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Are the 2006 World Health Organization standards for infant growth applicable to Hong Kong Chinese? Universalistic standards or epidemiological transition stage-specific norms

Key Messages

1. Parental socio-economic status was positively associated with length and body mass index of Hong Kong Chinese infants at 9 months.
2. Maternal smoking in pregnancy was negatively associated with infant length at 9 months.
3. Some of the World Health Organization (WHO) criteria for an optimal nurturing environment contributed positively to growth. At 36 months, Hong Kong Chinese infants were generally shorter and fatter than the WHO growth references.

Introduction

Infant growth is a key health indicator. Growth standards, particularly for height, can monitor whether child health and care needs are met effectively, such that children can achieve their full growth potential.[1] In 2006, the World Health Organization (WHO) issued growth charts to provide universalistic standards for optimal growth of infants worldwide. Nonetheless, the WHO sample did not include infant populations from China or East Asia. The WHO implicitly assumes that under optimal environmental conditions, infants and children can achieve their full genetic height potential within one generation, although there is evidence indicating a limit to inter-generational height increases and that incremental increases in height take place over many generations.[2] In a population-representative cohort of Hong Kong Chinese infants, their weights at 3, 12, and 36 months matched the 2006 WHO growth references closely, but their heights were shorter at 3 years of age.[3] The rapid and compressed epidemiological transition from essentially pre-industrial conditions a few generations ago to an affluent post-industrial society may not have allowed sufficient generations for infants to realise their full genetic height potential, regardless of an optimal current environment. There is also increasing evidence that rapid infant growth is associated with metabolic disease risk.[4] Given this dilemma, we examined how the WHO criteria for an optimal nurturing environment impacted infant growth in Hong Kong Chinese children.

Methods

This study was conducted from April 2008 to July 2008 and approved by the University of Hong Kong-Hospital Authority Hong Kong West Cluster Joint Institutional Review Board and the Ethics Committee of the Department of Health. In 1997, 8327 infants born in April or May were recruited from 47 government Maternal and Child Health Centres (MCHCs) in Hong Kong. The response rate was 95%, and 88% of all births in that period were included. A self-administered questionnaire was used to collect information on demographics (household type, household size, age, and education levels of parents), birth characteristics (parity, gestational week, and delivery method), tobacco exposure (maternal smoking, second-hand smoking exposure at home and elsewhere) and the infant characteristics (sex, birth weight, birth order, and feeding method). Families were encouraged to bring their infants to the MCHCs a few days after birth and at regular intervals until the age of 6 years for vaccinations and physical examinations (weight and length). The cohort was followed up at 3, 9, and 18 months using a self-administrated questionnaire. In addition, in 2005-6 all recorded weight and length/height measurements were abstracted from the MCHCs by the unique MCHC reference number, and all admissions to public hospitals were extracted from the Hospital Authority records by the unique birth certificate number.

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Infants with growth problems or in poor health attended the MCHCs for health checks more frequently, the closest measurement within one month of the scheduled well-baby checks at 1, 3, 9, 12, 18, 24, and 36 months and the scheduled height checks at 3, 9, and 36 months was used, except for 1 and 24 or 36 months the measurements were within 15 days and 4 months, respectively. We also checked and corrected measurements for errors of transcription if the z-score changed by 1.5 or more within 90 days. Preterm births and multiple births were excluded because their growth trajectory may have differed. Infants with physical birth defects or those not of Chinese ethnicity were also excluded.

Factors considered as potentially affecting growth were the criteria mentioned in the WHO multicentre growth study for an optimal nurturing environment, ie no maternal smoking before and after delivery, no economic constraints on growth, no serious morbidity likely to impact growth, and breastfeeding (Table). Analyses were adjusted for gestational age, birth order, mother's place of birth, and sex as appropriate. To determine the contribution of these factors to weight growth at 0-36 months, a shape invariant model with random effects was used. Relative differences in birth size and growth rate were reported. Multivariable linear regression was used to examine the contribution of these factors to weight and length at 9, 12, and 36 months, expressed as z-scores relative to the 2006 WHO references. Boys and girls were analysed together unless there was evidence of effect modification, ie a significant interaction term or different effect sizes by strata.

Results

Of the 8327 infants recruited, 123 twins and 20 non-Chinese were excluded, as were 99 with birth defects, 377 with a gestational age <37 weeks, 54 with missing gestational age, and six with an unreliably long reported gestational age of over 44 weeks. In each analysis infants with insufficient measurements or missing information were excluded. Preliminary analysis revealed that most factors had similar effects in boys and girls, so boys and girls were analysed together.

