Epidemiological investigation of physique situation for birth high-risk children aged 9-15 years in Chengdu, Southwest China

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Summary

Background: As the intrauterine environment can effect children's growth and development, this study aimed to explore the relationship between birth high-risk and physique situation of 9 to 15-year-old children by cross-sectional investigation, and to provide clues for the monitoring, prevention, and treatment of growth deviation in children. *Materials and Methods:* This study recruited 7,194 students aged 9 to 15 years in primary and junior schools. Their parents were asked to complete the birth situation questionnaire. Measurements included height, weight, and body mass index (BMI). Birth high-risk infant was defined according to the gestational age and birth weight. Growth deviation was classified as underweight, short stature, overweight, and obesity. *Results:* The prevalence of all kinds of growth deviations in preterm, full-term, and post-term birth groups were similar, the same as the physique situation at school age among both sexes. The incidence of small for gestational age (SGA) was 6.23%, when at school age, part of SGA had catch-up growth. However, the prevalence of underweight and short stature for SGA was highest in three groups. The weight and height at school age in SGA group was less than that in appropriate for gestational age (AGA) and large for gestational age (LGA) groups. The prevalence of overweight and obesity for LGA and macrosomia were highest in three groups. At school age, the weight in macrosomia and LGA groups was higher than that in the other groups. *Conclusions*: Longitudinal height and weight development and growth of children with birth high-risk are different from normal children. In order to improve healthy situation, more attention should be paid to height and weight development of those children with birth high-risk at school age, even in pre-school age. Prevention may already begin during pregnancy.

Key words: Birth high-risk; Puberty; Overweight; Obesity; Short stature.

Introduction

With the improvement of socio-economy and medical technology in developing countries, the percent of live offspring at birth with high risk became high, such as preterm, small for gestational age (SGA), large for gestational age (LGA), low birth weight, macrosomia, *etc*. It is estimated that depending on geographical region, between eight and 26 percent of all infants born worldwide are low birth weight [1]. The prevalence of SGA is about 7.50% ~13.4% in the general population; furthermore, it has also witnessed an increasing trend of macrosomia. Studies reported that macrosomia increased from five to eight percent in several urban areas in China. With the increase of high risk infants, this will bring great challenges to children's health.

Baker *et al.* supposed the environment of intrauterine and postnatal growth during critical periods of human development may have long-term implications for adult health [2-4]. It has been hypothesized that under-nutrition or other unhealthy factors during pregnancy induce alterations in metabolism, hormonal output, and distribution of cardiac output, which result in central obesity, diabetes, and cardiovascular disease in middle age [5]. Both high and low birth weight, premature and post-mature birth, as well as SGA, have been described as risk factors for later obesity.

The fetal origin of adult disease, or prenatal programming, has been the subject of much study during the past two decades. A large number of epidemiological studies have demonstrated a direct relationship between birth weight and body mass index (BMI) attained later in life [5, 6]. Birth weight can be easily measured, has reference norms, is part of the routine medical record, and may be available historically. Variation in weight at birth serves as a surrogate to reflect underlying mechanisms influencing growth. Moreover, overweight and obesity have become increasingly prevalent worldwide, even among children in developing countries. Some researchers found over-nutrition during pregnancy and high birth weight might cause obesity and related disorders in adulthood. A large national representative study found the association between fetal macrosomia and obesity in childhood, adolescence, and adulthood [7], but for those born SGA, most go on to achieve appropriate catch-up growth by two years of age, approximately 15% do not have a catch-up growth, and most of these children continue to experience poor growth

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throughout childhood [8, 9]. However excess catch-up growth may be related to metabolic disorders. Other authors demonstrated a relationship between low birth weight and increased upper body fat distribution in children and adults, which seems to have more important health consequences in adult life than overall obesity [10-12].

As part of a longitudinal study of the outcomes of birth weight, the authors used standardized health survey questionnaires of school children from project section of the national 11th Five-Year Plan to find the children with high risk at birth. Through the analysis of physical index, the authors aimed to examine the association between high risk at birth and physique situation at school age in a large city of Southwest China.

Materials and Methods

A multistage random cluster sampling method was used to select the school children aged nine to 15 years. Approximately 10,000 children were selected from nine elementary and secondary schools in three districts of Chengdu. The survey was conducted from January to March 2011. All of the parents agreed to take part in the survey. Standardized health survey questionnaires of school children from project section of the national 11th Five-Year Plan were distributed and completed by parents or guarantors, which generally compromised such content: (1) baseline of children: population, gender, birth date; (2) birth outcomes: expected date of confinement, gestational age, and birth weight. Furthermore, weight and height of children were strictly measured by specially-trained researchers. Weight and height were separately assessed to the nearest 100 g and 0.1 cm according to a standard measuring method. BMI was calculated as weight in kg divided by the square of height in meters. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committees of West China Second University Hospital, Sichuan University. Written informed consent was also obtained from all participants.

