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Growth trajectories in infants of Chinese-born immigrant mothers compared with Australian-born mothers living in Victoria, Australia

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Title: Growth trajectories in infants of Chinese-born immigrant mothers compared with Australian-born mothers living in Victoria, Australia

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Abstract

Background: Chinese immigrants are the third largest immigrant group in Australia. Little is known about growth trajectories of their offspring when moving to a Western country. The aim was to describe the growth trajectories between birth to 3.5 years in infants of Chinese-born immigrant mothers compared with Australian-born mothers living in Victoria, Australia.

Methods: Ten nurse measured weights and lengths from birth to 3.5 years were used to examine growth trajectory using linear spline multilevel models. Five knot points were identified at visit 2 (0.5 months), visit 4 (2 months), visit 5 (4.5 months), visit 8 (18 months) and visit 9 (25 months).

Results: Ethnic disparities in growth trajectories between these two groups were revealed in models adjusted for birthweight, gender and level of socioeconomic disadvantage. Infants of Chinese-born compared with Australian-born mothers revealed different growth rates and significant differences in predicted mean zBMI at all time points from birth to 44 months, except for 12 months. Specifically, infants of Chinese-born mothers started with lower predicted zBMI from birth until 0.5 months, but then had a higher zBMI from 1-8 months and then from 12-44 months they had a lower zBMI. Early and sharp acceleration of growth was also observed for infants of Chinese-born mothers (0.5-2 months) compared to infants of Australian-born mothers (2-18 months).

Conclusion: Differences in growth trajectories exist between infants of Chinese-born and Australian-born mothers. Better understanding of these ethnically patterned growth trajectories is important for identifying key opportunities to promote healthy growth in early life.

Key words: growth trajectories, infant, ethnicity, Asian immigrants

ARTICLE SUMMARY

Strengths and limitations of this study

- Modelling growth trajectory in a large sample size with longitudinal repeat measurements from birth -3.5 years old
- Spline and know modelling methodology was utilised which allows examination of zBMI trajectories across childhood whilst taking into account the different number of visits and measurements over time
- Spline and knot modelling methodology allows trajectories to be simplified for easy comparison across populations
- The model was adjusted for key covariates such as child sex, birth weight, and level of socioeconomic disadvantage; however maternal age was not included due to the amount of missing data on this variable
- Whilst the data was drawn from one local government area in Victoria, Australia; which has a high prevalence of Chinese immigrants, these findings may not be generalisable to the wider population

INTRODUCTION

Childhood obesity has serious health consequences [1] and can track into adult life. [2] In 2017-18 in Australia, 24.6% of children aged 2-4 years old were classified as overweight or obese. [3] The first 1000 days of a child's life have been emphasised to be crucial in developing a child's potential health and development over the life course. [4 5] Monitoring growth of infants can therefore support healthy growth and development of children. [6] Infant growth trajectories can give an indication of subsequent risk of poor health later in life. [7] Proposed determinants of growth trajectories and subsequent overweight and obesity include maternal smoking, pre-pregnancy maternal body mass index (BMI), socioeconomic status, ethnicity and infant feeding practices (e.g. early introduction of solids, introduction of infant formula). [5 8 9]

Australia is a multicultural country, with 29% of inhabitants born overseas. [10] In 2018, Chinese immigrants in Australia comprised 2.6% of the total population and were the second largest immigrant group in Australia. [10] Ethnic background has been demonstrated to be an important risk factor for overweight and obesity in Australian primary school aged children with Asian, North African, Middle Eastern, Southern, South Eastern and Eastern European backgrounds. [11-13] Using language spoken most at home to categorise cultural groups; a higher proportion of Asian primary-school aged children were classified as overweight/obese compared to English-speaking children (27.6% compared to 22.4%, respectively). [13] In another Victorian study, 34.8% of Eastern Asian primary school aged children were found to be overweight/obese (Scott 2018, under review) which is much higher than the national average of 25.2% children aged 8-11 years old who were classified as overweight/obese. [3] It is important to understand what might drive the differences in overweight and obesity prevalence in early life.

Maternal Child and Health (MCH) nurses are key providers of regular and free child and family wellness checks [14] in Victoria Australia. Rapid growth is a well-established risk factor for childhood obesity in the first six months of life. [15-17] There is currently no information on longitudinal growth trajectories of infants of Chinese-born immigrants living in Australia. Understanding growth trajectories may help health practitioners to identify children at the highest risk for later overweight and obesity. [18]

The aim of this study was to compare zBMI growth trajectories from birth to 3.5 years in infants of Chinese-born and Australian-born mothers residing in Australia. This information will inform optimal targeting of interventions aiming to promote heathy growth in this immigrant population and subsequently reduce their risk of overweight and obesity later in life.

METHODS

Patient and public involvement

Patients were not involved in the design, conduct, reporting or dissemination of this study.

Study setting and participants

Victoria's universal Maternal and Child Health Service provides ten contacts from birth until school age (birth, 2, 4, 8 weeks; 4, 8, 12, 18, 24, 42 months (3.5 years)) to assess child growth and development; with a focus on child and family wellbeing. [19] All data collected at each visit were imputed by the MCH nurse into an electronic database.

The longitudinal data in the current study was de-identified and exported from 16 MCH centres located in a local government area in Victoria with a high proportion of Chinese-born immigrants (making up 7% of the local population). [20] Data related to all infants of Chinese-born mothers; along with a random subsample of Australian-born infants was extracted by the custodian of the database. Country of birth for mothers was used to determine ethnicity. Mothers were categorised as "Chinese-born" if they were born in mainland China. Special Administration Regions such as Hong Kong, Macau, Wolong; and Taiwan Province were excluded. [21]

Maternal and child demographic factors

Demographic information collected from the primary caregiver included mother/infant date of birth, mother/infant country of birth, postcode, marital status of mother, current smoking status of mothers, infant Indigenous status, gestational age, infant gender and birth delivery method (vaginal, caesarean, other). Postcode was used to determine the level of socioeconomic disadvantage using socio-economic indexes for areas (SEIFA). [22] The level of socioeconomic disadvantage was examined by quintile, however due to low sample size, quintiles were recoded into dichotomous categories based upon the spread of the data; “low/medium” (quintiles 1-4) and “high” (quintile 5).

Anthropometric measures

At each of the 10 visits described above, the MCH nurse collected the age of the infant at the current visit; measured the child’s weight, length/height, head circumference; and noted medical history if applicable (e.g. immunisation status). Length was measured (to 0.1cm) in recumbent position on a measuring mat until 2 years of age, there after the child was measured standing upright using a portable stadiometer. Z-scores (zBMI) were calculated using the WHO macro in STATA and the WHO growth standards. [23]

Statistical analyses

For a flow chart of the sample, refer to Supplementary Figure 1. A total of 2226 singleton infants and mothers were included in the analysis (1082 infants of Chinese-born mothers, hereon referred to as Chinese-born; 1144 infants of Australian-born mothers, hereon referred to as Australian-born). Cases were excluded if there was a premature delivery (<37 weeks); the mother was born in regions other than mainland China (e.g. Hong Kong); if the child was of low birth weight of <2500g; no zBMI measurement and age difference between measurement occasions were zero or negative. This resulted in a total of 1864 infants and their mothers (930 Chinese-born and 934 Australian born) with complete data on child gender, birth weight and socioeconomic disadvantage.

