Original Article

The Influence of Ethnicity on Exclusively Breast-Fed Infants' Anthropometry in a Multiethnic Asian Population

James G Huang, [1]*MBBS(Hons)(S'pore), MRCPCH (Paeds)(UK)*, Shi Hua Chan, [2]*MBBS*, Le Ye Lee, [3,4]*MMed(Paeds), MRCPCH(UK)*

Abstract

Introduction: We studied the effects of ethnicity on early infant growth patterns in exclusively breast-fed (EBF) infants from a Singaporean multiethnic population. This was a prospective cohort study conducted in National University Hospital, Singapore. Materials and Methods: Healthy, EBF infants born at-term completing 37 weeks and above, and whose birthweight was appropriate for gestational age (>10th centile, <90th centile) were recruited. Infants were required to be EBF at least until the minimum age of weaning. All infants who were preterm and premature, formula-fed, required Intensive/High Dependency care, or born with major congenital anomalies were excluded. A multivariable linear regression analysis was conducted at 5 predetermined time-points (birth; 4-8 weeks; 3-4, 5-8, 12 months) to study the effects of antenatal/parental factors on infant growth. Results: A total of 213 infants were recruited. Maternal age, height and body mass index positively influenced birthweights while maternal hypertension and paternal smoking negatively influenced birthweights. Mean duration of breastfeeding was 8.9 months. Chinese ethnicity did not influence birth anthropometry, but was the single consistent factor that significantly increased weight and length Z-scores from 4-8 weeks until 8 months of life. Chinese ethnicity did not influence head growth throughout the first year of life. Conclusion: EBF Chinese infants have increased weights and lengths compared to non-Chinese infants until 8 months' age, despite similar birth anthropometry. This period of discrepant growth coincides with the average duration of breastfeeding. We hypothesise that ethnic variations in breast milk macronutrient composition influence early somatic growth in infants.

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Key words: Antenatal, Infant growth, Parental

Introduction

Exclusive breastfeeding for 6 months is a recommendation of the World Health Organization (WHO), for its benefits in reducing gastrointestinal tract infections and atopic outcomes in infants.[1] In line with this recommendation, the WHO has advocated the use of new growth curves based on anthropometric data pooled from approximately 8500 children with a wide range of ethnic backgrounds in the WHO Multicentre Growth Reference Study.[2] The new WHO growth curves aim to establish the breastfed infant as the new normative reference standard for early infant growth. Indeed, there have already been numerous prior studies focusing on the discrepancy in growth profiles between breast-fed and formula-fed infants,[3,4] with breast-fed infants generally having a lower weight-for-length than formula-fed infants between 6 to 12 months.[4] The new WHO growth curves also demonstrate that linear growth is similar across breast-fed children less than 2 years of age from 6 different study sites,[5] indicating all breast-fed children can potentially grow similarly regardless of ethnicity. However, a growing pool of literature demonstrates discrepancies between the new WHO growth curves and national growth

[1]Khoo Teck Puat-National University Children's Medical Institute, National University Health System, Singapore
[2]Yong Loo Lin School of Medicine, National University of Singapore, Singapore
[3]Department of Paediatrics, Yong Loo Lin School of Medicine, National University of Singapore, Singapore
[4]Department of Neonatology, National University Hospital, Singapore
Address for Correspondence: Dr James Huang Guoxian, Khoo Teck Puat-National University Children's Medical Institute, National University Health System Tower Block, Level 12, 1E Kent Ridge Road, Singapore 119228.
Email: james_huang@nuhs.edu.sg

standards. We aimed to study the effects of ethnicity on early infant growth patterns in exclusively breast-fed infants from an uniquely multiethnic Asian population, with the hypothesis that ethnicity does influence early growth patterns either through differing nutritional composition of breast milk from mothers,[6] or variations in maternal diet[7] and anthropometry in different ethnic groups. Current literature, however, supports that breast milk composition—at least in terms of macronutrients—stays fairly constant regardless of maternal diet,[8] hence suggesting inherent ethnic factors could influence breast milk nutritional composition and early infant growth in the predominantly breast-fed child. As earlier studies have shown that infant growth patterns have an influence on childhood obesity,[9,10] it is important that ethnicity and other epigenetic factors be evaluated as possible contributing factors to the global obesity epidemic.