Birth outcomes including birth weight and gestational age were analyzed to identify the abnormal birth, in which preterm birth as gestation < 37 weeks, full-term birth as gestation ≥ 37 weeks, and < 42weeks, post-term birth as gestation ≥ 42 weeks; SGA as birth weight below the 10th percentile for each gestational age, AGA as birth weight between the 10th and 90th percentile for each gestational age, LGA as birth weight above the 90th percentile for each gestational age by standards of national surveys of newborns in China; low birth weight as birth weight $< 2,500$g, normal birth weight as birth weight between 2,500 g and 4,000 g, macrosomia as birth weight $> 4,000$ g. Birth outcomes were further divided into nine categories according to gestational age (preterm, full term, and post-term), birth weight (low birth weight, normal birth weight, and macrosomia) and birth weight for gestational age (SGA, AGA, and LGA).

The authors chose the weight and height's standard of Chinese children aged zero to 18 years (2005) as the reference [13]. Growth deviation included underweight, short stature, overweight, and obesity. Underweight and short stature were defined as the weight and height below -2SD for age and gender. Overweight and obesity were defined by the age- and sex-specific BMI reference developed by China for children aged five to 19 years [14].

The SPSS statistical package, version 16.0 was applied to the statistic analyses. Quantitative data are presented as means ±SD. Prevalence data are expressed as percentages and are compared by using chi-squared tests. The physique situation differences between groups were tested by Student's t-test. A p value of less than 0.05 was considered statistically significant.

Table 1. — *Prevalence of underweight, short stature, overweight, and obesity at different gestational ages.*

Evaluation	Preterm (n = 226, 3.14%)	Full term (n = 6877, 95.59%)	Post term (n = 91, 1.26%)	Total
Underweight	8 (3.54%)	182 (2.65%)	1 (1.10%)	191 (2.65%)
Short stature	0 (0%)	130 (1.89%)	3 (3.30%)	133 (1.85%)
Overweight	24 (10.62%)	631 (9.18%)	11 (12.09%)	666 (9.26%)
Obesity	5 (2.21%)	188 (2.73%)	2 (2.20%)	195 (2.71%)

Results

Ten thousand questionnaires were distributed, 7,291 (72.9%) were recollected and 7,194 (effective rate 98.67%) that completed approved questionnaires and passed anthropometric measurements were recruited in the evaluation of physique situation. The age of subjects was between nine and 15 years. Among them, 3,494 (48.6%) were boys, whereas, 3,700 (51.4%) were girls.

The overall prevalence of preterm, full-term, and post-term birth was 3.14%, 95.59%, and 1.26%, respectively. The prevalences of underweight, short stature, overweight, and obesity at different gestational ages are shown in Table 1. The prevalences of all kinds of growth deviation in preterm, full-term, and post-term birth group were similar r ($p > 0.05$). The different gestational age's anthropometric measures by gender and the age groups are shown in Table 2. As shown in Table 2, only in male children aged 13 years, BMI for preterm birth was less than that for full-term birth. The height of full-term group was shorter than that of post-term group for female at 11 years of age. In addition, the weight, height, and BMI were similar across the different gestational age groups.

The overall prevalences of SGA, AGA, and LGA was 6.23%, 75.72%, and 18.06%, respectively. The prevalences of underweight, short stature, overweight, and obesity at different gestational ages and birth weights are shown in Table 3. The prevalences of underweight and short stature for SGA were highest in three groups ($\chi^2 = 6.954, 16.134, 18.206, 19.190, p < 0.05$). However, the prevalences of overweight and obesity for LGA were highest in three groups ($\chi^2 = 34.812, 17.505, p < 0.05$). As shown in Table 4, in male children aged nine to 15 years, the weight and height for LGA were higher than that for SGA and AGA, as well as in the female children.