Descriptive statistics (means and standard deviations), or proportions) were used to summarise data for Chinese-born and Australian-born mothers and their infants. Differences between ethnic groups (Chinese versus Australian-born) were tested using Chi-square tests or t-tests. To model the longitudinal zBMI growth trajectory in the current study from birth to 3.5 years, linear spline multilevel models were used to construct a series of linear splines joined at knot points, where the direction or the magnitude of growth changed. [24] This method allows true shapes of growth trajectories to be modelled and overcomes limitations of traditional methods to examine growth trajectory which include collinearity of repeated measures, measurement requirements (i.e. all individuals being the same age when measured, all individuals having complete measurements), bias from missing data, clustering and difficulty with the interpretation of growth coefficients. [24]

To identify the knot points, both fractional polynomials and lowess curve were used to identify the best fitting curve, from which five knot points where the direction or magnitude/slope of the growth changed were identified at: visit 2 (2 weeks/0.5 months), visit 4 (2 months), visit 5 (4.5 months), visit 8 (18 months) and visit 9 (25 months). This resulted in six splines (growth periods): birth to 0.5 months, 0.5-2 months, 2-4.5 months, 4.5-18 months, 18-25 months, and 15-44 months. The basic model included repeated measures of zBMI as the dependent variable; six splines as fixed effects; six splines as a level 1 random effect (accounting for correlation between measures) and maternal child health centre as a level 2 random effect (accounting for clustering) with an unstructured covariance structure. The intercept and coefficient (slope) of each spline of the fixed part represent zBMI at birth and growth rates for that growth period. Comparison of average observed and predicted zBMI at each time point from the spline model were similar indicating a good model fit (data not shown).

To explore whether the growth trajectory differed by being an infant of Chinese- or Australian-born mothers, ethnicity was analysed as the principal fixed effect. The interaction between ethnicity and splines were fitted, and the coefficient of each spline represented the mean difference in growth rates between infants of Chinese- and Australian-born mothers in that growth period. The effects of the following covariates on zBMI trajectory were also tested: Indigenous status, child gender, gestational age, birth weight, maternal marital status, delivery method, level of socioeconomic disadvantage (SEIFA), and smoking status. Separate models were performed to examine effects of these variables on zBMI trajectory. Variables significantly associated with zBMI trajectory were included as confounders in the multivariable model and included: child sex, birth weight, and level of socioeconomic disadvantage. Overall two growth trajectory models were constructed, one unadjusted, one adjusted for confounding variables. Given the similarity in results, only the adjusted models are presented. All analyses were conducted using Stata 14.0 (StataCorp, College Station, TX, USA) with significance set at $p<0.05$.

Ethical approval

Approval for this study was provided by the Deakin University Human Research Ethics Committee (2014-184). The local government area who was the custodian of the database provided written permission for analysis of the fully deidentified data.

RESULTS

Sample characteristics

Child and maternal sample characteristics are presented in Table 1. Compared to Australian born mothers; Chinese-born mothers were younger; experienced more socioeconomic disadvantage; a higher proportion were married; and a lower proportion were currently smoking. There were almost twice as many high birth weight infants of Australian-born mothers. There were no significant differences between infants according to gestational age at birth, gender, Indigenous status nor birthing delivery method

Table 1: Demographic characteristics of Chinese-born and Australian-born mothers, their infants living in Australia

	Chinese (n=930)		Australian (n=934)		
	n	**Mean (SD) or %**	**n**	**Mean (SD) or %**	**p value**
Infant characteristics					
Gestational age	919	39.4 (1.1)	921	39.5 (1.2)	ns
Birth weight					
Normal birth weight (<4kg)	864	92.9	802	86.0	<0.001
High birth weight (≥4kg)	66	7.1	131	14.0	
Indigenous status					
Yes	4	0.4	7	0.7	ns

No	910	99.6	901	99.3	
Gender					
Boys	465	50.0	459	49.2	ns
Girls	465	50.0	474	50.8	
Maternal characteristics					
Age	775	31.4 (4.5)	804	33.3 (4.5)	<0.001
Marital status					
Married	746	95.0	678	83.3	<0.001
Other	39	5.0	136	16.7	
Delivery method					
Vaginal	477	51.3	504	54.0	ns
Caesarean	297	31.9	288	30.9	
Other	156	16.8	141	15.1	
Level of socioeconomic disadvantage					
Low/medium	429	46.0	309	33.2	<0.001
High	501	54.0	624	66.8	
Smoking status					
Yes	2	0.2	17	2.1	<0.001
No	816	99.8	780	97.9	

Note: level of disadvantage calculated using SEIFA and postcode; ns: not significant

Ethnic differences in growth trajectories

The growth rates in each growth period of infants of Chinese-born and Australian-born mothers living in Australia is presented in Table 2. With adjustment for child birth weight, sex, and socioeconomic disadvantage, the growth rate was significantly different at all time points between infants of Chinese- and Australian-born mothers except for 2-4 months and 25-44 months. Compared with infants of Australian-born mothers, the growth rates for infants of Chinese-born mothers were significantly higher between 0-2 months; significantly lower between 4-18 months and then significantly higher again between 18-25 months. There was no significant difference in growth rates between groups at age 2-4 months, nor 25-44 months.

Table 2. Comparison of growth rates between infants of Chinese-born and Australian-born mothers living in Australia from multilevel spline model

	Chinese			Australian			Chinese vs Australian		
Period (months)	Mean zBMI	95%CI		Mean zBMI	95%CI		Adjusted mean difference	95%CI	
0-0.5m	-0.39	-0.50	-0.79	-0.79	-0.90	-0.68	0.40*	0.25	0.56
0.5-2m	0.30	0.26	-0.17	-0.17	-0.21	-0.14	0.47*	0.42	0.52
2-4m	-0.001	-0.02	0.02	0.02	0.004	0.04	-0.02	-0.05	0.002
4-18m	-0.004	-0.01	0.06	0.06	0.06	0.06	-0.06*	-0.07	-0.06
18-25m	-0.004	-0.01	-0.03	-0.03	-0.04	-0.02	0.03*	0.01	0.04
25-44m	0.005	0.0002	0.003	0.003	-0.0001	0.01	0.001	-0.004	0.01

Model adjusted child birth weight, sex, level of socioeconomic disadvantage. m: month. Values indicate the slope of the trajectory in each growth period in zBMI units. *P<0.05

The distinct differences in growth trajectories are represented in Figure 1, whereby infants of Chinese-born mothers experience a short deceleration at 0.5 months, then a sharp acceleration and period of rapid growth until 2 months. This period of accelerated growth occurs much earlier when compared with infants of Australian-born mothers who don't begin accelerated growth until 2-4 months. The accelerated growth period of infants of Chinese-born mothers is also steeper and spans across 1.5 months, whereby the accelerated growth period of infants of Australian-born mothers is slower, spanning 2-18 months. Infants of Chinese-born mothers have a higher predicted zBMI until ~12 months, subsequently infants of Australian-born mothers have a higher predicted zBMI over time.

Insert Figure 1 here

The predicted zBMI at each visit and the mean difference between Chinese vs Australian which constitute the growth curve are displayed in Table 3. The predicted mean zBMI is significantly different (either higher or lower) between infants of Chinese-born and Australian-born mothers at all time points except for 12 months. The result at 12 months is consistent with the growth trajectory in Figure 1, whereby the trajectories of the groups overlapped at this time point. Compared with infants of Australian-born mothers, infants of Chinese-born started with lower predicted zBMI from birth until 0.5 months, but then had a higher zBMI from 1-8 months. From 12-44 months infants of Chinese-born mothers had a lower zBMI compared with their Australian counterparts.