Materials and Methods

This was a prospective cohort study conducted in the National University Hospital, Singapore in which we recruited healthy exclusively breast-fed infants who were born at-term completing 37 weeks and above, and whose birthweight was appropriate for gestational age (>10th centile and less than <90th centile). Infants were required to be exclusively breast-fed as the sole source of nutrition until the minimum recommended age of weaning at 4 months' age: breast milk administration was either via direct latch or bottle-fed from milk expressed. No other food, formula or drink was allowed but the child was allowed oral rehydration solution, vitamin drops and supplements as per WHO's definition. Mothers were encouraged to continue breastfeeding after weaning, and the duration of breastfeeding was recorded for analysis.

Infants were recruited from the Well Baby Clinic, and mothers were recruited from breastfeeding awareness/promotion events. The parents were consented to agree for hospital clinic visits for anthropometric measurements, feeding and neurodevelopmental assessment and/or vaccinations at 4 subsequent prespecified time-points from birth (4-8 weeks' age, 3-4 months' age, 5-8 months' age and 12 months' age) based on our local Singaporean developmental assessment and immunisation schedule by the Health Promotion Board. If the parents opted for vaccinations to be performed at the local polyclinic and their infants underwent additional anthropometric measurements, only measurements done by our local hospital clinic staff and physician were recorded for analysis in our study. The consent was obtained from the eligible mothers prior to enrolling in the study. The study approval was obtained from the National Healthcare Group Domain Specific Ethics Review Board prior to initiating the study (reference number 2012/00326).

We had excluded all preterm and premature infants, formula-fed infants, infants who required admission to the Neonatology Intensive Care Unit/High Dependency Unit, and infants born with major congenital anomalies. Baseline birth data, antenatal data (maternal prepregnancy weight, weight gain during pregnancy, maternal comorbidities), as well as parental anthropometric information (body mass index [BMI]) from both parents were collected. The age of weaning and the duration of breastfeeding beyond the point of exclusive breastfeeding were also recorded for analysis.

The infant would have his or her length, weight (naked weight without clothing) and head circumference measured and documented into his or her Child Health booklet as well as hospital medical record system at scheduled follow-up visits for routine developmental assessment and immunisations, at the hospital's Well Baby Clinic. These measurements were performed at 4 subsequent prespecified time-points from birth that were chosen (4-8 weeks' age, 3-4 months' age, 5-8 months' age and 12 months' age). All weight, length and head circumference measurements were performed at the hospital's Well Baby Clinic by a team of neonatology-trained nurses and physician. Parental anthropometric information was also measured in the same clinic by the same team of nurses for consistency. Maternal anthropometry in the prepregnancy and pregnancy phases were collated from obstetric hospital records. Infant anthropometric data was thereafter standardised as Z-scores derived from the WHO growth curves, adjusted for postnatal age and gender.

Statistical analysis was performed with STATA 13.1. A multivariable linear regression analysis was conducted at each of the 5 predetermined time-points (birth, 4-8 weeks, 3-4 months, 5-8 months, 12 months) to determine the influence of other antenatal factors and parental anthropometry on infant growth. A forward stepwise regression analysis was conducted to allow variables significant at least at $P = 0.05$ to enter the model, and at least $P = 0.10$ to remain in the final model. The purpose of stepwise regression analysis was to minimise the effects of multicollinearity as several of the predictor variables was highly intercorrelated (e.g. midparental height and maternal/paternal anthropometry). The list of factors tested for significance in the multivariable model were as follows: 1) Chinese ethnicity; 2) maternal age; 3) maternal prepregnancy weight; 4) maternal maximum weight in pregnancy; 5) maternal postpregnancy weight; 6) maternal height; 7) maternal BMI; 8) maternal smoker status; 9) multiple pregnancy; 10) maternal hypertension/pre-eclampsia; 11) maternal gestational diabetes mellitus; 12) birth order; 13) paternal weight; 14) paternal height; 15) paternal BMI; 16) paternal smoker status; 17) paternal age; 18) midparental height; 19) birthweight; 20) birth length; 21) birth head circumference; 22) duration of breastfeeding;

and 23) age of weaning to solid foods. The latter 2 predictor variables (i.e. duration of breastfeeding and age of weaning) were excluded from the multivariate analysis for anthropometric growth patterns analysed at time-points prior to the onset of weaning (birth, 3-4 weeks, 3-4 months) to prevent conclusions based on reverse causality.