The overall prevalences of low birth weight, normal birth weight, and macrosomia were 2.40%, 93.84%, and 3.75%, respectively. The prevalences of underweight, short stature, overweight, and obesity at different birth weight are shown in Table 5. The prevalences of overweight for low birth weight group was less than that for normal birth weight and macrosomia ($\chi^2 = 4.188, 11.954, p < 0.05$). The prevalences

Table 2. — *The weight, height, and BMI for the age groups at different gestational ages.*

		Males						Females					
		Pre-term		Full-term		Post-term		Pre-term		Full-term		Post-term	
		Case	X ± SD	Case	X ± SD	Case	X ± SD	Case	X ± SD	Case	X ± SD	Case	X ± SD
	W	19	31.03 ± 8.13	280	34.86 ± 7.27	4	28.63 ± 4.57	13	32.96 ± 8.51	354	30.96 ± 5.69	4	28.62 ± 3.20
9~	H		137.84 ± 4.72		140.40 ± 6.34		139.75 ± 8.66		141.08 ± 11.59		138.07 ± 6.64		135.88 ± 1.65
	BMI		16.22 ± 3.68		17.62 ± 3.09		14.71 ± 2.44		16.42 ± 2.92		16.06 ± 2.57		15.48 ± 1.39
	W	23	36.30 ± 6.93	639	35.89 ± 7.38	8	32.56 ± 6.20	29	33.48 ± 6.13	712	34.03 ± 6.32	6	33.17 ± 6.88
10~	H		142.70 ± 6.40		143.53 ± 6.31		143.62 ± 10.30		143.28 ± 8.08		143.76 ± 6.91		140.40 ± 10.17
	BMI		17.76 ± 2.80		17.34 ± 2.91		15.71 ± 1.50		16.22 ± 2.00		16.41 ± 2.47		16.89 ± 3.27
	W	18	38.67 ± 9.17	594	39.75 ± 8.50	5	40.10 ± 6.73	24	36.35 ± 6.66	627	37.83 ± 7.18	11	36.27 ± 8.91
11~	H		148.28 ± 6.42		148.28 ± 7.51		146.60 ± 3.78		148.79 ± 5.98		149.50 ± 7.09		144.18 ± 9.49[c]
	BMI		17.44 ± 3.31		18.01 ± 3.36		18.61 ± 2.63		16.34 ± 2.38		16.85 ± 2.50		17.29 ± 2.92
	W	14	43.86 ± 7.82	665	45.28 ± 9.49	7	47.93 ± 5.82	22	43.50 ± 6.91	718	42.39 ± 7.23	12	45.08 ± 7.03
12~	H		156.96 ± 8.99		155.59 ± 8.26		153.86 ± 6.57		156.09 ± 4.57		155.20 ± 6.24		157.0 ± 4.09
	BMI		17.70 ± 2.03		18.58 ± 2.95		20.34 ± 3.04		17.80 ± 2.24		17.54 ± 2.45		18.22 ± 2.11
	W	18	45.73 ± 10.79	768	49.25 ± 9.97	12	46.30 ± 6.29	21	45.91 ± 7.78	771	45.27 ± 7.49	12	45.21 ± 6.62
13~	H		161.22 ± 6.52		161.25 ± 8.14		158.50 ± 6.64		157.95 ± 3.75		158.01 ± 5.69		156.75 ± 5.95
	BMI		17.46 ± 3.27		18.83 ± 2.90		18.45 ± 2.43[a]		18.37 ± 2.82		18.09 ± 2.57		18.48 ± 3.12
	W	10	55.25 ± 10.49	404	52.46 ± 10.80	1	64	10	47.10 ± 7.08	340	47.21 ± 7.27	9	45.39 ± 3.51
14~	H		166.10 ± 6.39		165.29 ± 10.80		168		158.80 ± 5.77		159.45 ± 5.56		158.89 ± 4.26
	BMI		19.96 ± 3.32		19.11 ± 3.24		22.68		18.82 ± 2.11		18.55 ± 2.55		17.97 ± 1.07

[a] Pre-term compare with full-term, $p < 0.05$; [b] pre-term compare with post-term, $p < 0.05$; [c] full-term compare with post-term, $p < 0.05$.

Table 3. — *Prevalence of underweight, short stature, overweight, and obesity at different gestational ages and birth weights.*

Evaluation	SGA (n = 448, 6.23%)	AGA (n = 5447, 75.72%)	LGA (n = 1299, 18.06%)	Total
Underweight	22 (4.91%)	149 (2.74%)	20 (1.54%)[a,b,c]	191 (2.65%)
Short stature	21 (4.69%)	96 (1.76%)	16 (1.23%)[a,b]	133 (1.85%)
Overweight	27 (6.03%)	460 (8.45%)	179 (13.78%)[b,c]	666 (9.26%)
Obesity	13 (2.90%)	125 (2.29%)	57 (4.39%)[c]	195 (2.71%)

[a] SGA compared with AGA, $p < 0.05$; [b] SGA compared with LGA, $p < 0.05$; [c] AGA compared with LGA, $p < 0.05$. SGA: newborn with birth weight < 10th percentile for gestational age, according to the standards of national surveys of newborns in China; AGA: newborn with birth weight between 10th percentile and 90th percentile for gestational age, according to the standards of national surveys of newborns in China; LGA: newborn with birth weight > 90th percentile for gestational age, according to the standards of national surveys of newborns in China.

of overweight and obesity for macrosomia were higher than that in normal birth weight group ($\chi^2 = 11.172, 6.339$, $p < 0.05$). As shown in Table 6, for male children, the weight and height in macrosomia group were higher than that in low birth weight and normal birth weight group, as well as for the female children.

