Original Article

Chest circumference in infancy predicts obesity in 3-year-old children

Izumi Akaboshi MD[1], Akito Kitano MD, PhD[2], Hiroaki Kan MD, PhD[3], Yougo Haraguchi MD, PhD[4], Yuuji Mizumoto MD[5], for the Kumamoto Infant Rapid Growth study group

[1]*Akaboshi Pediatric Clinic, Kumamoto City Medical Association, Kumamoto, Japan*
[2]*Kitano Pediatric Clinic, Kumamoto City Medical Association, Kumamoto, Japan*
[3]*Kan Clinic, Kumamoto City Medical Association, Kumamoto, Japan*
[4]*Haraguchi Children's Clinic, Kumamoto City Medical Association, Kumamoto, Japan*
[5]*Mizumoto Children's Clinic, Kumamoto City Medical Association, Kumamoto, Japan*

The purpose of this study was to investigate the associations between chest circumference in infancy and rapid growth or obesity at 3 years of age. We conducted a retrospective observational study of 1353 children in Kumamoto, Japan. Data collected included chest circumference, head circumference, weight, and body mass index. The area under the receiver operating characteristic curves for chest circumference were analyzed to determine the ability of this index to identify obesity at 3 years of age. Chest circumference at 3-4 months of age and increases in chest circumference during the first 3-4 months of life had higher mean standard deviation scores for rapid growth than for slow or no change in growth ($p<0.05$). Chest circumference and the increase in chest circumference were also positively correlated with rapid weight gain, and were associated with obesity at 3 years of age. The area under the curve for chest circumference was significantly different from the area under the curve for weight z-score at 6-9 months but not for weight z-score at 3-4 months. In conclusion, we found that chest circumference is associated with obesity in young children, and is positively correlated with rapid growth. Therefore, chest circumference may be a useful marker for rapid growth, and may help clinicians to identify obese children at 3 years of age.

Key Words: area under the curve, chest circumference, obesity, rapid growth, receiver operating characteristic curve

INTRODUCTION

Rapid weight gain in the postnatal period is characterized by a rapid increase in body weight, and is associated with obesity in later childhood and adulthood.[1–3] Weight gain is usually recorded in kg, 100 g/month, or as weight-for-age standard deviation (SD) scores.[1–3] Rapid weight gain is usually defined as a change in weight SD score >0.67, measured at two different times.[4] Rapid weight gain during infancy is associated with not only increased body mass index (BMI), but also increased adiposity in later life.[5] Indeed, a recent study in the Netherlands showed that rapid weight gain in the postnatal period is associated with an increase in skinfold thickness and truncal/peripheral fat ratio at 6 months of age.[6] However, no researchers have examined whether chest circumference (CHC) in infants represents an increased chest subcutaneous fat mass distribution. If subscapular skinfold thickness is correlated with CHC, the relationship between CHC, postnatal rapid growth, and future obesity is of considerable clinical interest.

In developing countries, a decreased CHC in newborn infants was associated with intrauterine growth retardation or low birth weight.[7,8] By contrast, in developed countries, it is unclear whether increased CHC in infancy is associated with rapid weight gain in the postnatal period or is predictive of obesity in later life. In Japan, CHC is routinely measured by pediatricians and clinical nurses at birth, at 3-4 months of age, and at 6-9 months of age, using methods described in the report of the National Growth Survey of Infants and Preschool Children in Japan 2000 implemented by the Ministry of Health, Labor and Welfare.

The purpose of this study was to assess the relationship between CHC, rapid infant growth, and obesity at 3 years of age. To establish CHC as a useful anthropometric predictor for obesity at 3 years of age, we used standardized methods, including receiver operating characteristic (ROC) curves and determined the area under the curve (AUC) to compare CHC z-scores (CHCZ) with other anthropometric measures to predict obesity in early childhood.

Corresponding Author: Dr Izumi Akaboshi, Akaboshi Pediatric Clinic, Kuwamizu, 1-16-16, Kumamoto, Japan.
Tel: +81 96 383 1251; Fax: +81 96 386 5170
Email: akaboshi@orange.ocn.ne.jp
Manuscript received 13 December 2011. Initial review completed 2 April 2012. Revision accepted 2 July 2012.