A repeated measures ANOVA analysis was conducted to display the trend of infant anthropometric change across the predefined 5 time-points (birth, 4-8 weeks, 3-4 months, 5-8 months, 12 months) between the Chinese and non-Chinese infants. At each predefined time-point, we also did a 1-way ANOVA analysis with Bonferroni correction, to compare infant anthropometric profiles between the 3 main ethnic groups in Singapore (Chinese, Malay, Indian).

Results

A total of 213 infants were recruited, whose baseline characteristics and parental variables are described in Table 1. Significant factors in the multivariable regression model predicting the corresponding anthropometric Z-scores are listed in Table 2. Maternal age, height and BMI associated with higher birthweights, whereas maternal hypertension and paternal smoking had a negative association with birthweights. Maternal height was also the single consistent parental anthropometric predictor variable influencing both birthweight and length. There was no influence of Chinese ethnicity on birth anthropometry. Chinese ethnicity was the single consistent factor that significantly increased weight and length Z-scores from 4-8 weeks until 8 months of life. However, Chinese ethnicity was not associated with increased head circumference throughout the first year of life. Figures 1A, 1B and 1C respectively display the results of the graphical plot comparing the trend of serial weight, length, and head circumference Z-scores in Chinese versus non-Chinese breast-fed infants.

By 12 months' of age, birth anthropometry data were the main factors predicting all anthropometric measurements and there was no longer an effect exerted by ethnicity. There was no significant association between duration of breastfeeding and age of weaning on all infant anthropometric measurements, except for a borderline significant negative influence of a later age of weaning on infant head circumference (coefficient -0.12, $P = 0.047$) at 5-8 months' age in the latter half of the breast-fed infant's life (Table 3).

Inter-Racial Differences in Anthropometry

At the individual time-points (4-8 weeks, 3-4 months, 5-8 months), Chinese infants consistently maintain a significantly higher weight Z-scores compared to the other 2 ethnic groups (Malay/Indian), while there are no differences in terms of weight between Malay and Indian infants.

Table 1. Baseline Characteristics and Parental Variables

Infants, n = 213	
Ethnicity, no. (%)	
Chinese	100 (46.95)
Malay	21 (9.86)
Indian	77 (36.15)
Others	15 (7.04)
Gender, no. (%)	
Male	106 (49.77)
Female	107 (50.23)
Mean birthweight (SD), kg	3.2 (0.4)
Mean birth length (SD), cm	50.3 (2.1)
Mean birth head circumference (SD), cm	33.6 (1.3)
Mean duration of breastfeeding (SD), months	8.9 (4.4)
Mean age of weaning (SD), months	5.9 (1.3)
Maternal Factors	
Mean maternal age (SD), years	32.1 (3.8)
Mean maternal body mass index (SD), kg/m2	22.7 (3.6)
Mean maternal weight gain during pregnancy (SD), kg	12.8 (4.8)
Mean maternal height (SD), m	1.60 (0.06)
Median birth order (range)	1 (1 – 5)
Multiple pregnancy (%)	0.9
Maternal smoker (%)	2.4
Maternal hypertension (%)	2.4
Maternal gestational diabetes (%)	10.3
Mean duration of breastfeeding (SD), months	8.9 (4.3)
Paternal Factors	
Mean paternal age (SD), years	35.1 (4.8)
Mean paternal body mass index (SD), kg/m2	24.9 (3.7)
Paternal smoker (%)	12.9
Mean paternal height (SD), m	1.72 (0.07)
Mean mid-parental height (SD), m	1.67 (0.08)

SD: Standard deviation

In terms of length Z-scores at 4-8 weeks, Chinese infants grew taller than Malay infants (mean difference 1.19 cm, $P = 0.001$), but not significantly more than Indian infants (mean difference 0.12 cm, $P = 1.00$). Indian infants are significantly taller than Malay infants (mean difference 1.07 cm, $P = 0.005$). Chinese infants consistently maintain a longer length than Malay infants ($P < 0.001$) until the age of 1 year, but not over Indian infants. Indian infants are significantly taller than Malay infants at 2 time-points (4-8 weeks and 5-8 months) in the analysis.