Discussion

Although there is high incidence of all kinds of growth deviations in developing countries, such as underweight,

Table 4. — *The weight, height, and BMI for the age groups at different gestational ages and birth weights.*

		Males						Females					
		SGA		AGA		LGA		SGA		AGA		LGA	
		Case	X ± SD	Case	X ± SD	Case	X ± SD	Case	X ± SD	Case	X ± SD	Case	X ± SD
9~	W	14	31.79 ± 3.41	205	33.71 ± 7.23	84	37.00 ± 7.37 [b,c]	25	30.36 ± 7.45	286	30.92 ± 5.78	60	31.69 ± 5.04
	H		138.21 ± 4.37		139.98 ± 6.55		141.17 ± 5.82		136.08 ± 7.92		138.72 ± 6.85		140.03 ± 6.03 [b]
	BMI		16.62 ± 1.44		17.14 ± 3.10		18.50 ± 3.27 [b,c]		16.38 ± 3.94		16.03 ± 2.56		16.09 ± 1.87
10~	W	23	33.88 ± 6.23	478	35.34 ± 7.08	169	37.62 ± 7.99 [b,c]	50	32.39 ± 6.31	586	33.69 ± 6.08	111	36.38 ± 6.91 [b,c]
	H		139.37 ± 5.21		143.21 ± 6.27		144.91 ± 6.42[a,b,c]		141.40 ± 9.02		143.32 ± 6.73		146.84 ± 6.30 [b,c]
	BMI		17.43 ± 3.01		17.15 ± 2.79		17.83 ± 3.14 [c]		16.19 ± 2.64		16.36 ± 2.46		16.78 ± 2.38
11~	W	36	35.94 ± 7.19	431	39.13 ± 7.86	150	42.33 ± 9.84 [a,b,c]	50	36.34 ± 8.19	518	37.57 ± 6.98	94	39.49 ± 7.54 [b,c]
	H		146.39 ± 7.98		147.79 ± 7.49		150.09 ± 6.93[b,c]		148.02 ± 8.36		149.37 ± 7.02		150.21 ± 6.90
	BMI		16.70 ± 2.64		17.88 ± 3.36		18.66 ± 3.35 [a,b,c]		16.42 ± 2.50		16.77 ± 2.45		17.43 ± 2.69 [b,c]
12~	W	34	44.51 ± 8.11	493	44.80 ± 9.35	159	46.93 ± 9.77 [c]	61	41.26 ± 6.98	592	42.23 ± 7.16	99	44.59 ± 7.39 [b,c]
	H		152.74 ± 7.29		155.27 ± 8.31		157.23 ± 8.04 [b,c]		154.04 ± 5.85		155.17 ± 6.22		156.54 ± 5.85 [b,c]
	BMI		19.02 ± 2.80		18.47 ± 2.96		18.85 ± 2.92		17.36 ± 2.61		17.48 ± 2.40		18.14 ± 2.45 [b,c]
13~	W	40	47.12 ± 9.91	617	48.60 ± 9.46	141	52.00 ± 11.49[b,c]	52	44.85 ± 7.96	644	45.10 ± 7.52	108	46.58 ± 6.89
	H		159.72 ± 8.81		160.81 ± 7.93		163.34 ± 8.23[b,c]		155.89 ± 6.53		157.90 ± 5.67		159.54 ± 4.53 [a,b,c]
	BMI		18.40 ± 3.30		18.69 ± 2.72		19.38 ± 3.46 [c]		18.47 ± 3.27		18.04 ± 2.54		18.27 ± 2.42
14~	W	29	48.04 ± 9.02	306	52.45 ± 11.11	80	54.59 ± 9.64[a,b]	29	42.42 ± 7.88	286	47.51 ± 7.08	44	48.03 ± 6.35 [a,b]
	H		162.52 ± 7.25		165.17 ± 8.00		166.89 ± 7.17[b]		155.97 ± 4.46		159.58 ± 5.52		160.61 ± 5.46 [a,b]
	BMI		18.10 ± 2.42		19.14 ± 3.39		19.55 ± 2.85 [b]		17.41 ± 2.94		18.83 ± 2.48		18.62 ± 2.31 [a,b]