METHODS

The subjects enrolled in this retrospective study are described in more detail elsewhere.[9] Briefly, 1569 healthy children aged 3-17 years visited our pediatric clinic in Kumamoto City for vaccination. All of the children brought their *Maternal and Child Health Handbook*, published by the Ministry of Health, Labor and Welfare of Japan, documenting their anthropometric and medical/vaccination records from birth to 3 years of age. We reviewed the handbooks for each child and recorded anthropometric data for up to 3 years of age in a database.

For this study, we excluded subjects born in multiple births, those born before 36 weeks or after 42 weeks of gestation, and those with incomplete or incorrectly recorded data (weight at 3-4 months and 3 years of age). After applying these criteria, 1353 subjects (697 boys and 656 girls) were included in this analysis. Oral informed consent was obtained from the parents or guardians of all subjects.

Anthropometric measurements were performed at birth, 3-4 months, 6-9 months, and 3 years of age. Anthropometric data were recorded at public health centers and pediatric clinics in Kumamoto City as part of routine health examinations, or at healthy baby check-ups. At each examination, weight without clothes was measured to the nearest 0.1 kg, while CHC and head circumference (HC) were measured to the nearest 0.1 cm using a non-elastic flexible tape. CHC was measured without clothes at the levels of the nipples and below the inferior angle of the scapulae, if the infants did not cry. Head circumference was measured using standard methods at birth, 3-4 months, and 6-9 months of age. Weight z-score (WZ), CHCZ, and HC z-score (HCZ) for each age group are expressed as age- and sex-specific SD scores (z-scores) determined using the Japan growth reference scores for 1990.[10] BMI was calculated as weight/height squared (kg/m^2). Chest circumference gain was calculated as CHCZ at 3-4 months or 6-9 months of age minus CHCZ at birth. Chest circumference z-scores at 3-4 months of age and CHC gain at 3-4 months of age were each divided into quartiles (quartile 1: 0–24th percentile; quartile 2: 25th–49th percentile; quartile 3: 50th–74th percentile; quartile 4: ≥ 75th percentile)..

The rate of weight gain during the first 3-4 months of life is expressed in units of 100 g/month, as previously described.[1] The SD score for weight gain was calculated as weight SD score at 3-4 months minus birth weight SD score. Changes in SD score between birth and 3-4 months of age greater or less than 0.67 were defined as rapid or slow growth, respectively, as described previously.[11] Obesity at 3 years of age, the main outcome in this study, was defined according to the age- and sex-specific BMI cut-off values proposed by the Japanese obesity criteria,[12] and was equivalent to a cut-off of 25 kg/m^2 at 17.5 years of age.

Differences in anthropometric measurements and changes in SD scores for weight during the first 3-4 months of age were tested for significance using one-way analysis of variance (ANOVA). Comparisons between multiple groups were made using the Bonferroni/Dunn test or the Tukey–Kramer test. Correlations between anthropometric variables and the rate of weight gain from birth to 3-4 months of age or changes in SD scores for weight at 3-4 months of age were analyzed using Pearson's correlation analysis. The extended Fisher's exact test was used to compare the prevalence rates of three weight categories using web-based software (http://aoki2.si.gunma-u.ac.jp/exact/exact.html). Receiver operating characteristic curves were used to evaluate the ability of different anthropometric measurements (WZ, CHCZ, HCZ, CHC gain and HC gain) at 3-4 months and 6-9 months of age to predict obesity at 3 years of age. The AUCs were determined to assess the predictive capability of each variable. The ROCCOMP command in STATA 11.0 (Stata Corp., College Station, TX, USA) was used to compare the AUCs between pairs of ROC curves. Values of $p<0.05$ were considered statistically significant. Statistical analyses were performed using Statview version 5.0 (SAS Institute Inc., Cary, NC, USA) and STATA release 11.0 (Stata Corp.).