Discussion

Much of earlier literature has been centred upon the anthropometric differences between breast-fed and formula-fed infants. The new WHO growth curves published out of

Table 2. Multivariable Regression Model (Stepwise Regression) Predicting the Corresponding Anthropometric Z-Scores

Time-Point of Measurement	Z-Scores	Significant Factors	Coefficient	*P* Value
Birth	Weight	Maternal height	4.60	<0.001
		Maternal current weight	0.02	0.006
		Maternal hypertension	-1.36	0.004
		Maternal age	0.03	0.033
		Paternal smoker	-0.35	0.047
	Length	Maternal maximum weight	0.02	0.006
		Maternal height	3.42	0.022
		Paternal weight	0.02	0.029
	Head circumference	Maternal age	0.05	0.022
		Maternal current weight	0.01	0.038
		Infant gender	0.34	0.021
		Birth order	0.25	0.033
4 – 8 weeks	Weight	Birthweight	1.29	<0.001
		Chinese ethnicity	0.65	<0.001
		Father's weight	0.01	0.050
	Length	Birthweight	1.49	<0.001
		Chinese ethnicity	0.28	0.041
		Father's weight	0.01	0.021
	Head circumference	Birthweight	1.25	<0.001
3 – 4 months	Weight	Birthweight	1.15	<0.001
		Chinese ethnicity	0.69	<0.001
		Father's weight	0.01	0.011
	Length	Birthweight	0.79	0.002
		Birth length	0.16	0.001
		Chinese ethnicity	0.48	0.001
	Head circumference	Birth head circumference	0.23	<0.001
		Birthweight	0.49	0.014
		Father's weight	0.01	0.008
5 – 8 months	Weight	Birthweight	0.69	0.001
		Birth length	0.09	0.019
		Chinese ethnicity	0.60	<0.001
		Maternal maximum weight during pregnancy	0.02	0.013
	Length	Birthweight	1.11	<0.001
		Birth length	0.14	0.008
		Chinese ethnicity	0.66	<0.001
	Head circumference	Birthweight	0.51	0.022
		Birth head circumference	0.16	0.026
		Maternal gestational diabetes	0.50	0.027
12 months	Weight	Birth length	0.14	0.028
		Birth head circumference	0.35	0.002
		Birth order	-0.58	0.001
	Length	Birth head circumference	0.53	0.005
		Father's height	-8.02	0.024
	Head circumference	NULL	NULL	NULL