[a] SGAcompared with AGA, $p < 0.05$; [b] SGA compared with LGA, $p < 0.05$; [c] AGA compared with LGA, $p < 0.05$.
SGA: newborn with birth weight < 10th percentile for gestational age, according to the standards of national surveys of newborns in China;
AGA: newborn with birth weight between 10th percentile and 90th percentile for gestational age, according to the standards of national surveys of newborns in China;
LGA: newborn with birth weight > 90th percentile for gestational age, according to the standards of national surveys of newborns in China;

Table 5. — *Prevalence of underweight, short stature, overweight, and obesity at different birth weights.*

Evaluation	Low birth weight (n = 173, 2.40%)	Normal birth weight (n = 6751, 93.84%)	Macrosomia (n = 270, 3.75%)	Total
Underweight	8 (4.62%)	180 (2.67%)	3 (1.11%)	191 (2.65%)
Short stature	4 (2.31%)	128 (1.90%)	1 (0.37%)	133 (1.85%)
Overweight	8 (4.62%)	617 (9.14%)	41 (15.19%)[a,b,c]	666 (9.26%)
Obesity	3 (1.73%)	178 (2.64%)	14 (5.19%)[c]	195 (2.71%)

[a] low birth weight compared with normal birthweight, $p < 0.05$
[b] low birth weight compared with macrosomia, $p < 0.05$
[c] normal birthweight compared with macrosomia, $p < 0.05$

short stature, overweight, and obesity, the latter two have become a worldwide epidemic, however little is still known regarding the exact cause of this trend or how best to stop it. For children's health, prevention may be a better approach than treatment. According to the theory of "programming", prevention efforts should begin very early in life. Birth weight and gestational age can reflect the condition of growth and development in utero at a certain extent. Some evidence suggests an association between birth weight with adolescent obesity, adult obesity, and other growth deviations [15]. By using a population-based approach, the present study analyzed the gestational age and birth weight impacting on physique situation of school children aged nine to 15 years in Chengdu, which is one of the youngest cities in Southwest China.

The prevalences of underweight, short stature, overweight, and obesity in preterm, full-term and post-term birth group were similar ($p > 0.05$), the same as the physique situation at school age among different sexes. The result was similar as that of the Knops and Saenger studies [16,17]. Knops *et al.* found that premature AGA children in the Netherlands attained normal height at ten years of age [16]. The Saenger *et al.* study concluded that the follow-up growth was not significantly different in preterm SGA, and in preterm AGA with prenatal growth restraint [17]. According to the gestational age, the physique situation at school age had no difference. The reason may be that most of preterm with relative normal weight grow normally in utero, due to of all kinds of factors, the fetus interrupts its growth in utero, and during premature delivery. These infants can exert normal growth potency in the healthy environment after birth.

Obesity is a growing concern worldwide. The prevalence of obesity has risen dramatically in developed countries over the past two to three decades [18, 19]. In developing countries, the transition from rural agrarian to urban economies has accelerated the appearance of obesity [20]. This study had shown that the tendency of obesity was more likely in LGA and macrosomia group, which was in keeping with the widely reported increase in the incidence of obesity in young children, and was undoubtedly nutritionally related [19, 21, 22]. The weights in macrosomia and LGA group for male children were higher than that in other group, as well as the female children. The result was consistent with Loaiza *et al.* [23]. A positive relationship between macrosomia, LGA, and obesity at first grade was found. Macrosomia children were more likely to be obese at first grade after assessing the effects of confounding prenatal variables. When weight gain between birth and first grade was > 120% of reference value, the obesity risk was 20 times higher. Wang Y *et al.* found that adolescent obesity rates

Table 6. — *The weight, height, and BMI for the age groups at different birth weights.*