RESULTS

The characteristics of the study subjects are shown in Table 1. The prevalence rate of obesity at 3 years of age was approximately 14.0%, and was higher in boys than in girls (Table 1). Weight z-score from birth to 6-9 months in the boys and girls included in this study were greater than the Japan growth reference for 1990.[10] However, CHCZ from birth to 6-9 months were lower than the national reference. The CHCZ and HCZ values at birth in infants with slow growth were higher than those in infants with rapid growth and in those with no change in growth ($p<0.05$; one-way ANOVA). CHCZ, CHC gain, HCZ, and HC gain at both 3-4 months and 6-9 months were much greater in infants with rapid growth compared with infants with slow growth or no change in growth ($p<0.05$; one-way ANOVA; Table 2).

The rate of weight gain during the first 3-4 months of life was positively correlated with both CHCZ and CHC gain at 3-4 months of age. Moreover, the change in SD score for weight from birth to 3-4 months was significantly correlated with CHC gain at 3-4 months, CHC gain at 6-9 months of age, and CHCZ at 3-4 months (Table 3).

The prevalence of obesity at 3 years of age was high in infants who experienced rapid growth or no change in growth during the first 3-4 months of life and in those in the highest CHCZ quartile (SD score ≥0.52) at 3-4 months of age (3.1% and 3.5%, respectively). Approximately 50% of obese children at 3 years of age had a CHCZ greater than the 75th percentile (i.e., quartile 4, SD scores ≥0.52), which was strongly associated with obesity at 3 years of age. The prevalence of obesity at 3 years of age was highest in the group of children with rapid growth and those who were in CHC gain quartile 4 (SD score ≥0.55; 3.5%; Table 4).

The AUC for obesity at 3 years of age was highest for WZ at 6-9 months (AUC=0.741), whereas the AUCs for CHCZ at both 3-4 months (0.693) and 6–9 months (0.695) of age were similar to the AUC for WZ at 3-4 months (0.705). The four ROC curves for CHCZ and WZ at both 3-4 months and 6-9 months of age crossed each other, which indicates that none of these curves are graphically or statistically superior for predicting obesity at 3 years (data not shown).

Table 1. Subject characteristics

Parameter	All subjects	Boys	Girls	p-value
WZ at birth	0.25 ± 0.91 (1351)	0.31 ± 0.91 (696)	0.18 ± 0.91 (655)	0.008
WZ at 3-4 months	0.25 ± 0.91 (1353)	0.26 ± 0.87 (697)	0.24 ± 0.96 (656)	0.743
WZ at 6-9 months	0.19 ± 0.99 (1283)	0.23 ± 0.94 (665)	0.15 ± 1.03 (618)	0.139
CHCZ at birth	–0.02 ± 0.96 (1349)	–0.05 ± 0.96 (695)	0.01 ± 0.96 (654)	0.297
CHCZ at 3-4 months	–0.14 ± 0.97 (1245)	–0.12 ± 0.96 (642)	–0.16 ± 0.98 (603)	0.443
CHCZ at 6-9 months	–0.17 ± 1.01 (1184)	–0.29 ± 1.03 (617)	–0.04 ± 0.98 (567)	<0.0001
CHC gain from 0 to 3-4 months	–0.12 ± 1.10 (1241)	–0.07 ± 1.06 (640)	–0.18 ± 1.14 (601)	0.095
CHC gain from 0 to 6-9 months	–0.15 ± 1.17 (1183)	–0.23 ± 1.14 (617)	–0.07 ± 1.19 (566)	0.021
CHC gain from 3-4 to 6-9 months	–0.23 ± 0.87 (1168)	–0.17 ± 0.88 (609)	0.13 ± 0.83 (559)	<0.0001
HZ at birth	–0.90 ± 1.01 (1348)	–0.09 ± 0.95 (695)	–0.09 ± 1.06 (653)	0.864
HZ at 3-4 months	–0.13 ± 0.84 (1320)	–0.15 ± 0.89 (679)	–0.10 ± 0.79 (640)	0.212
HZ at 6-9 months	0.14 ± 0.95 (1227)	0.05 ± 0.95 (637)	0.24 ± 0.94 (590)	0.0007
HZ gain from 0 to 3-4 months	–0.03 ± 1.04 (1314)	–0.06 ± 1.01 (677)	–0.01 ± 1.08 (637)	0.328
HZ gain from 0 to 6-9 months	0.23 ± 1.11 (1226)	0.14 ± 1.09 (637)	0.32 ± 1.13 (589)	0.004
Rate of weight gain from birth to 3-4 months (100 g/month)	9.83 ± 1.76 (1353)	10.4 ± 1.70 (697)	9.24 ± 1.63 (656)	<0.0001
BMI at 3 years of age	15.8 ± 1.14 (1353)	15.9 ± 1.09 (697)	15.7 ± 1.18 (656)	0.035
Obesity (%)	14.04 (1353)	8.20 (697)	5.84 (656)	0.039†

