ORIGINAL ARTICLE

Predicting childhood overweight status by accelerated weight gain from neonatal period to infancy

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Background: The increased prevalence of obesity in early childhood is a public health problem. Childhood obesity may affect cardiorespiratory fitness and can induce obesity and its comorbidities in adulthood. We aimed to assess childhood overweight status by accelerated weight gain during infancy. **Materials and Methods:** This is a historical cohort that was conducted on 637 7-year-old students of Guilan province, north of Iran. Data were collected, including demographic characteristics, weight at 4, 6, 12, and 18 months, and clinical examination. The ROC curve was designated based on the standardized z-scores, and the most appropriate cutoff point by sensitivity and specificity was noted for predicting obesity at 7 years. Rapid weight gain (RWG) was also assessed. **Results:** Among participants, 334 (53.3%) were female. In this study, the mean and standard deviation of RWG in 0–4 months, 0–6 months, 0–12 months, and 0–18 months were 3.50 ± 0.89, 4.64 ± 1.02, 6.54 ± 1.21, and 8.00 ± 1.46 kg, respectively. The highest AUC was dedicated to 0–18 months (0.7 ± 0.05) and the suitable cut-off for RWG in this interval was 8.55 kg with 65.5% and 72.0% sensitivity and specificity, respectively. **Conclusion:** Although in the previous investigations, the changes in the first 3 years of life had a significant role in further complications, regarding our results, it seems that even earlier consideration of excess weight gain may be necessary.

Key words: Child, obesity, overweight, weight

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INTRODUCTION

Childhood obesity is a noncommunicable disease which have taken a worldwide attention due to its prevalence and considered to be a public health problem. Childhood obesity tends to be continued across adulthood and induce comorbidities of adulthood obesity such as type 2 diabetes mellitus and cardiovascular diseases.[1]

It has been shown that obesity is multifactorial and has a close relationship with genetic, psychological, and environmental factors. Various factors may be associated with childhood obesity including nutrition in early life, excessive gestational weight gain,[2] maternal smoking during pregnancy, parent feeding practices, duration of breastfeeding, body mass index (BMI), father's weight, birth order, age, birth weight, and rapid weight gain (RWG).[3,4]

RWG by definition is the upward centile trend in weight growth charts. In recent years, researchers have been focused on future obesity that will be caused by RWG during infancy.[5] Investigations have proven that RWG is directly associated with BMI in which a change in weight z-score >0.67 in RWG during infancy would result in two- to three-fold increase in subsequent adulthood obesity.[6] Another systematic review and meta-analysis showed that infants with RWG had 3.66 times greater

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chance of being obese in adulthood.[7] However, regarding the value of RWG and later obesity, it has been understood that infants fed formula had a higher impact on RWG and the following adulthood obesity than breastfed infants.[8] As obesity and dyslipidemia are common in childhood, cardiometabolic risk factors should be screened in addition to obesity, especially in children with RWG.[9] Even thought, the exact time of RWG which led to subsequent adulthood obesity is not clear, by understanding the causes of childhood adiposity, epidemiology of RWG in infant, and investigating the association of RWG during infancy in different populations, one can determine the risk factors of later obesity and propose the later actions to prevent its health complications.[10]

Based on a key role of RWG in the first 1000 days of life as an important predictor for childhood obesity and overweight,[11] the need for investigating the impact of RWG in different regions of world and introducing effective approaches to prevent childhood obesity, we aimed to assess the association of RWG during 0–18 months of infancy with later obesity at 7 years.

MATERIALS AND METHODS

This is a prospective cohort study which was conducted on 637, 7-year old children with term birth (≥37 weeks of gestation) and normal birth weight (2500–4000 g) from Guilan province. Samples were selected by clustered sampling method. Written consents were obtained and all participants were examined by trained physicians practicing in 15 regional urban health centers from which the data for the study were recorded. We used CDC growth and BMI charts for evaluating children. This study was a grant approved by the Vice-Chancellor of Research at Guilan University of Medical Sciences (Number: 93121131).

Data were collected by a form including demographic characteristics such as weight at 0, 4, 6, 12, and 18 months of age, and current clinical examinations. All examiners used the same tools for measuring the variables. All tools were calibrated daily.

For determining an appropriate cutoff point for predicting RWG on obesity at 7 years, the differences between the weight of the child at birth and 4, 6, 12, and 18 months of age were calculated. Then, the z-scores of weight were mentioned based on the mean and standard deviation (SD) of the population and the differences were standardized.