		Males						Females					
		Low birth weight		Normal birth weight		Macrosomia		Low birth weight		Normal birth weight		Macrosomia	
		Case	X ± SD	Case	X ± SD	Case	X ± SD	Case	X ± SD	Case	X ± SD	Case	X ± SD
9～	W	10	28.85 ± 4.18	276	34.60 ± 7.36	17	36.89 ± 7.65[a,b]	10	29.45 ± 4.75	351	31.01 ± 5.84	10	32.35 ± 4.57
	H		136.20 ± 4.21		140.23 ± 6.21		142.47 ± 7.63[a,b]		137.40 ± 5.89		138.75 ± 6.91		140.40 ± 4.65
	BMI		15.50 ± 1.80		17.53 ± 3.14		18.17 ± 3.55[a,b]		15.53 ± 1.77		16.07 ± 2.62		16.35 ± 1.42
10～	W	12	35.08 ± 5.72	624	35.72 ± 7.38	34	38.68 ± 6.96[c]	19	33.37 ± 6.80	708	33.93 ± 6.23	20	37.19 ± 7.86 c
	H		141.71 ± 6.41		143.42 ± 6.28		145.76 ± 7.39[c]		141.05 ± 8.84		143.70 ± 6.91		147.00 ± 6.44 b,c
	BMI		17.48 ± 2.77		17.29 ± 2.92		18.12 ± 2.45		16.67 ± 2.14		16.39 ± 2.46		17.06 ± 2.61
11～	W	15	33.17 ± 6.81	571	39.64 ± 8.09	31	44.40 ± 13.11[a,b,c]	19	34.79 ± 5.47	624	37.73 ± 7.19	19	41.18 ± 7.32 b,c
	H		145.53 ± 6.92		148.28 ± 7.48		149.37 ± 7.07		146.53 ± 7.30		149.43 ± 7.14		150.74 ± 5.62
	BMI		15.62 ± 2.83		17.97 ± 3.26		19.71 ± 4.36[a,b,c]		16.16 ± 1.90		16.82 ± 2.51		18.04 ± 2.50 b,c
12～	W	8	43.56 ± 7.09	642	45.08 ± 9.42	36	49.15 ± 9.31[c]	18	41.61 ± 5.48	708	42.32 ± 7.20	26	46.98 ± 7.69 b,c
	H		156.88 ± 8.46		155.42 ± 8.15		158.58 ± 9.61[c]		155.28 ± 4.11		155.21 ± 6.22		156.44 ± 5.95
	BMI		17.64 ± 1.93		18.55 ± 2.98		19.40 ± 2.36		17.24 ± 1.92		17.51 ± 2.43		19.11 ± 2.44 b,c
13～	W	19	43.89 ± 10.17	750	49.15 ± 9.88	29	52.03 ± 10.79[a,b]	21	48.30 ± 9.11	756	45.17 ± 7.39	27	46.07 ± 8.22
	H		159.89 ± 6.26		161.08 ± 8.07		165.28 ± 8.65[b,c]		156.19 ± 6.88		157.97 ± 5.60		160.15 ± 5.17 b,c
	BMI		17.09 ± 3.46		18.83 ± 2.88		18.91 ± 2.98[a,b]		19.91 ± 4.33		18.06 ± 2.49		17.91 ± 2.80 a,b
14～	W	10	49.58 ± 11.13	393	52.36 ± 10.59	12	61.62 ± 13.55[b,c]	7	42.00 ± 9.87	343	47.29 ± 7.15	9	46.22 ± 5.32
	H		163.30 ± 8.30		165.30 ± 7.85		167.33 ± 7.54		158.71 ± 3.64		159.40 ± 5.61		160.56 ± 3.47
	BMI		18.41 ± 2.63		19.08 ± 3.23		21.78 ± 3.29[a,b]		16.62 ± 3.57		18.59 ± 2.50		17.89 ± 1.50 a

[a] low birth weight compared with normal birth weight, $p < 0.05$; [b] low birth weight compared with macrosomia, $p < 0.05$; [c] normal birth weight compared with macrosomia, $p < 0.05$.

raised with birth weight [24]. A U-shaped relationship between birth weight and risk of type 2 diabetes was found in the schoolchildren aged six to 18 years in Taiwan [24]. High birth weight also has an association with maternal nutritional situation. Overweight and obese women have a higher risk of macrosomia and LGA. Fetal lipid is deposited quite rapidly during the last trimester of pregnancy. While lean body mass is lower by 22% in SGA, and 20% higher in LGA compared to AGA newborns, there is 51% less fat mass in SGA and 128% more fat mass in LGA newborns [25]. A study of 140,000 American adults found that when the birth weight of full-term increases by one kg, the overweight risk in adult increases by 50% (26). In the present study, the prevalence of overweight for low birth weight group was lowest in three groups. When physique situation was analyzed, the weight and height in low birth weight group were less than that in normal birth weight and macrosomia groups, especially in nine-, 11-, and 13-year-old male children. However, for female children, low birth weight group did not differ significantly in weight, height, and BMI with normal birth weight. The result was consistent with Maureen's discovery. Study of the long-term growth of very low birth weight (VLBW) found that the females with VLBW demonstrated greater catch-up in growth than their male counterparts, such that by 20 years of age, they did not differ significantly in weight, height, or BMI when compared with their normal birth weight peers (27). In contrast, the VLBW males remained shorter and weighed less than their normal birth weight controls. Some authors have demonstrated a relationship between low birth weight and increased upper body fat distribution in children and adults, which seems to have more important health consequences in adult life than overall fatness [15].