Table 3. Comparison of predicted zBMI between Australian versus Chinese children from multilevel spline model with adjustment for child birth weight, sex, level of socioeconomic disadvantage.

	Chinese			Australian			Chinese vs Australian		
	Mean zBMI	95%CI		Mean zBMI	95%CI		Adjusted mean difference	95%CI	
Birth	0.04	0.02	0.06	0.38	0.36	0.40	-0.33*	-0.38	-0.29
0.5m	-0.16	-0.18	-0.15	-0.03	-0.05	-0.01	-0.13*	-0.18	-0.08
1m	-0.02	-0.04	0.00	-0.12	-0.14	-0.10	0.10*	0.05	0.15
2m	0.26	0.24	0.28	-0.28	-0.30	-0.26	0.54*	0.49	0.59
5m	0.26	0.24	0.28	-0.22	-0.24	-0.20	0.47*	0.42	0.53
8m	0.24	0.22	0.26	-0.02	-0.03	0.004	0.26*	0.20	0.31
12m	0.23	0.20	0.25	0.24	0.22	0.26	-0.01	-0.06	0.04
18m	0.20	0.18	0.22	0.60	0.58	0.62	-0.40*	-0.46	-0.35
25m	0.18	0.16	0.21	0.41	0.39	0.43	-0.23*	-0.29	-0.16
44m	0.30	0.26	0.34	0.49	0.46	0.52	-0.19*	-0.29	-0.09

m: month. *P<0.05

DISCUSSION

This is the first known study to compare growth trajectories from birth to 3.5 years of age in infants of Chinese-born compared with Australian-born mothers living in Victoria, Australia. This study reveals distinct ethnic differences in growth trajectories between infants of Chinese-born compared with Australian-born mothers. In particular, infants of Chinese-born mothers started with lower predicted zBMI from birth until 0.5 months, but then had a higher zBMI from 1-8 months and then from 12-44 months they had a lower predicted zBMI. Early and sharp acceleration of growth was also observed for infants of Chinese-born mothers (0.5-2 months) compared to a slower, longer acceleration of growth in infants of Australian-born mothers (2-18 months).

There are a number of possible explanations for the ethnic disparities in growth reported in the current study. It is possible that the lower zBMI from birth to 0.5 months in infants of Chinese-born immigrants is due to genetic factors. Anthropometric examination of 2,695 full-term infants in British Columbia, Canada revealed that Chinese and South Asian infants (i.e. Indian, Pakistani, Bangladeshi) were smaller than Western counterparts. [25] Recently, a narrative review also reported differences in foetal growth, birthweight, post-natal growth and body composition in Asian compared to Caucasian infants; and between Asian countries (e.g. China, India, Hong Kong) and acknowledge the need to conduct longitudinal studies to understand more about influences on growth in the pre-pregnancy (e.g. maternal weight), pregnancy (e.g. diet, maternal weight gain) and post-natal (e.g. feeding practices) stages. [26]

The reported differences in growth trajectory by ethnicity in this study may also question the suitability of applying the WHO growth reference charts for infants of Chinese immigrants. For example, deviations from WHO growth standards have been reported for Hong Kong Chinese infants and Chinese infants who were shorter and lighter compared to WHO growth standards at different time points. [26] Disparities from WHO growth standards have also been shown in adults (regardless of gender) [27] and school-aged children. [28] Yang et.al also [29] reported differences in Chinese growth charts compared to WHO regarding undernutrition and obesity in a sample of children (n= 15,886) indicating that differences could be due to sampling differences with children used to create the charts, differences in feeding criteria (i.e. mixed feeding in Chinese growth charts, exclusive breastfeeding in WHO), and inclusion criteria for birth weight (low birth weight was excluded from Chinese growth charts and may change weight distribution). However the WHO Multicentre Growth Reference Study found that variation in site (i.e. country) only accounted for 3% of variation therefore race/genetic factors may not be the key factor driving differences in growth.[29] Despite this, the WHO growth standards are considered valuable to promote healthy growth [29] and these charts have been acknowledged as valuable for comparison amongst countries and regions. [27] Future research to examine WHO growth standards and local growth charts to identify distinct differences among ethnicity [29] and the implications for practice is required. [27]

The higher zBMI in infants of Chinese-born mothers from 1-8 months may reflect cultural differences in feeding practices. Sociocultural factors, individual knowledge, beliefs and attitudes will influence a mother's infant feeding practices [30] which will influence infant growth. A common Chinese cultural belief is that a plump baby is a healthy baby [31 32] and social norms equate a heavy baby to high levels of parenting quality and competence. [28] These cultural beliefs may encourage feeding practices that increase the risk of childhood overweight and obesity such as use of formula [33] and nonresponsive feeding practices. [34] Breastfeeding, formula feeding and complementary feeding practices are complex to unpick and it can be difficult to isolate which feeding component is most influential on growth trajectory.[35] A cross-sectional analysis of a national database revealed that disparities in early feeding practices exist in infants of Chinese-born compared to Australian-born mothers living in Australia. [36] The key differences in feeding practices in infants of Chinese-born mothers include a higher proportion currently being breastfed; but of concern were obesity promoting behaviours such as being exposed to infant formula, water-based drinks (e.g. cordial, soft drink) and fruit juice at a younger age. [36] Furthermore, qualitative interviews with Chinese-born mothers have revealed the need to build support in feeding practices (i.e. building confidence to breastfeed exclusively, dealing with grandparental pressure to formula feed, how to approach returning to work) and perceptions of healthy growth. [30] Cultural understanding by health professionals of the influences on a mother's feeding practices and their effect on growth trajectory during infancy is required. Culturally tailored strategies to support healthy growth which take into account cultural beliefs, attitudes, practices should also be implemented by health professionals. This could include increasing access to face-to-face and online support from health professionals who are familiar with Chinese language and culture. [30] Additional longitudinal research examining these factors, and the risk for developing overweight and obesity in this minority population is required.

The finding of a lower zBMI in infants of Chinese-born mothers from 12-44 months compared to Australian counterparts could be due to cultural differences in diets. A recent study has revealed Chinese immigrants living in

Australia eat significantly more vegetables and fruits per day; and less meat and cheese per week; compared to their Australian-born counterparts. [37] Infants of Chinese immigrants in France have also been shown to consume significantly less dairy products compared to their French counterparts; along with eating less energy (kcal) per day at 1-3 years, and 4-6 years old. [38] Therefore, infants of Chinese heritage may have a diet composed of a higher proportion of vegetables and plant sources, rather than a typical Australian diet that tends to be higher in meat and protein and energy dense foods and beverages; and this may influence growth trajectory.

Given that Asian populations have an increased risk of developing metabolic diseases at a having a lower BMI (due to the higher proportion of total and central adiposity compared to white populations)[39], it is important for health professionals to track growth, feeding behaviours and other predictors (e.g. level of disadvantage) over time to identify children who may be a risk of overweight and obesity later in life. [18] Monitoring of growth in early childhood is required to understand how children grow, what factors might explain differences in growth[40] and what the risk of childhood overweight and obesity might be. It is also important to understand that ethnic minority groups are not homogenous; and language, beliefs, heritage within particular ethnic groups need to be considered.[41] The current study has highlighted early accelerated growth in Chinese-born mothers in this sample population. Rapid growth is a significant risk factor for later obesity,[9] therefore a deeper understanding of the factors influencing growth patterns in these ethnic groups in order to intervene early is required. Longitudinal studies into later childhood and adulthood to track zBMI and related health outcomes long term is also recommended.