The ROC curve was designated based on the standardized z-scores. The most appropriate cutoff point by sensitivity and specificity was noted for predicting the obesity at 7 years.

RWG was defined as an increase in weight-for-age z-scores of 0.67 SDs.[12,13]

Children at 7 years were divided into normal (5^{th}–85^{th} percentile) or overweight and obese (85^{th}–95^{th}, and >95^{th} percentile, respectively) groups based on BMI percentile for sex and age. In these groups, the pattern of weight gain was indicated as the change in weight-for-age z-scores in each age group and was classified as catch-down growth (z score <−0.67), normal (z score − 0.67 ± 0.67), and RWG (≥+0.67).

Statistical analysis

Data analysis was done by SPSS software, version 21. Data were reported by descriptive statistics. Chi-square test was used to compare qualitative data. Cutoff point and sensitivity and specificity using the ROC curve were designated. Logistic regression analysis by backward LR method was applied in multivariate analysis. We imported $P < 0.05$ indicated statistical significance.

RESULTS

In this investigation, 50 out of 637 enrolled participants were excluded due to incomplete records. Among the participants, 334 (53.3%) were girls and the remained were boys. In this study, the mean and SD of RWG in 0–4 months, 0–6 months, 0–12 months, and 0–18 months were 3.50 ± 0.89, 4.64 ± 1.02, 6.54 ± 1.21, and 8.00 ± 1.46 kg, respectively.

All AUC intervals for different age groups were significant for predicting obesity at 7 years of age, but based on the AUC index, the highest belonged to 0–18 months and the suitable cutoff for RWG in this interval was 8.55 kg with sensitivity and specificity of 65.5% and 72.0%, respectively.

Results showed that gaining weight >4.078 and 3.428 kg from the ages of 0–4 months, 0–6 months increased the probability of obesity at the age of 7 years, respectively [Table 1].

The relationship between obesity at 7 years and the pattern of weight gain in different age groups showed that only 0–12 months and 0–18 months weight gain significantly related with childhood obesity ($P = 0.006$ and $P < 0.0001$, respectively). The response trend over time is shown in Figure 1.

The percentage of obesity in children with RWG at 0–12 months was 10.4% which was 3 folds higher than normal weight and children with catch-down growth. Furthermore, 12.7% of children with RWG at 0–18 months were obese at 7 years which was, respectively, 4 and 7 folds higher than normal and catch down growth children [Table 2].

Table 1: The cutoff point for weight gain at different age groups

Variable (s)	AUC	SE	SP	z	Cut off	Sensitivity (%)	Specificity (%)
RWG Z score 0–4	0.639	0.054	0.012	0.140	4.078	75.0	41.0
RWG Z score 0–6	0.637	0.054	0.013	−0.083	3.428	51.2	65.5
RWG Z score 0–12	0.633	0.056	0.015	0.117	6.680	62.1	60.0
RWG Z score 0–18	0.700	0.049	0.000	0.090	8.555	65.5	72.0

A metric for binary classification. RWG=Rapid weight gain; AUC=Area under curve; SE=Standard error, SP=Standard price

Table 2: The percentage of obesity based on pattern of weight gain

Range	Status	BMI obesity				*P*
		Normal		Overweight and obese		
		Count	Row N %	Count	Row N %	
Weight gain 0–4	Catch-down growth	122	96.8	4	3.2	0.154
	Normal	327	95.6	15	4.4	
	RWG	113	91.9	10	8.1	
Weight gain 0–6	Catch-down growth	131	97.8	3	2.2	0.131
	Normal	323	95.0	17	5.0	
	RWG	107	92.2	9	7.8	
Weight gain 0–12	Catch-down growth	131	97.0	4	3.0	0.006
	Normal	318	96.4	12	3.6	
	RWG	112	89.6	13	10.4	
Weight gain 0–18	Catch-down growth	138	98.6	2	1.4	0.001
	Normal	308	96.6	11	3.4	
	RWG	110	87.3	16	12.7	