Variables are presented as means ± standard deviation (n).
WZ: weight z-score; CHCZ: chest circumference z-score; CHC gain: change in chest circumference z-score; HZ: head circumference z-score; HZ gain: change in head circumference z-score, obesity: defined according to the reference criteria for Japan.[12]
† Chi-square test.

The AUCs for anthropometric markers for predicting obesity at 3 years of age are compared in Table 5. The AUC for CHCZ at 3-4 months was not significantly different from the AUCs for CHCZ at 6-9 months, WZ at 3-4 months, and HCZ 6-9 months, as indicated by ROCCOMP (χ^2=0.02, p=0.890; χ^2=0.71, p=0.401; and χ^2=2.48, p=0.115, respectively). However, the AUC for WZ at 6-9 months was significantly different from all of the other anthropometric measurements, including CHCZ at both 3-4 months and 6-9 months of age (Table 5).

DISCUSSION

To our knowledge, there are no prior reports concerning the use of CHCZ to evaluate rapid growth during infancy and obesity in early childhood. This study provides evidence that CHCZ at both 3-4 months and 6-9 months of age is a good predictor of obesity at 3 years of age. Weight z-score at 3-4 months is also a good predictor, although inferior to WZ at 6-9 months of age. Receiver operating characteristic analysis, including the ROCCOMP procedure, is a useful tool to determine the associations of several independent variables with one outcome, and whether the AUCs of two different variables are significantly different. The results of the ROC analyses in this study indicate that both CHCZ and WZ at 3-4 months of age are equally useful in predicting obesity at 3 years of age. Interestingly, the AUC for HCZ at 6-9 months was not significantly different to the AUCs for CHCZ at either 3-4 months or 6-9 months, but was significantly different to the AUC for WZ at 3-4 months. These results suggest that CHCZ at both 3-4 months and 6-9 months of age is more important than HCZ at 6-9 months of age in terms of predicting obesity at 3 years of age.

In our study, we found marked differences between boys and girls for several variables, including the prevalence of obesity at 3 years of age, rate of weight gain from birth to 3-4 months (recorded as 100 g/month), BMI at 3 years of age, and CHCZ at 6-9 months of age. By applying the BMI cut-off values proposed by the International Obesity Task Force (≥17.6 kg/m^2 for females and ≥ 17.9 kg/m^2 for males)[13] and the reference criteria for Japan (≥17.0 kg/m^2 for females and ≥16.9 kg/m^2 for males),[12] we found that the prevalence of obesity in children at 3 years of age was higher when the reference criteria for Japan were applied (4.73% vs 14.0%). Notably, the prevalence of obesity at 3 years of age was 4.8-fold

Table 2. Comparison of anthropometric characteristics according to rate of growth from birth to 3-4 months of age