The strengths of this study include modelling growth trajectory in a large sample size with repeat measurements. [40 42] The modelling approach (spline and knot methodology) has the strength of allowing examination of trajectories of zBMI across childhood whilst taking into account the different number of visits and measurements of infants over time. [42] This approach also allows the trajectories to be simplified, with a good fit between actual and predicted values[42] and summarises the growth trajectories so they can be easily compared across populations.[24] Another key strength of this study was the large sample size for specifically Chinese ethnic groups without having to aggregate this cultural group into “Asians”; and obtain a deeper understanding of the specific ethnic disparities in growth.[43] However, we also acknowledge several limitations. Infants in this study were assigned to mother’s self-reported ethnicity only[40] and the father's self-reported ethnicity was largely missing. The repeat measurement data was drawn from one local government area in Victoria, which may not be generalizable to the wider population.[40] Low birth weight infants were excluded, however it has been suggested that universal low birth weight of <2500g may not be applicable to Asian infants who are born with a lighter birth weight; and may overestimate the proportion classified as such.[26] Other covariates such as maternal age could not be included in the model due the amount of missing data. Data on infant feeding measures (e.g. breastfeeding, formula feeding, mixed feeding and timing of the introductions of solids) would be beneficial to further explore the differences in growth patterns by ethnicity.

CONCLUSION

Ethnic disparities in growth trajectories between infants of Chinese-born compared to Australian-born mothers living in Victoria were revealed in models adjusted for birthweight, gender and level of socioeconomic disadvantage. A clearer understanding of these ethnically patterned growth trajectories is important for identifying key opportunities to promote healthy infant feeding and growth in early life in different ethnic groups, particularly for Chinese immigrants. Strategies to promote optimal growth will need to consider sociocultural factors. Further research is required to examine ethnic differences in growth into early childhood, and the risk of adiposity and other long term health outcomes.

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CONTRIBUTORS

KC conceived the study. KB obtained access to the data, supported data analysis and led the primary writing of the manuscript. MZ conducted the analysis of the data. All authors contributed to interpretation of the findings and the development of the manuscript.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL

Approval for this study was provided by the Deakin University Human Research Ethics Committee (2014-184). The local government area who was the custodian of the database provided written permission for analysis of the fully deidentified data.

DATA AVAILABILITY STATEMENT

Data may be obtained from a third party and are not publicly available. De-identified data was obtained by specific request to a local government area of Victoria. As we are not the custodian of the data, we cannot grant sharing of this data.

What is already known about this topic:

- Chinese immigrants are the third largest immigrant group in Australia
- Growth trajectories can indicate risk of overweight, obesity and disease risk later in life
- Growth trajectories of infants of Chinese-born immigrants living in Australia is unknown

What this study adds:

- This is the first known comparison of growth trajectories from birth to 3.5 years in infants of Chinese-born compared with Australian-born mothers living in Australia
- Ethnic disparities in growth trajectories between infants of Chinese-born and Australian-born mothers were revealed in models adjusted for birthweight, gender and level of socioeconomic disadvantage
- Early, sharp accelerated growth was observed for infants of Chinese-born mothers (0.5-2 months) compared to a longer acceleration in infants of Australian-born mothers (2-18 months)

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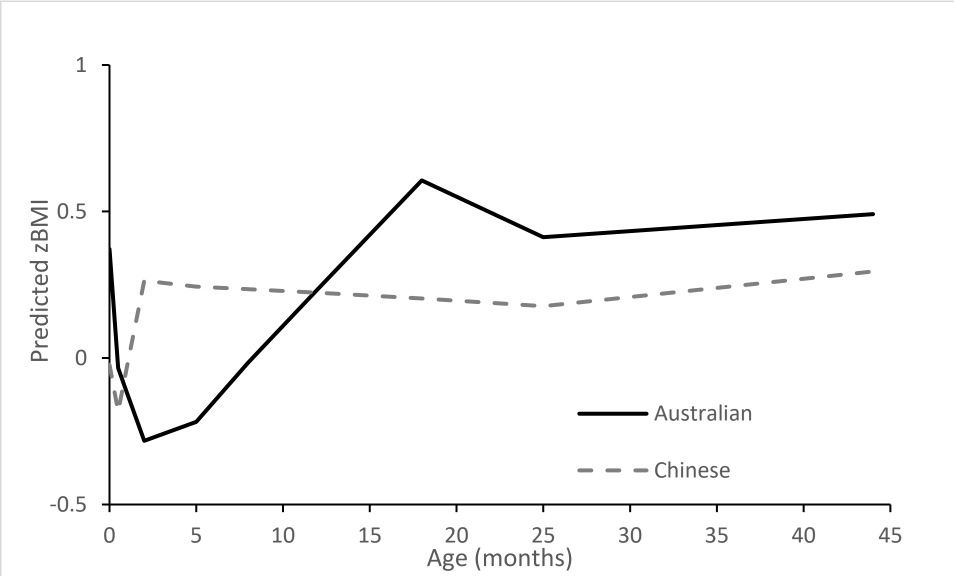
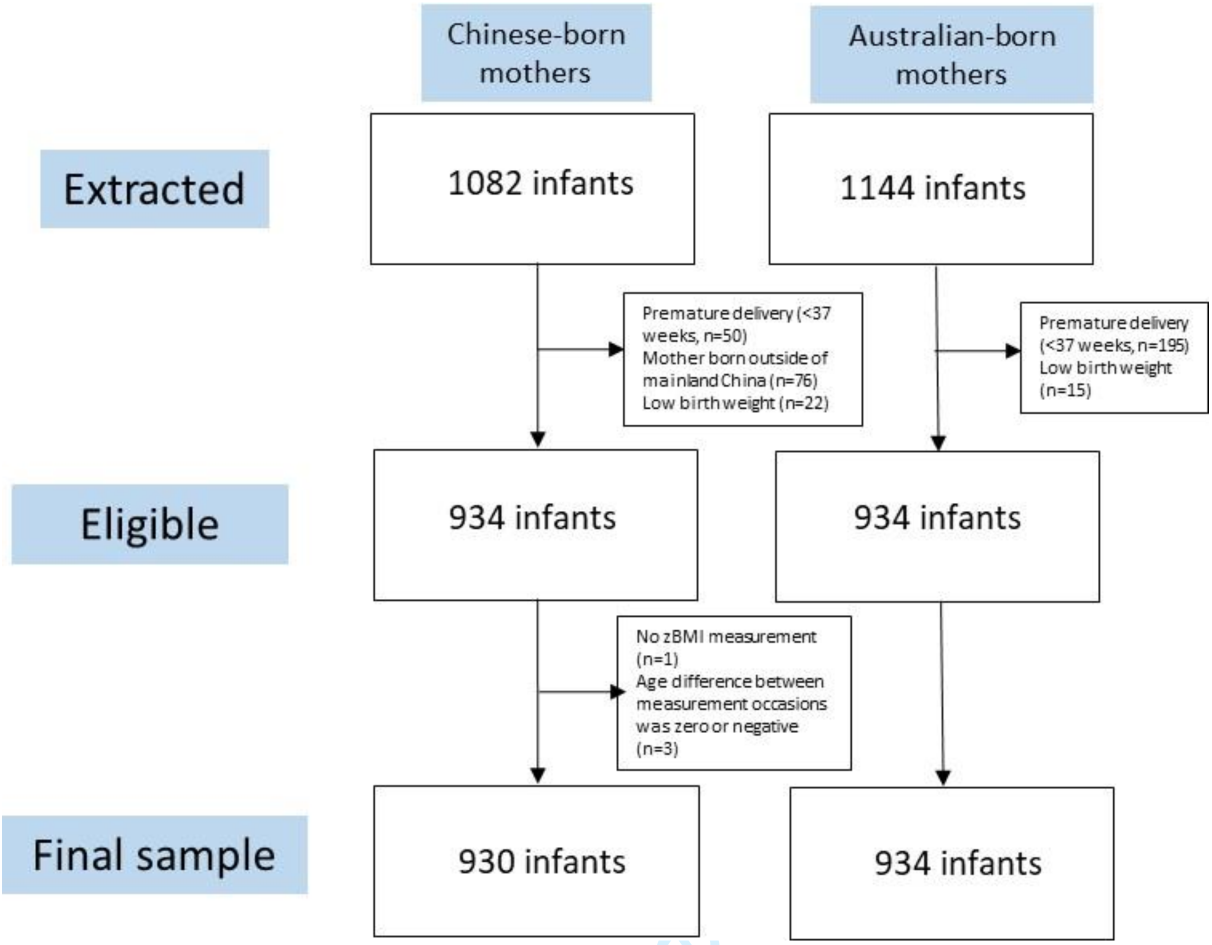


