, birth weight by itself showed higher association levels with BMI z-score, WC and WHtR during adolescence, compared to the birth weight z-score. Although not further explored, other authors have reported similar results.[6,7,29,30] In this study, birth weight was the second-best predictor of adolescent BMI z-score. In addition, gestational age was positively correlated with birth weight and negatively associated with birth weight z-score, with a higher correlation level within the former. These results suggest that the use of a z-score, adjusting for gestational age may have affected and biased the association between the variables under study.[25] A similar finding regarding the use of birth weight z-score was reported by Delbaere et al.[31]

Conversely to our hypothesis and to the results reported by other authors,[5,32] overweight onset during the period of adiposity rebound was not associated with BMI and WC severity. Instead, overweight onset, as a continuum variable, was negatively correlated with BMI z-score, WC, WHtR and BFM. The negative correlation between overweight onset and WC/WHtR was as relevant as the one between overweight onset and BMI z-score. The association between WC and impaired metabolic profiles in adolescents with overweight has already been widely described.[33,34]

Regression analyses showed that overweight duration and not overweight onset was the best predictor of adolescent BMI z-score. Prolonged inadequate dietary and physical activity behaviors may lead to excessive weight gain and in turn, to harmful metabolic adaptations and adipose tissue dysfunction as early as in childhood.[35] Adipose tissue dysfunction, is characterized by changes in adiponectin and leptin levels as well as in insulin sensitivity.[35] However, it is not completely understood whether these metabolic changes are a consequence or a trigger of an adipose tissue increased proliferative capacity which may be potentiated by overweight duration.[35] As overweight duration may lead to short and long-run psychological consequences, such as body dissatisfaction, low self-esteem, poor health-related quality of life and even depression it may negatively affect behavior change thus perpetuating the cycle.[36,37]

The retrospective nature of this study has not allowed for dietary and physical activity data collection. Another limitation is the cross-sectional design, not allowing for causal inferences. Nevertheless, to the best of our knowledge, no other study has investigated the interaction between the method of delivery, birth weight and overweight onset on overweight severity in a sample of adolescents with overweight. The fact that this study brings further knowledge to the study of BMI severity during adolescence is its main strength.

In summary, this study showed a positive association between CS and early overweight onset, which reinforces the need for a careful assessment of the risk-benefit balance to conduct a CS on an individual basis. Overweight onset and particularly overweight duration were associated with BMI z-scores severity. Nevertheless, CS was not a perinatal predictor of adolescent BMI z-score, which suggests that life-style may interrupt the burden of CS on BMI z-score throughout growth. On the other hand, birth weight was the perinatal factor best associated with BMI z-score. This finding, in addition to the fact that overweight duration was found to be the best predictor of BMI z-score severity, led us to conjecture that increased birth weight may anticipate overweight onset, and consequently overweight duration in the presence of inadequate lifestyle behaviors.

Funding

AVS is supported by the Portuguese Foundation for Science and Technology (SFRH/BD/130193/2017). AVS funding organization played no role in this research. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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