NULL: No significant predictive factor identified

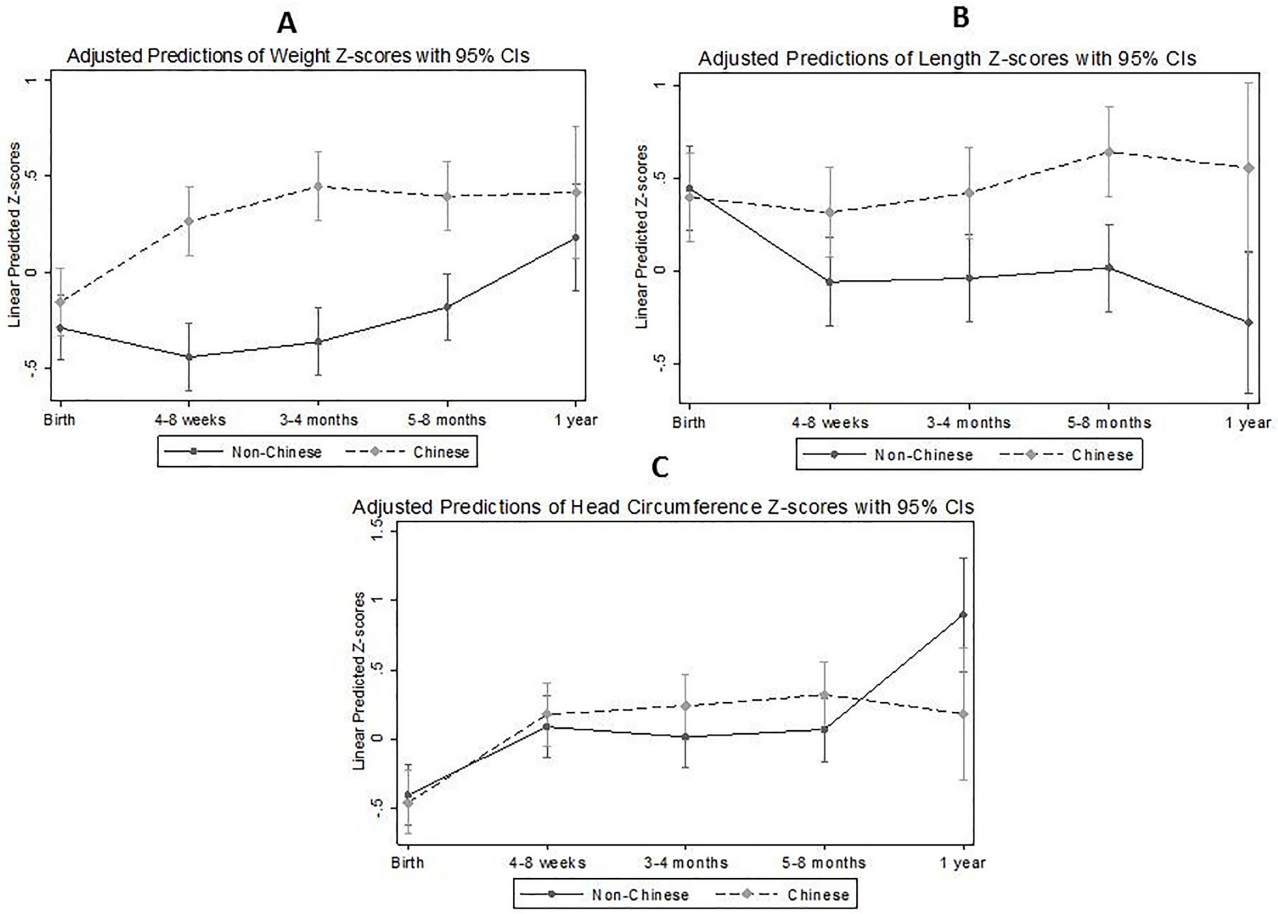

Fig. 1. Graphical plot of serial (A) weight (B) length and (C) head circumference Z-scores between Chinese and non-Chinese infants.

Table 3. Univariate and Multivariate Analysis (Without Stepwise Regression) of the Effects of Total Breastfeeding Duration and Age of Weaning on Infant Anthropometry in the Second Half of the First Year of Life

Age of Infant	Z-Scores	Total Breastfeeding Duration		Age of Weaning	
		Univariate Coefficient (*P* Value)	Multivariate Coefficient (*P* Value)	Univariate Coefficient (*P* Value)	Multivariate Coefficient (*P* Value)
5 – 8 months	Weight	-0.03 (0.038)	-0.03 (0.081)	-0.02 (0.727)	0.05 (0.381)
	Length	-0.06 (0.002)	-0.03 (0.258)	-0.11 (0.118)	-0.05 (0.488)
	Head circumference	0.01 (0.880)	0.02 (0.224)	-0.09 (0.084)	-0.12 (0.047)
12 months	Weight	-0.03 (0.413)	0.01 (0.972)	0.01 (0.977)	0.161 (0.330)
	Length	-0.05 (0.352)	-0.05 (0.588)	0.07 (0.728)	0.49 (0.100)
	Head circumference	-0.13 (0.171)	-0.08 (0.661)	-0.28 (0.386)	-0.42 (0.377)