	All subjects	Slow growth	No change in growth	Rapid growth
CHCZ at birth	–0.20 ± 0.96	0.47 ± 0.89*	–0.08 ± 0.86**	–0.41 ± 1.05
	(1347)	(325)	(716)	(306)
CHCZ at 3-4 months	–0.14 ± 0.97	–0.63 ± 0.83	–0.18 ± 0.86****	0.47 ± 1.03***
	(1244)	(297)	(663)	(284)
CHCZ at 6-9 months	–0.17 ± 1.01	–0.52 ± 0.93	–0.21 ± 0.94****	0.29 ± 1.11***
	(1183)	(280)	(641)	(262)
CHC gain from 0 to 3-4 months	–0.12 ± 1.10	–1.08 ± 0.86	–0.12 ± 0.82****	0.88 ± 0.99***
	(1240)	(297)	(660)	(283)
CHC gain from 0 to 6-9 months	–0.15 ± 1.16	–0.99 ± 0.95	–0.14 ± 0.96****	0.70 ± 1.19***
	(1182)	(280)	(640)	(262)
CHC gain from 3-4 to 6-9 months	–0.03 ± 0.87	0.12 ± 0.84*	–0.02 ± 0.83	–0.19 ± 0.96
	(1167)	(275)	(630)	(262)
HCZ at birth	–0.09 ± 1.01	0.30 ± 0.94*	–0.13 ± 0.95**	–0.41 ± 1.07
	(1346)	(325)	(715)	(306)
HCZ at 3-4 months	–0.13 ± 0.84	–0.20 ± 0.83	–0.16 ± 0.84	0.03 ± 0.85***
	(1318)	(317)	(704)	(297)
HCZ at 6-9 months	0.14 ± 0.95	0.13 ± 0.91	0.07 ± 0.92	0.32 ± 1.05***
	(1226)	(288)	(666)	(272)
HC gain from 0 to 3-4 months	–0.03 ± 1.04	–0.49 ± 0.95	–0.02 ± 0.98****	0.43 ± 1.08***
	(1313)	(317)	(700)	(296)
HC gain from 0 to 6-9 months	0.23 ± 1.11	–0.17 ± 1.01	0.19 ± 1.03****	0.73 ± 1.22***
	(1225)	(288)	(665)	(272)
Rate of weight gain from birth to 3-4 months (100 g/month)	9.83 ± 1.76	8.13 ± 1.20	9.84 ± 1.26****	11.6 ± 1.48***
	(1351)	(325)	(719)	(307)
BMI at 3 years of age	15.8 ± 1.14	15.6 ± 1.10	15.8 ± 1.06****	16.1 ± 1.28***
	(1351)	(325)	(719)	(307)
Obesity at 3 years of age		2.6%	6.9%	4.5%
	(1351)	(325)	(719)	(307)

Variables are presented as means ± standard deviation (n).
WZ: weight z-score; CHCZ: chest circumference z-score; CHC gain: change in chest circumference z-score; HZ: head circumference z-score; HZ gain: change in head circumference z-score, obesity: defined according to the reference criteria for Japan.[12]
**p*<0.05 for slow growth vs no change in growth/rapid growth
***p*<0.05 for no change in growth vs rapid growth
****p*<0.05 for rapid growth vs no change in growth/slow growth
*****p*<0.05 for no change in growth vs slow growth

Table 3. Correlations between anthropometric characteristics and the rate of weight gain or change in SD score for weight from birth to 3-4 months of age

	Rate of weight gain		Change in SD score for weight	
	r	*p*-value	*r*	*p*-value
CHCZ at birth	–0.027	0.315	–0.360	<0.0001
CHCZ at 3-4 months	0.693	<0.0001	0.454	<0.0001
CHCZ at 6-9 months	0.437	<0.0001	0.314	<0.0001
CHC gain from 0 to 3-4 months	0.578	<0.0001	0.698	<0.0001
CHC gain from 0 to 6-9 months	0.408	<0.0001	0.558	<0.0001
CHC gain from 3-4 to 6-9 months	–0.195	<0.0001	–0.138	<0.0001
HCZ at birth	–0.018	0.512	–0.286	<0.0001
HCZ at 3-4 months	0.260	<0.0001	0.099	0.0003
H.CZ at 6-9 months	0.226	<0.0001	0.084	0.004
HC gain from 0 to 3-4 months	0.224	<0.0001	0.350	<0.0001
HC gain from 0 to 6-9 months	0.208	<0.0001	0.325	<0.0001

SD: standard deviation; WZ: weight z-score; CHCZ: chest circumference z-score; CHC gain: change in chest circumference z-score; HZ: head circumference z-score; HZ gain: change in head circumference z-score.

higher in boys (1.7% vs 8.2%) and 1.9-fold higher in girls (3.03% vs 5.84%) using the Japanese reference criteria. However, rapid growth from birth to 3-4 months of age was found in 22.7% of study subjects, and was similar in boys and girls (10.9% vs 11.8%).