Figure 1: Average predicted zBMI trajectory by ethnicity from multilevel spline model with adjustment for child sex, birth weight, level of socioeconomic disadvantage.

Supplementary Figure 1: Flow chart on sample used in study



STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Content under: *Study setting and participants; Maternal and child demographic factors* Page 5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Content under *Maternal and child demographic factors* Page 5 and *Anthropometric measures* page 6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Content under: *Study setting and participant* page 5, *Maternal and child demographic factors* Page 5; *Anthropometric measures* page 6
Bias	9	Describe any efforts to address potential sources of bias	Content under *Statistical analysis* page 6
Study size	10	Explain how the study size was arrived at	*Study setting and participant* page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4 paragraphs in the methods section

			detailing this, page 5-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4 paragraphs in the methods section detailing this, page 6-7
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8, Table 1 Suppl.Figure 1
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table 2 Table 3 Figure 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2 Table 3 Figure 1
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	See methods pg. 7
Discussion			
Key results	18	Summarise key results with reference to study objectives	Paragraph 1, page 11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Paragraph 6, pg 13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 11-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	Paragraph 6, pg 14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Funding, pg 15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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A longitudinal analysis of growth trajectories in young children of Chinese-born immigrant mothers compared with Australian-born mothers living in Victoria, Australia

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Title: A longitudinal analysis of growth trajectories in young children of Chinese-born immigrant mothers compared with Australian-born mothers living in Victoria, Australia

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Abstract

Background: Chinese immigrants are the third largest immigrant group in Australia. Little is known about growth trajectories of their offspring when moving to a Western country. The aim was to describe the growth trajectories between birth to 3.5 years in children of Chinese-born immigrant mothers compared with Australian-born mothers living in Victoria, Australia.

Methods: Ten nurse measured weights and lengths from birth to 3.5 years were used to examine growth trajectory using linear spline multilevel models. Five knot points were identified at visit 2 (0.5 months), visit 4 (2 months), visit 5 (4.5 months), visit 8 (18 months) and visit 9 (25 months).

Results: Ethnic disparities in growth trajectories between these two groups were revealed in models adjusted for birthweight, sex and level of socioeconomic disadvantage. Children of Chinese-born compared with Australian-born mothers revealed different growth rates and significant differences in predicted mean zBMI at all time points from birth to 44 months, except for 12 months. Specifically, when compared to children of Australian-born mothers, children of Chinese-born mothers started with lower predicted zBMI from birth until 0.5 months, had a higher zBMI from 1-8 months and a lower zBMI from12-44 months. Early and sharp acceleration of growth was also observed for children of Chinese-born mothers (0.5-2 months) when compared to children of Australian-born mothers (2-18 months).

Conclusion: Differences in growth trajectories exist between young children of Chinese-born and Australian-born mothers. Better understanding of these ethnically patterned growth trajectories is important for identifying key opportunities to promote healthy growth in early life.

Key words: growth trajectories, infant, ethnicity, Asian immigrants, children

ARTICLE SUMMARY

Strengths and limitations of this study

- Modelling growth trajectory in a large sample size with longitudinal repeated measurements from birth - 3.5 years old
- Linear spline multilevel modelling methodology was utilised which allows examination of zBMI trajectories across childhood whilst taking into account the different number of visits and measurements over time
- Spline and knot modelling methodology allows trajectories to be simplified for easy comparison across populations
- The model was adjusted for key covariates such as child sex, indigenous status, gestational age, maternal marital and smoking status, delivery methodand level of socioeconomic disadvantage; however maternal age was not included due to the amount of missing data on this variable
- Whilst the data was drawn from one local government area in Victoria, Australia; which has a high prevalence of Chinese immigrants, these findings may not be generalisable to the wider population

INTRODUCTION

[illegible] both

Childhood obesity has serious health consequences [1] and can track into adult life. [2] In 2017-18 in Australia, 24.6% of children aged 2-4 years old were classified as overweight or obese. [3] The first 1000 days of a child's life have been emphasised to be crucial in developing a child's potential health and development over the life course. [4 5] Monitoring growth of infants can therefore support healthy growth and development of children. [6] Infant growth trajectories can give an indication of subsequent risk of poor health later in life. [7] Proposed determinants of growth trajectories and subsequent overweight and obesity include maternal smoking, pre-pregnancy maternal body mass index (BMI), socioeconomic status, ethnicity and infant feeding practices (e.g. early introduction of solids, introduction of infant formula). [5 8 9]

Australia is a multicultural country, with 29% of inhabitants born overseas. [10] In 2018, Chinese immigrants in Australia comprised 2.6% of the total population and were the second largest immigrant group in Australia. [10] Ethnic background has been demonstrated to be an important risk factor for overweight and obesity in Australian primary school aged children with Asian, North African, Middle Eastern, Southern, South Eastern and Eastern European backgrounds. [11-13] Using language spoken most at home to categorise cultural groups; a higher proportion of Asian primary-school aged children were classified as overweight/obese compared to English-speaking children (27.6% compared to 22.4%, respectively). [13] In another Victorian study, 34.8% of Eastern Asian primary school aged children were found to be overweight/obese[14] which is much higher than the national average of 25.2% children aged 8-11 years old who were classified as overweight/obese. [3] It is important to understand what might drive these differences in overweight and obesity prevalence in early life.