It is commonly thought that catch-up growth was a phenomenon seen in infants born with SGA or low birth weight and/or low birth length. Catch-up growth is considered to be achieved when the child's weight or height is below the mean -2SD. In the present study, the incidence of SGA was 6.23%, when at school age, part of SGA had catch-up growth. However, the prevalence of underweight and short stature for SGA were highest in three groups. In spite of only part significant difference, the weight and height for SGA were less than that for AGA. The results were similar as that of a large study of 40,000 American children between 1988 and 1994. Despite catch up growth, the study found that infants born SGA tend to remain shorter and lighter with smaller head circumferences through early childhood compared with infants born AGA [28]. After assessing socio-economy status, Westwood *et al*. showed a significant deficit in height in SGA non-asphyxiated children aged 13-19 years [15]. It was also estimated that about 15% to 20% of infants with growth restriction had short stature at the age of four years and 7.9% were still short at 18 years of age [29]. In Albertsson-Wikland and Karlberg's studies, infants who had a short stature at two years were much more likely to also have a short stature at adult age and 8% of SGA were short at five years - a percentage that remained unchanged at least until the age of 18 years [30-32]. Other investigators found growth-restricted infants did not fully catch up with control group of infants in height, weight or body stature by the age of nine years and as a result, were substantially smaller and lighter and might very well remain as such throughout life.

The present study did not find that the incidence of overweight and obesity was higher in SGA group than in other group, that were not consistent with most research.

Since it was designed in a cross-sectional and retrospective study, the retrospective bias was unavoidable. Hence the authors had already been tracking the detailed birth information of these enrolled children according to their birth certificate, meanwhile more information about environment and life styles, as well as diet structure, family history, and some laboratory index would be further analyzed in later work.

In conclusion, the present study confirms that birth situation has an impact on the growth and development at school age. So great are the influences of intrauterine conditions on the developing fetus that they are not easily reversed when normal nutrition is restored. Further follow-up studies are needed in order to determine physique situation in a population of birth high-risk children and what percentage of subjects has a growth deviation. Preventive efforts should be performed during pregnancy. Such information is useful for the management of birth high- risk children and may be valuable for professionals working in follow-up clinics and dealing with parents of children at risk.

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XF participated in the design of the study, data collection and management, data processing and statistic analysis, and the manuscript writing. YF participated in the study design, coordinated the study personnel, trained the four researchers, and participated in data processing and analysis, and the manuscript writing. LP and HTZ participated in the data collection and data processing. MM conceived the study and participated in its design and supervision, and helped to draft the manuscript and review it. All authors read and approved the final manuscript.

References

[1] World Health Organization 2005 World Health Statistics 2005. Geneva, World Health Organization.

[2] Hales C.N., Barker D.J.: "Type 2 (non-insulin-dependent) diabetes mellitus: the thrifty phenotype hypothesis". *Diabetologia,* 1992, *35*, 595.

[3] Barker D.J., Godfrey K.M., Gluckman P.D., Harding J.E., Owens J.A., Robinson J.S.: "Fetal nutrition and cardiovascular disease in adult life". *Lancet,* 1993, *341*, 938.

[4] Barker D.J., Osmond C., Forsen T.J., Kajantie E., Eriksson J.G.: "Trajectories of growth among children who have coronary events as adults". *N. Engl. J. Med.,* 2005, *353*, 1802.

[5] Barker D.J.: "Obesity and early life". *Obstet. Rev.,* 2007, *8* (suppl.), 45.

[6] Eriksson J., Forsen T., Tuomilehto J., Osmond C., Barker D.: "Size at birth, childhood growth and obesity in adult life". *Int. J. Obes. Relat. Metab. Disord.,* 2001, *25,* 735.

[7] Wang Y., Gao E., Wu J., Zhou J., Yang Q., Walker M.C. *et al*.: "Fetal macrosomia and adolescence obesity: results from a longitudinal cohort study". *Int. J. Obes. (Lond.)*, 2009, *33,* 923.

[8] Albertsson-Wikland K., Karlberg J.: "Postnatal growth of children born small for gestational age". *Acta Paediatr.,* 1997, *423* (suppl.), 193.

[9] Ong K.K., Ahmed M.L., Emmett P.M., Preece M.A., Dunger D.B.: "Association between postnatal catch-up growth and obesity in childhood: prospective cohort study". *BMJ,* 2000, *320,* 967.

[10] Malina M., Katzmarzyk P.T., Beunen G.: "Birth weight and its relationship to size attained and relative fat distribution". *Obes. Res.*, 1996, *4,* 385.