Using a retrospective study design, we showed that CHCZ and CHC gain during early infancy are positively correlated and are associated with rapid weight gain during the first 3-4 months of life. Increased CHC may represent subcutaneous adiposity in the trunk in early infancy, even though we did not formally assess fat distribution in this study, by measuring skinfold thickness for example. This interpretation is supported by several observational studies in which rapid weight gain in the postnatal period is positively associated with subcutaneous fat distribution in the trunk in later life.[14–17] Notably, Olhager et al[18] conducted MRI studies and found that 90% of all adipose tissue is located in subcutaneous depots during

Table 4. Prevalence of obesity at 3 years of age according to changes in SD scores for weight from birth to 3-4 months of age, and quartiles of CHCZ and CHC gain

	n	Slow growth	No change in growth	Rapid growth
CHCZ				
Quartile 1	304	11 (0.9)	9 (0.7)	1 (0.1)
Quartile 2	295	9 (0.7)	15 (1.2)	2 (0.2)
Quartile 3	332	8 (0.6)	25 (2.0)	8 (0.6)
Quartile 4	312	3 (0.2)	38 (3.1)	44 (3.5)
Total n		297	663	283
p-value				0.0002†
CHC gain				
Quartile 1	309	22 (1.9)	11 (1.0)	2 (0.2)
Quartile 2	312	6 (0.5)	29 (2.5)	3 (0.3)
Quartile 3	306	2 (0.2)	24 (2.1)	10 (0.9)
Quartile 4	312	1 (0.1)	23 (2.0)	40 (3.5)
Total n		297	660	282
p-value				<0.0001†

Values are n (%) of subjects in each group relative to the total number of subjects.
CHCZ: chest circumference z-score; CHC gain: change in chest circumference z-score.
†Extended Fisher's exact test was used to determine the *p* values, which are for comparisons among all three growth categories

Table 5. Comparisons of the areas under the receiver operating characteristic curves for anthropometric measurements to predict obesity at 3 years of age

Variables	AUC	95% CI
WZ at 3-4 months	0.705	0.662-0.749
WZ at 6-9 months	0.741	0.699-0.782
CHCZ at 3-4 months	0.693	0.647-0.740
CHCZ at 6-9 months	0.695	0.651-0.739
CHC gain from 0 to 3-4 months	0.576†‡	0.529-0.624
CHC gain from 0 to 6-9 months	0.563†‡	0.516-0.609
CHC gain from 3-4 months to 6-9 months	0.502†‡	0.451-0.552
HCZ at 3-4 months	0.634†‡	0.589-0.678
HCZ at 6-9 months	0.644	0.599-0.689
HC gain from 0 to 3-4 months	0.485†‡	0.439-0.531
HC gain from 0 to 6-9 months	0.514†‡	0.465-0.560

AUC: area under the curve; WZ: weight z-score; CHCZ: chest circumference z-score; CHC gain: change in chest circumference z-score; HZ: head circumference z-score; HZ gain: change in head circumference z-score.
Statistical comparison of pairs of AUCs
CHCZ at 3-4 months vs CHCZ at 6-9 months: χ^2=0.02, *p*=0.890
CHCZ at 3-4 months vs WZ at 3-4 months: χ^2=0.71, *p*=0.401
CHCZ at 3-4 months vs WZ at 6-9 months: χ^2=6.84, *p* 0.009
CHCZ at 6-9 months vs WZ at 3-4 months: χ^2=0.46, *p*=0.499
CHCZ at 6-9 months vs WZ at 6-9 months: χ^2=11.24, *p*=0.008
WZ at 3-4 months vs WZ at 6-9 months: χ^2=6.39, *p*=0.012
CHCZ at 3-4 months vs HCZ at 6-9 months: χ^2=2.48, *p*=0.115
CHCZ at 6-9 months vs HCZ at 6-9 months: χ^2=3.56, *p*=0.059
HCZ at 6-9 months vs WZ at 3-4 months: χ^2=5.60, *p*=0.0179
HCZ at 6-9 months vs WZ at 6-9 months: χ^2=17.38, *p*<0.0001
†CHCZ at 3-4 months vs the other variables: χ^2 ≥5.6, *p*<0.05
‡CHCZ at 6-9 months vs the other variables: χ^2 ≥5.5, *p*<0.05