Maternal Child and Health (MCH) nurses are key providers of regular and free child and family wellness checks [15] in Victoria Australia. Given the importance of healthy growth for all development, these nurses measure height and weight at each of 10 scheduled visits between birth and 3 years enabling tracking of both failure to thrive and unexpected rapid growth a well-established risk factor for childhood obesity in the first six months of life. [16-18] There is currently no information on longitudinal growth trajectories of infants or young children of Chinese-born immigrants living in Australia. Understanding growth trajectories may help health practitioners to identify children at the highest risk for later overweight and obesity. [19]

The aim of this study was to compare zBMI growth trajectories from birth to 3.5 years in young children of Chinese-born and Australian-born mothers residing in Australia. This information will inform optimal targeting of interventions aiming to promote heathy growth in this potentially at risk immigrant population.

METHODS

Patient and public involvement

Patients were not involved in the design, conduct, reporting or dissemination of this study.

Study setting and participants

Victoria's universal Maternal and Child Health Service provides ten contacts from birth until school age (birth, 2, 4, 8 weeks; 4, 8, 12, 18, 24, 42 months (3.5 years)) to assess child growth and development; with a focus on child and family wellbeing. [20] All data collected at each visit were entered by the MCH nurse into an electronic database.

The longitudinal data in the current study was de-identified and exported from 16 MCH centres located in a local government area in Victoria with a high proportion of Chinese-born immigrants (making up 7% of the local population). [21] Data related to all children of Chinese-born mothers; along with a random subsample of Australian-born children was extracted by the custodian of the database. Country of birth for mothers was used to determine ethnicity. Mothers were categorised as "Chinese-born" if they were born in mainland China. Special Administration Regions such as Hong Kong, Macau, Wolong; and Taiwan Province were excluded. [22]

Maternal and child demographic factors

Demographic information collected from the primary caregiver included mother/child date of birth, mother/child country of birth, postcode, marital status of mother, current smoking status of mothers, child Indigenous status, gestational age, child sex and birth delivery method (vaginal, caesarean, other). Postcode was used to determine the level of socioeconomic disadvantage using socio-economic indexes for areas (SEIFA). [23] The level of socioeconomic disadvantage was examined by quintile, however due to low sample size, quintiles were recoded into dichotomous categories based upon the spread of the data; "low/medium" (quintiles 1-4) and "high" (quintile 5).

Anthropometric measures

At each of the 10 visits described above, the MCH nurse collected the age of the child at the current visit; measured the child's weight, length/height, head circumference; and noted medical history if applicable (e.g. immunisation status). Length was measured (to 0.1cm) in recumbent position on a measuring mat until 2 years of age, there after the child was measured standing upright using a portable stadiometer. Z-scores (zBMI) were calculated using the WHO macro in STATA and the WHO growth standards. [24] For details regarding the number of visits, mean age, weight, height, zBMI of the ten time points by ethnicity; refer to Supplementary File 1.

Statistical analyses

For a flow chart of the sample, refer to Supplementary Figure 1. A total of 2226 singleton children and mothers were included in the analysis (1082 children of Chinese-born mothers, hereon referred to as Chinese-born; 1144 children of Australian-born mothers, hereon referred to as Australian-born). Cases were excluded if there was a premature delivery (<37 weeks); the mother was born in regions other than mainland China (e.g. Hong Kong); if the child was of low birth weight of <2500g as evidence suggests low birth weight babies may have increased risk of poorer development and illness and may grow differently;[25] no zBMI measurement and age difference between measurement occasions were zero or negative. This resulted in a total of 1864 children and their mothers (930 Chinese-born and 934 Australian-born) with complete data on child sex, birth weight and socioeconomic disadvantage.

Descriptive statistics (means, standard deviations, proportions) were used to summarise data for Chinese-born and Australian-born mothers and their children. Differences between ethnic groups (Chinese- versus Australian-born) were tested using Chi-square tests or t-tests. To model the longitudinal zBMI growth trajectory in the current study from birth to 3.5 years, linear spline multilevel models were used to construct a series of linear splines joined at knot points, where the direction or the magnitude of growth changed. [26] This method allows true shapes of growth trajectories to be modelled and overcomes limitations of traditional methods to examine growth trajectory which include collinearity of repeated measures, measurement requirements (i.e. all individuals being the same age when measured, all individuals having complete measurements), bias from missing data, clustering and difficulty with the interpretation of growth coefficients. [26] This method has been utilised in other published studies to examine growth trajectories in early childhood, and also by ethnic subgroups.[26-29]

To identify the knot points, both fractional polynomials and lowess curves were used to identify the best fitting curve, from which five knot points, where the direction or magnitude/slope of the growth changed, were identified at: visit 2 (2 weeks/0.5 months), visit 4 (2 months), visit 5 (4.5 months), visit 8 (18 months) and visit 9 (25 months). This resulted in six splines (growth periods): birth to 0.5 months, 0.5-2 months, 2-4.5 months, 4.5-18 months, 18-25 months, and 15-44 months. The basic model included repeated measures of zBMI as the dependent variable; six splines as fixed effects; six splines as a level 1 random effect (accounting for correlation between measures) and maternal child health centre as a level 2 random effect (accounting for clustering) with an unstructured covariance structure. The intercept and coefficient (slope) of each spline of the fixed part represent zBMI at birth and growth rates for that growth period. Comparison of average observed and predicted zBMI at each time point from the spline model were similar indicating a good model fit (refer to Supplementary File 1 for model fit information).

To explore whether the growth trajectory differed by being a child of Chinese- or Australian-born mothers, ethnicity was analysed as the principal fixed effect. The interaction between ethnicity and splines were fitted, and the coefficient of each spline represented the mean difference in growth rates between children of Chinese- and Australian-born mothers in that growth period. Overall two growth trajectory models were constructed, one unadjusted, one adjusted for covariates. The following covariates were considered: Indigenous status, child sex, gestational age, maternal marital status, delivery method, level of socioeconomic disadvantage (SEIFA), and smoking status. Pearson correlation revealed no significant relationships among these covariates, they were simultaneously included in the model as covariates.

Multiple imputation by chained equation with 10 datasets was used to impute missing covariates. The percentage missing on these covariates were 1 to 15%. Estimates from ten imputed datasets were combined using the 'mi estimate' command. Given the similarity in results, only the adjusted models are presented. All analyses were conducted using Stata 14.0 (StataCorp, College Station, TX, USA) with significance set at p<0.05.

Ethical approval

Approval for this study was provided by the Deakin University Human Research Ethics Committee (2014-184). The local government area who was the custodian of the database provided written permission for analysis of the fully deidentified data.

RESULTS

Sample characteristics

Child and maternal sample characteristics are presented in Table 1. Compared to Australian-born mothers; Chinese-born mothers were younger; experienced more socioeconomic disadvantage; a higher proportion were married; and a lower proportion were currently smoking. Birthweight was significantly lower in children of Chinese-born mothers and there were almost twice as many high birth weight children of Australian-born mothers. There were no significant differences between infants according to gestational age at birth, sex, Indigenous status nor birthing delivery method.