RWG=Rapid weight gain; BMI=Body max index

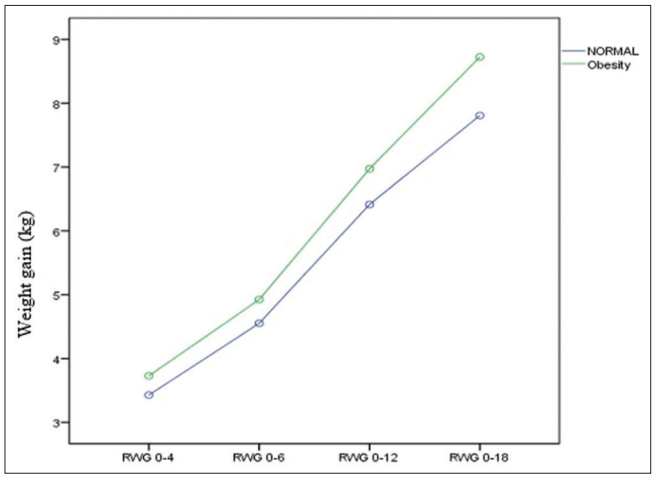

Figure 1: Response trend over time

Logistic regression analysis showed that RWG in 0–18 months had the highest effect on obesity at 7 years in both boys and girls ($P < 0.001$) with odds-ratio 1.93 and 1.4, respectively [Table 3].

DISCUSSION

Weight gain during infancy is the underlying reason for later obesity.[14] The present study demonstrated that the prevalence of RWG was approximately 20% in all age groups. This result was lower than previous studies. Bertotto *et al.* and Ekelund *et al.* indicated that the prevalence of excess weight gain at 1st year of age was 30% and 25.4%, respectively.[15,16] Although Bertotto *et al.* documented 20% of children as overweight and 5.5% as obese.[17] Another study by Retamal and Mascie-Taylor showed RWG prevalence of 30% and obesity prevalence of 10% and concluded that when the children were categorized at overweight or obese group, they tended to remain with it.[18] This difference may rise from the fact that we assessed RWG based on mean percentile of weight in our participants and not regarding CDC growth charts. Furthermore, Eckhardt *et al.* indicated some inconsistencies regarding the growth references and age intervals in which they stated that RWG prevalence of CDC reference tends to produced higher percentiles in early infancy (0–3 months of age) and WHO standards tends to produced higher percentiles in later infancy (6–12 months of age). They reported RWG prevalence for 0–3 month age interval of 9.9% for both references which were in concordant with and validated our results.[19]

In the 1st month after birth, babies experience growth velocity, which decrease in later months. This is why the cutoff point for weight gain in the first 6 months was lower than the first 4 months. Previous investigators believed that this difference might be noted because of rapid physiologic weight gain (gestational weight gain) in the first 4 months after birth than the 4th to 8th months.[20] In addition, underlying reasons may arise from the pre- and postnatal exposures including smoking during pregnancy,[21] pre-pregnancy weight status,[22] and breastfeeding[23] on infant weight gain. In concordance with this result, a

Table 3: Stepwise backward logistic regression method of logistic regression analysis regarding sex

Sex	OR	95% CI for OR		*P*
		Lower	Upper	
Girl				
Step 1[a]				
RWG 0–4	1.065	0.554	2.048	0.851
RWG 0–6	0.869	0.851	1.691	0.680
RWG 0–12	0.995	0.680	1.625	0.983
RWG 0–18	1.509	0.983	2.132	0.020
Step 4[a]				
RWG 0–18	1.431	0.020	1.749	0.000
Boy				
Step 1[a]				
RWG 0–4	1.855	0.000	4.102	0.127
RWG 0–6	0.723	0.127	1.771	0.478
RWG 0–12	0.703	0.478	1.444	0.338
RWG 0–18	2.430	0.338	3.998	0.000
Step 4[a]				
RWG 0–18	1.935	0.000	2.531	0.000

RWG=Rapid weight gain; OR=Odds ratio; CI=Confidence interval. [a]P-value<0.05 indicated statistical significance

randomized feeding trial reported that consuming more dietary energy during early infancy leads to weight gain.[24] It seems that the weight gain more than 3.428 kg in the first 6 months of life might be occurred as a result of poor weight gaining and consequently motivate parents to boost feeding.[25]

Our results showed a lack of significant association of RWG in 0–4 months with childhood obesity, and overweight. Similar to our findings, a study investigating 128 individuals from infancy to 17 years concluded that those with accelerated weight gain in early infancy did not result in later obesity.[26] In contrast, Stettler *et al*. reported a prevalence of RWG at 7 years of 5.4% and mentioned that RWG pattern during the first 4 months of life was significantly associated with an increased risk of overweight at 7 years.[27] This result was inconsistent with ours. Kain *et al*. also declared that obesity and overweight may promote general or central obesity at 7 years of age[28] so, early prevention was recommended.