the first 4 months of life. Rapid weight gain during the early postnatal period is associated with expansion of subcutaneous fat within the truncal region, and this subcutaneous fat mass tends to persist until 2 years of age.[19,20] These studies suggest that increased CHC in early infancy is associated with rapid weight gain in the early postnatal period and with increased central adiposity. Further studies are needed to examine the relationship between CHC and skinfold thickness, particularly subscapular skin thickness, during early infancy. In Japan, CHC is routinely measured at healthy baby check-ups, in accordance with the procedures of the National Growth Survey of Infants and Preschool Children implemented by the Ministry of Health, Labor and Welfare. Measuring CHC in early infants is safe, easy to conduct, and inexpensive. We can also apply age- and sex-specific national reference values for CHC in Japan for comparative analysis. [10] Chest circumference z-scores during early infancy may be a useful tool in screening for obesity, rapid weight gain, and altered body fat distribution. Chest circumference z-scores can also be measured in epidemiologic research and in routine clinical practice. Measurement of CHCZ in early infancy, together with weight-related indices, may allow clinicians to timely initiate interventions aimed at reducing the risk of obesity in childhood.

AUTHOR DISCLOSURES

We declare no conflicts of interest.

REFERENCES

1. 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.
2. Ong KKL, Ahmed ML, Emmett PM, Preece MA, Dunger DB. Association between postnatal catch-up growth and obesity in childhood: prospective cohort study. BMJ. 2000; 320:967-71.
3. Ong KK, Loos RJF. Rapid infancy weight gain and subsequent obesity: systematic reviews and hopeful suggestions. Acta Paediatr. 2006;95:904-8.
4. Monterio POA, Victora CG. Rapid growth in infancy and childhood and obesity in later life – a systematic review. Obes Rev. 2005;6:143-54.
5. Stettler N, Iotova V. Early growth patterns and long-term obesity risk. Curr Opin Nutr Metab Care. 2010;13:294-9.
6. Holzhauer S, Hokken Koelega AC, Ridder M, Hofman A, Moll HA, Steegers EA, Witteman JC, Jaddoe VW. Effect of birth weight and postnatal weight gain on body composition in early infancy: The Generation R Study. Early Hum Dev. 2009;85:285-90.
7. Rondo PH, Tomkins AM. Chest circumference as an indicator of intrauterine growth retardation. Early Hum Dev. 1996; 44:161-7.
8. Mullany LC, Darmstadt GL, Khatry SK, Leclerq SC, Tielsch JM. Relationship between the surrogate anthropometric measures, foot length and chest circumference and birth weight among newborns of Sarlahi, Nepal. Eur J Clin Nutr. 2007;61:40-6.
9. Akaboshi I, Haraguchi Y, Mizumoto Y, Kitano A, Kan H. Taller stature after postnatal rapid weight gain in early infancy predicts overweight status at age 3. Acta Paediatr. 2008;97:1460-4.
10. Takaishi M, Takano A, Kati N, Omori S. National growth survey for infants and preschool children : The report of Ministry of Health, Labor and Welfare 1990 (in Japanese). In Takaishi M, editor. Series of child health No.38. Tokyo: The Japanese Society of Child Health; 1992. pp. 81-93
11. Ekelund U, Ong K, Linné, Y, Neovius M, Brage S, Dunger DB, Wareham NJ, Rössner S. 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.
12. Kato N, Sato K, Takimoto H, Sudo N. BMI for age references for Japanese children – based on the 2000 growth survey. Asia Pac J Public Health. 2008;20(Suppl):118-27.
13. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000;320:1240-3.
14. Leunissen RW, Kerkhof GF, Stijnen T, Hokken-Koelega A. Timing and tempo of first-year rapid growth in relation to cardiovascular and metabolic risk profile in early adulthood. JAMA. 2009;301:2234-42.
15. Chomtho S, Wells JC, Williams JE, Davies PS, Lucas A, Fewtrell MS. Infant growth and later body composition: evidence from the 4-component model. Am J Clin Nutr. 2008; 87:1776-84.
16. Demerath EW, Reed D, Choh AC, Soloway L, Lee M, Czerwinski SA, Chumlea WC, Siervogel RM, Towne B. Rapid postnatal weight gain and visceral adiposity in adulthood: the Fels Longitudinal Study. Obesity. 2009;17:2060-6.
17. Karaolis-Danckert N, Buyken AE, Kulig M, Kroke A, Forster J, Kamin W, et al. How pre- and postnatal risk factors modify the effect of rapid weight gain in infancy and early childhood on subsequent fat mass development: results from the Multicenter Allergy Study 90. Am J Clin Nutr. 2008;87: 1356-64.
18. Olhager E, Flinke E, Hannerstad U, Forsum E. Studies on human body composition during the first 4 months of life using magnetic resonance imaging and isotope dilution. Pediatr Res. 2003;54:906-12.
19. Ay L, Hokken-Koelega AC, Mook-Kanamori DO, Hofman A, Moll HA, Mackenbach JP, Witteman JC, Steegers EA, Jaddoe VW. Tracking and determinants of subcutaneous fat mass in early childhood: the Generation R study. Int J Obes. 2008;32:1050-9.
20. Drumus B, Mook-Kanamori DO, Holzhauer S, Hofman A, van der Beek EM, Boehm G, Steegers EA, Jaddoe VW. Growth in fetal life and infancy is associated with abdominal adiposity at the age of 2 years. The Generation R Study. Clin Endocrinol. 2010;72:633-40.