Table 1: Demographic characteristics of Chinese-born and Australian-born mothers, their children living in Australia

	Chinese (n=930)	**Australian (n=934)**

	n	Mean (SD) or %	n	Mean (SD) or %	p value
Child characteristics					
Gestational age	919	39.4 (1.1)	921	39.5 (1.2)	ns
Birth weight					
Birth weight (kg)	930	3.4 (0.4)	933	3.5 (0.4)	<0.001
Normal birth weight (<4kg)	864	92.9	802	86.0	<0.001
High birth weight (≥4kg)	66	7.1	131	14.0	
Indigenous status					
Yes	4	0.4	7	0.7	ns
No	910	99.6	901	99.3	
Sex					
Boys	465	50.0	459	49.2	ns
Girls	465	50.0	474	50.8	
Maternal characteristics					
Age	775	31.4 (4.5)	804	33.3 (4.5)	<0.001
Marital status					
Married	746	95.0	678	83.3	<0.001
Other	39	5.0	136	16.7	
Delivery method					
Vaginal	477	51.3	504	54.0	ns
Caesarean	297	31.9	288	30.9	
Other	156	16.8	141	15.1	
Level of socioeconomic disadvantage					
Low/medium	429	46.0	309	33.2	<0.001
High	501	54.0	624	66.8	
Smoking status					
Yes	2	0.2	17	2.1	<0.001
No	816	99.8	780	97.9	

Note: level of disadvantage calculated using SEIFA and postcode; ns: not significant

Ethnic differences in growth trajectories

The growth rates in each growth period of children of Chinese-born and Australian-born mothers living in Australia is presented in Table 2. With adjustment for child birth weight, sex, and socioeconomic disadvantage, the growth rate was significantly different at all time points between children of Chinese- and Australian-born mothers except for 2-4 months and 25-44 months. Compared with children of Australian-born mothers, the growth rates for children of Chinese-born mothers were significantly higher between 0-2 months; significantly lower between 4-18 months and then significantly higher again between 18-25 months. There was no significant difference in growth rates between groups at age 2-4 months, nor 25-44 months.

Table 2. Comparison of growth rates between children of Chinese-born and Australian-born mothers living in Australia from multilevel spline model

Period (months)	Chinese			Australian			Chinese vs Australian		
	Growth rate	95%CI		Growth rate	95%CI		Adjusted mean difference	95%CI	
0-0.5m	-0.41	-0.53	-0.29	-0.77	-0.90	-0.68	0.36*	0.19	0.54
0.5-2m	0.29	0.25	0.33	-0.16	-0.21	-0.14	0.45*	0.39	0.51
2-4m	-0.0002	-0.02	0.02	0.02	0.00	0.04	-0.02	-0.05	0.01
4-18m	-0.01	-0.01	0.0001	0.06	0.06	0.06	-0.06*	-0.07	-0.06
18-25m	-0.004	-0.01	0.01	-0.03	-0.04	-0.02	0.03*	0.01	0.04
25-44m	0.006	0.00	0.01	0.003	0.00	0.01	0.003	0.00	0.01

Model adjusted for Indigenous status, child sex, gestational age, maternal marital status, delivery method, level of socioeconomic disadvantage (SEIFA), and smoking status m: month. Values indicate the growth rate (slope) of the trajectory in each growth period (zBMI unit per month). *P<0.05

The distinct differences in growth trajectories are represented in Figure 1, whereby children of Chinese-born mothers experience a short deceleration at 0.5 months, then a sharp acceleration and period of rapid growth until 2 months. This period of accelerated growth occurs much earlier when compared with children of Australian-born mothers who don't begin accelerated growth until 2-4 months. The accelerated growth period of children of Chinese-born mothers is also steeper and spans across 1.5 months, whereby the accelerated growth period of children of Australian-born mothers is slower, spanning 2-18 months. Children of Chinese-born mothers have a higher predicted zBMI until ~12 months, subsequently children of Australian-born mothers have a higher predicted zBMI over time.

Insert Figure 1 here

The predicted zBMI at each visit and the mean difference between Chinese vs Australian which constitute the growth curve are displayed in Table 3. The predicted mean zBMI is significantly different (either higher or lower) between children of Chinese-born and Australian-born mothers at all time points except for 12 months. The result at 12 months is consistent with the growth trajectory in Figure 1, whereby the trajectories of the groups overlapped at this time point. Compared with children of Australian-born mothers, children of Chinese-born started with lower predicted zBMI from birth until 0.5 months, but then had a higher zBMI from 1-8 months. From 12-44 months children of Chinese-born mothers had a lower zBMI compared with their Australian counterparts.

Table 3. Comparison of predicted zBMI between Australian versus Chinese children from multilevel spline model with adjustment for covariates

	Chinese			Australian			Chinese vs Australian		
	Mean zBMI	**95%CI**		**Mean zBMI**	**95%CI**		**Adjusted mean difference**	**95%CI**	
Birth	0.05	0.04	0.07	0.37	0.36	0.38	-0.31*	-0.35	-0.28
0.5m	-0.16	-0.17	-0.15	-0.03	-0.05	-0.02	-0.13*	-0.16	-0.10
1m	-0.02	-0.03	-0.01	-0.11	-0.12	-0.10	0.09*	0.05	0.12
2m	0.26	0.25	0.27	-0.26	-0.27	-0.25	0.51*	0.48	0.55

5m	0.26	0.24	0.27	-0.20	-0.22	-0.19	0.46*	0.43	0.49
8m	0.24	0.23	0.25	-0.01	-0.02	0.00	0.25*	0.21	0.28
12m	0.22	0.20	0.23	0.24	0.23	0.25	-0.02	-0.05	0.01
18m	0.19	0.17	0.20	0.60	0.59	0.62	-0.41*	-0.45	-0.38
25m	0.17	0.16	0.19	0.41	0.39	0.42	-0.24*	-0.28	-0.20
44m	0.28	0.25	0.31	0.47	0.45	0.49	-0.19*	-0.26	-0.13

Model adjusted for Indigenous status, child sex, gestational age, ~~birth weight,~~ maternal marital status, delivery method, level of socioeconomic disadvantage (SEIFA), and smoking status m: month. *P<0.05

DISCUSSION

This is the first known study to compare growth trajectories from birth to 3.5 years of age in children of Chinese-born compared with Australian-born mothers living in Victoria, Australia. This study reveals distinct ethnic differences in growth trajectories between children of Chinese-born compared with Australian-born mothers. In particular, children of Chinese-born mothers started with lower predicted zBMI from birth until 0.5 months, but then had a higher zBMI from 1-8 months and then from 12-44 months they had a lower predicted zBMI. Early and sharp acceleration of growth was also observed for children of Chinese-born mothers (0.5-2 months) compared to a slower, longer acceleration of growth in children of Australian-born mothers (2-18 months).

There are a number of possible explanations for the ethnic disparities in growth reported in the current study. It is possible that the lower zBMI from birth to 0.5 months in children of Chinese-born immigrants is due to genetic factors. Anthropometric examination of 2,695 full-term infants at birth in British Columbia, Canada revealed that Chinese and South Asian infants (i.e. Indian, Pakistani, Bangladeshi) were smaller than Western counterparts. [30] Recently, a narrative review also reported differences in foetal growth, birthweight, post-natal growth and body composition in Asian compared to Caucasian infants; and between Asian countries (e.g. China, India, Hong Kong) and acknowledge the need to conduct longitudinal studies to understand more about influences on growth in the pre-pregnancy (e.g. maternal weight), pregnancy (e.g. diet, maternal weight gain) and post-natal (e.g. feeding practices) stages. [31]