the Multicentre Growth Reference Study aimed to establish the breast-fed infant as the ideal reference standard for anthropometric measurements. There are a considerable number of published studies concluding that infants' growth patterns have significant discrepancy between national growth standards and the WHO growth curves, e.g. Japanese children tend to be smaller on the WHO growth curves.[11] Our study is the first study studying the effects of ethnicity on serial anthropometry of exclusively breast-fed infants in a multiethnic population, and demonstrates divergent growth patterns between different ethnic groups coinciding with the mean duration of breastfeeding in our cohort. This discrepancy in growth patterns appear to taper off in the last 4 months of the infant's first year, when the majority (median duration of breastfeeding: 7.5 months) of mothers have stopped breastfeeding. This strongly suggests an

ethnic factor influencing either breast milk composition or the practice of breastfeeding to favour a discrepant growth pattern of a particular ethnic group. The setting of the study is in Singapore, a developed Southeast Asian urbanised city-state located in the tropics. Its uniform urban setting, relatively narrow socioeconomic gap and lack of seasonality make it an ideal setting to study human milk composition and breast-fed infants, as the former factors have been contributory factors[12,13] for variability in human milk composition and anthropometry of the breast-fed infant.[14,15]

Our study findings show that both Chinese breast-fed male and female infants are heavier and taller for most of the first year over their non-Chinese counterparts; these differences remained strongly significant, having adjusted for a comprehensive list of covariates such as infant gender, duration of breastfeeding, time of weaning, maternal comorbidities and parental anthropometric parameters. This lends support to the growing pool of evidence that interethnic differences in breast-fed infants may lead to discrepant growth measurements on the new WHO growth curves. A recent native Chinese study of a large cohort of exclusively breast-fed infants indicated that Chinese children had heavier weight, longer length and bigger head circumference on the new WHO growth curves.[16] A study by Júlíusson et al likewise demonstrated that the proportion of Belgian and Norwegian children classified as underweight and overweight are significantly higher on the WHO growth curves.[17] A study by Dwipoerwantoro et al on Indonesian infants—either breast-fed or formula-fed—were also noted to have lower weight-for-age and length-for-age Z-scores on the WHO growth curves, leading the authors to conclude the new growth curves may incorrectly classify infants as undernourished.[18]

Our study also noted that Chinese and non-Chinese infants begin with similar birth anthropometric indices, yet quickly display discrepant growth patterns until the age of 8 months' age to a point of non-difference at 12 months. This suggests that ethnicity did not have a sustained effect on anthropometric profiles. Considering that this tapering of the initial discrepancy in growth curves coincides with the average point of cessation of any form of breastfeeding (mean duration of breastfeeding is until 8.9 months of age), an interethnic variation in either the breastfeeding practice itself or the nutritional composition of the breast milk is hypothesised. In support of the latter hypothesis, Su and colleagues noted that the nutritional profile of breast milk differed significantly between the 3 major ethnic groups in Singapore. At the postnatal time-point of 1-2 weeks, breast milk from Indian mothers had the highest eicosatetraenoic acid (ETA) concentration while Malay mothers had the lowest; at 6-8 weeks, Indian mothers' breast milk maintained to have the highest ETA concentration while Chinese mothers had significantly higher docosahexaenoic acid (DHA). No significant differences were seen at 3 months, 6 months and 12 months but this finding could have been limited by smaller numbers of breast milk samples collected at these time-points.[6] While the role of long-chain polyunsaturated fatty acids has been primarily associated with growth of the nervous system,[19,20] we did not note any ethnic influence on head circumference in the first year (the latter measurement was influenced more by birth anthropometry).

Previous publications support the hypothesis of interethnic variations in breast milk macronutrient composition, in particular variations in breast milk fat content which could explain the discrepant growth curves between Chinese and non-Chinese exclusively breast-fed infants. Human breast milk fat content varies substantially across populations between 2.8 to 4.78 g/100 ml (Australian women:[21] 3.74 g/100 ml; Bangladeshi women:[22] 2.66 g/100 ml; Swedish women:[23] 5.69g/100 ml), whereas carbohydrate and protein content tends to vary less between populations;[23,24] A study published by Thakkar and colleagues on human breast milk fat content from a cohort of 50 predominantly Chinese Singaporean mothers (76% Chinese [38/50]; 24% non-Chinese [12/50]) demonstrated a high mean breast milk fat content varying from 4.17 +/- 0.92 g/100 ml (at 30 days of age) to 4.65 +/- 2.10 g/100 ml (at 120 days of age). The authors were however unable to perform a statistical comparison of breast milk fat content between the ethnic groups due to the low numbers of non-Chinese infants recruited.[25]