Original Article

Chest circumference in infancy predicts obesity in 3-year-old children

Izumi Akaboshi MD[1], Akito Kitano MD, PhD[2], Hiroaki Kan MD, PhD[3], Yougo Haraguchi MD, PhD[4], Yuuji Mizumoto MD[5], for the Kumamoto Infant Rapid Growth study group

[1]*Akaboshi Pediatric Clinic, Kumamoto City Medical Association, Kumamoto, Japan*
[2]*Kitano Pediatric Clinic, Kumamoto City Medical Association, Kumamoto, Japan*
[3]*Kan Clinic, Kumamoto City Medical Association, Kumamoto, Japan*
[4]*Haraguchi Children's Clinic, Kumamoto City Medical Association, Kumamoto, Japan*
[5]*Mizumoto Children's Clinic, Kumamoto City Medical Association, Kumamoto, Japan*

嬰兒期的胸圍預測兒童 3 歲時的肥胖

此研究的目的為探討嬰兒期的胸圍與快速成長或 3 歲時肥胖的相關性。此回溯性觀察研究對象包含 1353 位日本熊本市的兒童。資料收集包含胸圍、頭圍、體重及身體質量指數。分析接受器操作特徵曲線(ROC)下面積用以決定預測 3 歲兒童肥胖的指標。生長速度較快的幼童在 3-4 個月時的胸圍和 3-4 個月時的胸圍增加，比起生長速度較慢或體重沒有改變者，具有較高的平均標準差分數($p<0.05$)。胸圍以及胸圍增加數值與快速體重增加及 3 歲時的肥胖具有正相關。胸圍的曲線下面積與 6-9 個月時體重 Z 分數的曲線下面積具有顯著差異，但與 3-4 個月的數值則無顯著差異。結論是，胸圍與幼童的肥胖以及成長速度具有正相關性。因此，嬰兒期的胸圍可能是有用的成長速度指標，而有助於臨床評估 3 歲幼童是否肥胖。

關鍵字：曲線下面積、胸圍、肥胖、快速成長、接受器操作特徵曲線