As shown in the Table, 4.5% of the mothers smoked in pregnancy, 16.5% of the infants were exclusively breastfed for at least 1 month, and 1.3% of the infants had serious morbidity. The mean birth weight in boys (3.29 kg) and girls (3.18 kg) was below the WHO standard (by z-scores equivalent to 58 g in boys and 49 g in girls). Maternal education and breastfeeding were associated with faster growth. Serious morbidity had little association with growth. Infants of mothers who smoked in pregnancy were smaller at birth, but grew faster. By 9 months (n=3404) infant length was associated with parental education and tobacco smoke exposure, but not with breastfeeding or serious morbidity. Infants whose parents had grade 12 or higher levels of education had similar length as the WHO reference and were longer than infants whose parents had grade 9 or lower levels of education by a mean of 0.30 cm (difference in z-score, 0.14; 95% confidence interval (CI), 0.04-0.24). Infants of more educated parents also had higher mean body mass index by 0.15 kg/m^2 (difference in z-score, 0.10; 95% CI, 0.00-0.20) than infants of parents whose education level was grade 9 or lower. The latter also had a higher mean body mass index by 0.42 kg/m^2 (difference in z-score, 0.29; 95% CI, 0.23-0.36) than the WHO references. On average, infants whose mothers smoked in pregnancy were shorter at 9 months than infants with no pre- or post-natal tobacco smoke exposure by about 0.41 cm (difference in z-score, -0.18; 95% CI, -0.01-0.35). However, these differences in length associated

Table. Adjusted relative birth weights and growth rates at 0-36 months among 3071 boys and 2765 girls in Hong Kong

Variable	% of children	Adjusted relative birth weight* (95% CI)	Adjusted relative growth rate* (95% CI)
Father's education			
Grade 9 or below	42.2	1.00	1.00
Grade 10 to 11	34.3	1.01† (1.00-1.01)	0.98† (0.96-0.99)
Grade 12 or above	23.5	1.00 (0.99-1.01)	0.99 (0.97-1.01)
Mother's education			
Grade 9 or below	38.8	1.00	1.00
Grade 10 to 11	45.2	1.00 (1.00-1.01)	1.04† (1.02-1.05)
Grade 12 or above	16.0	1.01† (1.00-1.02)	1.05† (1.02-1.07)
Tobacco smoke exposure			
No	29.4	1.00	1.00
Second-hand smoking exposure in utero only	33.2	1.00 (1.00-1.01)	1.01 (1.00-1.02)
Second-hand smoking exposure at home after birth	32.9	1.00 (0.99-1.01)	1.01 (0.99-1.02)
Mother smoked during pregnancy	4.5	0.98† (0.96-0.99)	1.04† (1.01-1.07)
Exclusive breastfeeding‡			
No	83.5	1.00	1.00
Yes	16.5	0.99 (0.99-1.00)	1.02† (1.01-1.03)
Hospitalised for diarrhoea by 18 months			
No	98.7	1.00	1.00
Yes	1.3	0.99 (0.98-1.00)	1.02 (1.00-1.04)

* Adjusted for sex, gestational age, birth order, and mother's place of birth
† P<0.05
‡ Breastfeeding was based on the duration of exclusive breastfeeding (0-183 days) and included as a time-dependent variable, thus giving an estimate of the effect on growth for the duration of breastfeeding.

with parental education and tobacco smoke exposure were no longer evident at 36 months (n=2612). These toddlers had consistently lower height but higher body mass index values than the WHO references, regardless of parental education, tobacco exposure, breastfeeding, or serious morbidity.

Discussion

Regarding the 1997 cohort of Hong Kong Chinese infants, their birth weight was on average lower than the 2006 WHO references. Parental socio-economic position, tobacco smoke exposure, and to some extent breastfeeding were associated with different growth rates. Infants whose parents had grade 12 or higher levels of education were similar to the WHO 2006 references in terms of length at 9 months. On average, these infants had a higher body mass index than infants of less educated parents who also had a higher body mass index than the WHO references. Maternal smoking in pregnancy was associated with faster growth, but these infants were smaller at birth. Infants whose mothers smoked in pregnancy were shorter than infants without any tobacco smoke exposure at 9 months. By 36 months our toddlers were shorter and fatter than the WHO references, regardless of parental education, tobacco smoke exposure, or serious morbidity.

This study confirmed that several of the WHO criteria for an optimal nurturing environment were associated with infant growth differences. Hong Kong Chinese infants did not achieve the WHO height standards at 36 months. In infants of educated parents who achieved WHO standards of length growth at 9 months, their body mass index was higher than the WHO reference. Thus, attributes of the current environment appeared not to have contributed to the generally shorter height at 36 months. However, information on diet was not collected, so we cannot rule out the possibility that these infants and toddlers generally had a diet that was low in nutrients that specifically promote linear growth. These infants also had lower birth weights than the WHO references, which may also have been reflected in their birth length, with corresponding implications for infant length and toddler height. In well-nourished populations, maternal diet is not strongly related to birth weight. It is possible that a cultural preference for slimness in the mothers resulted in inadequate nutrition during pregnancy, which constrained the offspring's linear growth potential. Alternatively, birth weight may also reflect childhood living conditions in previous generations,[5] so another possible pathway is that these infants' linear growth was constrained by living conditions in previous generations, ie by epigenetic constraints. Finally, we cannot rule out the possibility that Hong Kong Chinese are genetically shorter, although the current strong trend in height suggests that Hong Kong Chinese have not yet reached their full genetic height potential. Given that rapid infant growth is associated with adult obesity and metabolic risk, attention should be paid to ensuring Hong Kong infants achieve appropriate linear growth without becoming overweight.

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