Current study based on the pattern of weight gain on different age groups showed that RWG at 0–12 months and 0–18 months were significantly related with childhood obesity. Furthermore, our results indicated that RWG at 0–18 months promotes the risk of obesity at 7 years. This result was consistent with the study of Goodell *et al*.[29] They noted that the existence of RWG during the 1st year of life induced 9.24 (confidence interval [CI]: 3.73–22.91) folds increased the risk of obesity compared to the lack of RWG.

Furthermore, results showed that RWG at 0–18 months with the cutoff point of 8.555 had the both highest sensitivity and specificity and is the predictor of obesity at 7 years. Nearly close to this number, Gungor *et al*. assessed children aged 0–24 months and noted that weight gain of 9.01 kg or more had the best combined sensitivity and specificity for childhood weight gain.[30] Determining the best cutoff point has the advantages of less false-negative and false-positive results and assured us that less bias engaged in our study.

Although in the previous investigations, the changes in the first 3 years of life had a significant role in further complications, regarding our results, it seems that even earlier consideration of excess weight gain may be necessary. In addition, investigators did not assess breast feeding or the solids/foods consumption during infancy and 7 years of age and it may be the limitation of this study. Besides, the association between obesity and socio-economic status was not assessed, therefore, performing multicenter investigations on nutritional status are highly recommended to produce comprehensive results and introduce obesity prevention strategies.

Altogether, our results demonstrated the significant association of accelerated weight gain at two age intervals (0–12 months and 0–18 months) with later obesity at 7 years. In addition, weight gain of 8.55 kg or more at 0–18 months was set as cutoff point for predicting obesity with the highest sensitivity and specificity in the assessed population. Interestingly, cutoff point at 0–4 months was higher than 0–6 months (4.078 compared to 3.428) which enabled us to propose controlled feeding strategy in infants even with no significant RWG to prevent later obesity. Furthermore, logistic regression analysis indicated that RWG at 0–18 months had the highest effect on obesity.

CONCLUSIONS

Our finding provides a road to be paved for understanding the importance of RWG in specific time intervals during infancy and its subsequent obesity. In the investigated population, 0–18 months of age proposed as a predictor for later obesity. This exact time period informs us to prevent future obesity complications if noticing weight gain over 8.55 kg at 0–18 months of age.