[11] Law C.M., Barker D.J., Osmond C., Fall C.H., Simmonds S.J.: "Early growth and abdominal fatness in adult life". *J. Epidemiol. Community Health*, 1992, *46,* 184.

[12] Kissebah A.H., Krakower G.R.: "Regional adiposity and morbidity". *Physiol. Rev.*, 1994, *74,* 761.

[13] Li H., Ji C.Y., Zong X.N., Zhang Y.Q.: "Height and weight standardized growth charts for Chinese children and adolescents aged 0 to 18 years". *Zhonghua Er Ke Za Zhi*, 2009, *47*, 487.

[14] Group of China Obesity task force: "Body mass index reference norm for screening overweight and obesity in Chinese children and adolescents". *Zhonghua Liu Xing Bing Xue Za Zhi,* 2004, *25,* 97.

[15] Kozieł S., Jankowska E.A.: "Birthweight and stature, body mass index and fat distribution of 14-year-old Polish adolescents". *J. Paediatr. Child Health*, 2002, *38,* 55.

[16] Knops N.B., Sneeuw K.C., Brand R., Hille E.T., den Ouden A.L., Wit J.M. *et al*.: "Catch-up growth up to ten years of age in children born very preterm or with very low birth weight". *BMC Pediatr.,* 2005, *5*, 26.

[17] Saenger P., Czernichow P., Hughes I., Reiter E.O.: "Small for gestational age: short stature and beyond". *Endocr. Rev.,* 2007, *28,* 219.

[18] Flegal K.M., Carroll M.D., Ogden C.L., Johnson C.L.: "Prevalence and trends in obesity among US adults, 1999-2000". *JAMA,* 2002, *288,* 1723.

[19] Ogden C.L., Flegal K.M., Carroll M.D., Johnson C.L.: "Prevalence and trends in overweight among US children and adolescents, 1999-2000". *JAMA*, 2002, *288,* 1728.

[20] Popkin B.M.: "The nutrition transition in low-income countries". *Nutr. Rev.*, 1994, *52,* 285.

[21] Martorell R., Kettel Khan L., Hughes M.L., Grummer-Strawn L.M.: "Overweight and obesity in preschool children from developing countries". *Int. J. Obes. Relat. Metab. Disord.,* 2000, *24,* 959.

[22] Chinn S., Rona R.J.: "Prevalence and trends in overweight and obesity in three cross sectional studies of British children, 1974-94". *BMJ*, 2001, *322,* 24.

[23] Loaiza S., Coustasse A., Urrutia-Rojas X., Atalah E.: "Birth weight and obesity risk at first grade in a cohort of Chilean children". *Nutr. Hosp*., 2011, *26,* 214.

[24] Wei J.N., Sung F.C., Li C.Y., Chang C.H., Lin R.S., Lin C.C. *et al.: "*Low birth weight and high birth weight infants are both at an increased risk to have type 2 diabetes among school children in taiwan". *Diabetes Care*, 2003, *26*, 343.

[25] Bergmann R.L., Bergmann K.E., Dudenhausen J.W.: "Undernutrition and growth restriction in pregnancy". *Nestle Nutr. Workshop Ser. Pediatr. Program,* 2008, *61,* 103.

[26] Gillman M.W., Rifas-Siman S.L., Berkey C.S., Field A.E., Colditz G.A.: "Maternal gestational diabetes, birth weight, and adolescent obesity". *Pediatrics*, 2003, *111*, e221.

[27] Hack M., Schluchter M., Cartar L., Rahman M., Cuttler L., Borawski E.: "Growth of very low birth weight infants to age 20 years". *Pediatrics,* 2003, *112,* e30.

[28] Yanney M., Marlow N.: "Paediatric consequences of fetal growth restriction". *Semin. Fetal. Neonatal. Med*., 2004, *9*, 411.

[29] Seminara S., Rapisardi G., La Cauza F., Mattei P., Donzelli G.: "Catch-up growth in short-at-birth NICU graduates". *Horm Res.,* 2000, *53,* 139.

[30] Albertsson-Wikland K., Karlberg J.: "Natural growth in children born small for gestational age with and without catch-up growth". *Acta Paediatr*., 1994, *339,* 64.

[31] Karlberg J., Albertsson-Wikland K.: "Growth in full-term small-for-gestational-age infants: From birth to final height". *Pediatr. Res.*, 1995, *38*,733.

[32] Albertsson-Wikland K., Boguszewski M., Karlberg J.: "Children born small-for-gestational age: Postnatal growth and hormonal status". *Horm Res*., 1998, 49 (# suppl. 2), 7.

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