We were also able to demonstrate that parental anthropometry (either maternal or paternal height/weight) were predominant influencing factors for infant anthropometric measurements at birth (Table 2). These findings were supported by prior cohort studies.[26,27] In particular, maternal height was a consistent highly significant predictor variable on infant birthweight and length—this is explained by a taller maternal height predicting bigger pelvic dimensions and favouring a larger neonatal size to prevent obstructed labour.[27,28] Paternal smoking had a significant negative influence on infant birthweight, consistent with a prior study on environmental tobacco smoke exposure having a greater impact than maternal smoking itself.[29] Maternal smoking also remained low in prevalence (2.4% c.f. paternal smoking 12.9%). Maternal hypertension was unsurprisingly a risk factor for lower birthweights.[30] Predictor variables for birth head circumference were consistent with prior studies, namely infant gender,[31] birth order[32] and maternal weight.[33] Throughout the rest of the first year of life, birth anthropometric indices were the main predictor variables of growth patterns. Chinese ethnicity had a highly significant influence on birthweight and length until

8 months of age, but not head circumference. Breastfeeding itself has a positive influence on head growth[34,35] and the mechanisms, while not clearly elucidated, are postulated to be the micronutrients e.g. sialic acid,[36] the wide variety of hormones and growth factors favouring brain growth.[35] We hypothesise that the lack of significant influence of the Chinese ethnicity on head circumference, may be due to the minimal variance of the abovementioned micronutrient or neuronal growth factor content between breast milk from different ethnic groups in Singapore.

There were limitations within this study: we had studied a small sample size although we were able to prove a statistical difference with our recruited cohort. The strict inclusion criteria that mothers were to at least exclusively breastfeed until the age of weaning, and to not use formula supplementation throughout the period of study, limited recruitment numbers. This reflects the typical high attrition rate of exclusive breastfeeding based on prior breastfeeding surveys in Singapore.[37,38] We also did not have data on parental socioeconomic status, which could have influenced maternal breast milk nutrition, although we did analyse both parental anthropometry as a surrogate marker for parental nutritional status and we did not expect significant inter-individual nutrition variation in a nutritionally affluent society like Singapore's. It is noted that parental socioeconomic status exerts a primary influence on the initiation of breastfeeding and duration of breastfeeding[39-42] (based on prior studies), and the latter variables had been already included in our primary analysis.

We also did note a under-representation of the Malay community within our cohort. This was similar to the observed differences in breastfeeding prevalence amongst the 3 major ethnic groups in a large cohort of Singaporean women,[38] in which prevalence of any breastfeeding was 22% amongst Malay mothers (c.f. 46% in Chinese and 41% in Indian mothers). We were also not able to determine the mode of delivery of breast milk (i.e. direct breastfeeding versus expressed breastfeeding) and the actual amount of breast milk delivered to each infant. These additional factors may also potentially explain interethnic variations in infant anthropometry. Pang et al noted that ethnicity in Singapore influenced both the mode and prevalence of breastfeeding. For instance, Chinese mothers preferred to feed their infants with expressed breast milk as opposed to directly breastfeeding them.[38] Future studies to strengthen our findings would be to explore the ethnic influences on local maternal diet, childrearing and weaning practices as prior data demonstrates sociocultural and ethnic differences influence breastfeeding and complementary feeding practices.[43,44]

Conclusion

We demonstrated that there is a significantly discrepant growth pattern in terms of weight and length between exclusively breast-fed Chinese and non-Chinese infants until the age of 8 months, after which this apparent effect of ethnicity tapers off. This period of discrepant growth coincides with the average duration of breastfeeding in our cohort, leading us to hypothesise an ethnic factor influencing breast milk macronutrient content (particularly breast milk fat, or the act of breastfeeding itself). Further studies are warranted to determine the reasons for these observations in a multiracial population, particularly ethnic variations in breast milk composition and/or breastfeeding practices.

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