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Ethical considerations

informed consent letters were obtained from parents.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Goran MI, Ball GD, Cruz ML. Obesity and risk of type 2 diabetes and cardiovascular disease in children and adolescents. J Clin Endocrinol Metab 2003;88:1417-27.
2. Diesel JC, Eckhardt CL, Day NL, Brooks MM, Arslanian SA, Bodnar LM. Is gestational weight gain associated with offspring obesity at 36 months? Pediatr Obes 2015;10:305-10.
3. Soltani PR, Ghanbari A, Rad AH. Obesity related factors in school-aged children. Iran J Nurs Midwifery Res 2013;18:175-9.
4. Koomanaee S, Tabrizi M, Naderi N, Hassanzadeh Rad A, Boloky Moghaddam K, Dalili S. Parental anthropometric indices and obesity in children. Acta Med Iran 2016;54:270-5.
5. Ellis KJ. Body composition in infancy: Impact on health later in life. Nestle Nutr Workshop Ser Pediatr Program 2010;65:213-20.
6. Ong KK, Loos RJ. Rapid infancy weight gain and subsequent obesity: Systematic reviews and hopeful suggestions. Acta Paediatr 2006;95:904-8.
7. Zheng M, Lamb KE, Grimes C, Laws R, Bolton K, Ong KK, *et al.* Rapid weight gain during infancy and subsequent adiposity: A systematic review and meta-analysis of evidence. Obes Rev 2018;19:321-32.
8. Appleton J, Russell CG, Laws R, Fowler C, Campbell K, Denney-Wilson E. Infant formula feeding practices associated with rapid weight gain: A systematic review. Matern Child Nutr 2018;14:e12602.
9. Dalili S, Rezvani SM, Dalili H, Mohtasham Amiri Z, Mohammadi H, Medghalchi A, *et al.* Cardio-metabolic risk factors in Iranian children: Where we are and the others? Acta Med Iran 2014;52:831-6.
10. Druet C, Stettler N, Sharp S, Simmons RK, Cooper C, Smith GD, *et al.* Prediction of childhood obesity by infancy weight gain: An individual-level meta-analysis. Paediatr Perinat Epidemiol 2012;26:19-26.
11. Aris IM, Bernard JY, Chen LW, Tint MT, Pang WW, Soh SE, *et al*. Modifiable risk factors in the first 1000 days for subsequent risk of childhood overweight in an Asian cohort: Significance of parental overweight status. Int J Obes (Lond) 2018;42:44-51.
12. Ellis KJ. Visceral fat mass in childhood: A potential early marker for increased risk of cardiovascular disease. Am J Clin Nutr 1997;65:1887-8.
13. Rosenbloom AL. Obesity, insulin resistance, beta-cell autoimmunity, and the changing clinical epidemiology of childhood diabetes. Diabetes Care 2003;26:2954-6.
14. Taveras EM, Rifas-Shiman SL, Belfort MB, Kleinman KP, Oken E, Gillman MW. Weight status in the first 6 months of life and obesity at 3 years of age. Pediatrics 2009;123:1177-83.
15. Bertotto ML, Valmórbida J, Broilo MC, Campagnolo PD, Vitolo MR. Association between weight gain in the first year of life with excess weight and abdominal adiposity at preschool age. Rev Paul Pediatr 2012;30:507-12.
16. Ekelund U, Ong K, Linné Y, Neovius M, Brage S, Dunger DB, *et al*. Upward weight percentile crossing in infancy and early childhood independently predicts fat mass in young adults: The Stockholm weight development study (SWEDES). Am J Clin Nutr 2006;83:324-30.
17. Bertotto ML, Valmórbida J, Broilo MC, Campagnolo PDB, Vitolo MR. Associação entre ganho de peso no primeiro ano de vida com excesso de peso e adiposidade abdominal na idade pré-escolar. J Rev Paul Pediatr 2012;30:507-12.
18. Retamal R, Mascie-Taylor CG. Trends of weight gain and prevalence of overweight and obesity from birth to three years of age. Obes Res Clin Pract 2019;13:6-11.
19. Eckhardt CL, Eng H, Dills JL, Wisner KL. The prevalence of rapid weight gain in infancy differs by the growth reference and age interval used for evaluation. Ann Hum Biol 2016;43:85-90.
20. Hu J, Aris IM, Oken E, Ma Y, Ding N, Gao M, *et al*. Association of total and trimester-specific gestational weight gain rate with early infancy weight status: A prospective birth cohort study in China. Nutrients 2019;11:E280.
21. Kozyrskyj AL, Kalu R, Koleva PT, Bridgman SL. Fetal programming of overweight through the microbiome: Boys are disproportionately affected. J Dev Orig Health Dis 2016;7:25-34.
22. Bridgman SL, Azad MB, Persaud RR, Chari RS, Becker AB, Sears MR, *et al*. Impact of maternal pre-pregnancy overweight on infant overweight at 1 year of age: Associations and sex-specific differences. Pediatr Obes 2018;13:579-89.
23. Zheng JS, Liu H, Li J, Chen Y, Wei C, Shen G, *et al*. Exclusive breastfeeding is inversely associated with risk of childhood overweight in a large Chinese cohort. J Nutr 2014;144:1454-9.
24. Ong KK, Emmett P, Northstone K, Golding J, Rogers I, Ness AR, *et al*. Infancy weight gain predicts childhood body fat and age at menarche in girls. J Clin Endocrinol Metab 2009;94:1527-32.
25. DiSantis KI, Hodges EA, Johnson SL, Fisher JO. The role of responsive feeding in overweight during infancy and toddlerhood: A systematic review. Int J Obes (Lond) 2011;35:480-92.
26. Ekelund U, Ong KK, Linné Y, Neovius M, Brage S, Dunger DB, *et al*. Association of weight gain in infancy and early childhood with metabolic risk in young adults. J Clin Endocrinol Metab 2007;92:98-103.
27. Stettler N, Zemel BS, Kumanyika S, Stallings VA. Infant weight gain and childhood overweight status in a multicenter, cohort study. Pediatrics 2002;109:194-9.
28. Kain J, Martínez M, Close M, Uauy R, Corvalán C. The association of excessive growth with development of general and central obesity at 7 years of age in every period after birth in Chilean children. Nutrition 2016;32:426-31.
29. Goodell LS, Wakefield DB, Ferris AM. Rapid weight gain during the first year of life predicts obesity in 2-3 year olds from a low-income, minority population. J Community Health 2009;34:370-5.
30. Gungor DE, Paul IM, Birch LL, Bartok CJ. Risky vs rapid growth in infancy: Refining pediatric screening for childhood overweight. Arch Pediatr Adolesc Med 2010;164:1091-7.