The reported differences in growth trajectory by ethnicity in this study may also question the suitability of applying the WHO growth reference charts for children of Chinese immigrants. For example, deviations from WHO growth standards have been reported for Hong Kong Chinese infants and Chinese infants who were shorter and lighter compared to WHO growth standards at different time points. [31] Disparities from WHO growth standards have also been shown in adults (regardless of gender) [32] and school-aged children. [33] Yang et.al also [34] reported differences in Chinese growth charts compared to WHO regarding undernutrition and obesity in a sample of children (n= 15,886) indicating that differences could be due to sampling differences with children used to create the charts, differences in feeding criteria (i.e. mixed feeding in Chinese growth charts, exclusive breastfeeding in WHO), and inclusion criteria for birth weight (low birth weight was excluded from Chinese growth charts and may change weight distribution). However the WHO Multicentre Growth Reference Study found that variation in site (i.e. country) only accounted for 3% of variation therefore race/genetic factors may not be the key factor driving differences in growth.[34] Despite this, the WHO growth standards are considered valuable to promote healthy growth [34] and these charts have been acknowledged as valuable for comparison amongst countries and regions. [32] Future research to examine WHO growth standards and local growth charts to identify distinct differences among ethnicity [34] and the implications for practice is required. [32]

The higher zBMI in children of Chinese-born mothers from 1-8 months may reflect cultural differences in feeding practices. Sociocultural factors, individual knowledge, beliefs and attitudes will influence a mother's infant feeding practices [35] which will influence child growth. A common Chinese cultural belief is that a plump baby is a healthy baby [36 37] and social norms equate a heavy baby to high levels of parenting quality and competence. [33] These cultural beliefs may encourage feeding practices that increase the risk of childhood overweight and obesity such as use of formula [38] and nonresponsive feeding practices. [39] The Chinese-born immigrant infant feeding and growth hypothesis proposes that infant of Chinese-born mothers will be exposed to less breastfeeding, more infant formula feeding and earlier introduction of solids – ultimately increasing protein intake.[38] This higher protein intake in excess of requirements (Early Protein Hypothesis) [40 41] may result in rapid growth trajectory and an increased risk of the infant being overweight and or obese. [38] Recent studies have highlighted the use of formula in this Chinese subgroup – with 90% of Chinese-born mothers introducing formula to their infants, with the average age of introduction of formula being one month of age; Chinese-born mothers being twice more likely to use formula, and to introduce it earlier compared to Australian-born counterparts;[42] and more recently 55% of Chinese-born mothers to introduce formula in the first month of age (regardless of whether they breastfed).[43]

Breastfeeding, formula feeding and complementary feeding practices are complex to unpick and it can be difficult to isolate which feeding component is most influential on growth trajectory.[44] A cross-sectional analysis of a national database revealed that disparities in early feeding practices exist in infants of Chinese-born compared to Australian-born mothers living in Australia. [42] The key differences in feeding practices in infants of Chinese-born mothers include a higher proportion currently being breastfed; but of concern were obesity promoting behaviours such as being exposed to infant formula, water-based drinks (e.g. cordial, soft drink) and fruit juice at a younger age. [42]

Furthermore, qualitative interviews with Chinese-born mothers have revealed the need to build support in feeding practices (i.e. building confidence to breastfeed exclusively, dealing with grandparental pressure to formula feed, how to approach returning to work) and perceptions of healthy growth. [35] The first three days postpartum have been recently highlighted as a vulnerable period for formula supplementation; and breast feeding control (mother's self-efficacy for breastfeeding) to predict exclusive breastfeeding. Cultural understanding by health professionals of the influences on a mother's feeding practices and their effect on growth trajectory during infancy is required. For example, health professionals can play a role in supporting breast feeding intentions, self-efficacy and awareness of the Australian infant feeding guidelines. A recent qualitative study in 11 first time Chinese mothers in Australia also revealed the importance of integrating breastfeeding with motherhood identity which motivated mothers and built self-efficacy in breastfeeding, allowing greater persistence through breastfeeding challenges.[45] Family members can also influence infant feeding practices in Chinese mothers.[35 45] Culturally tailored strategies to support healthy growth which take into account cultural beliefs, attitudes, practices should be implemented by health professionals. This could include increasing access to face-to-face and online support from health professionals who are familiar with Chinese language and culture. [35] It could also include strengthening family relationships and support for mothers throughout the perinatal period by educating spouses and grandmothers on breastfeeding.[45] Awareness of, and how to access support services such as lactation and mental health services is also required.[45] Additional longitudinal research examining these factors, and the risk for developing overweight and obesity in this minority population is required.

The finding of a lower zBMI in children of Chinese-born mothers from 12-44 months compared to Australian counterparts could be due to cultural differences in diets. A recent study has revealed Chinese immigrants living in Australia eat significantly more vegetables and fruits per day; and less meat and cheese per week; compared to their Australian-born counterparts.[46] Young children of Chinese immigrants in France have also been shown to consume significantly less dairy products compared to their French counterparts; along with eating less energy (kcal) per day at 1-3 years, and 4-6 years old.[47] Therefore, young children of Chinese heritage may have a diet composed of a higher proportion of vegetables and plant sources, rather than a typical Australian diet that tends to be higher in meat and protein and energy dense foods and beverages; and this may influence growth trajectory.

Given that Asian populations have an increased risk of developing metabolic diseases at a lower BMI (due to the higher proportion of total and central adiposity compared to white populations)[48], it is important for health professionals to track growth, feeding behaviours and other predictors (e.g. level of disadvantage) over time to identify children who may be a risk of overweight and obesity later in life.[19] Monitoring of growth in early childhood is required to understand how children grow, what factors might explain differences in growth[29] and what the risk of childhood overweight and obesity might be. It is also important to understand that ethnic minority groups are not homogenous; and language, beliefs, heritage within particular ethnic groups need to be considered.[49] The current study has highlighted early accelerated growth in Chinese-born mothers in this sample population. Rapid growth is a significant risk factor for later obesity,[9] therefore a deeper understanding of the factors influencing growth patterns in these ethnic groups in order to intervene early is required. Longitudinal studies into later childhood and adulthood to track zBMI and related health outcomes long term is also recommended.

The strengths of this study include modelling growth trajectory in a large sample size with repeat measurements. [29,50] The modelling approach (spline and knot methodology) has the strength of allowing examination of trajectories of zBMI across childhood whilst taking into account the different number of visits and measurements of children over time. [50] This approach also allows the trajectories to be simplified, with a good fit between actual and predicted values[50] and summarises the growth trajectories so they can be easily compared across populations.[26] Another key strength of this study was the large sample size for specifically Chinese ethnic groups without having to aggregate this cultural group into “Asians”; and obtain a deeper understanding of the specific ethnic disparities in growth.[51] However, we also acknowledge several limitations. Children in this study were assigned to mother’s self-reported ethnicity only[29] and the father’s self-reported ethnicity was largely missing. The repeat measurement data was drawn from one local government area in Victoria, which may not be generalizable to the wider population.[29] Future studies should explore growth trajectories in a larger population drawn from the national population. Child anthropometry was measured objectively by different MCH nurses, however MCH nurses are highly trained and follow consistent measurement procedures. Low birth weight infants were excluded, however it has been suggested that universal low birth weight of <2500g may not be applicable to Asian children who are born with a lighter birth weight; and may overestimate the proportion classified as such.[31] Other covariates such as maternal age could not be included in the model due the amount of missing data. Maternal BMI was not collected. Whilst zBMI is a useful screening tool, assumptions about body composition and adiposity are limited using zBMI. Further research examining weight-for-age and length-for-age over time may also shed light on differences in growth trajectories. Data on child feeding measures (e.g. breastfeeding, formula feeding, mixed feeding and timing of the introductions of solids) would be beneficial to further explore the differences in growth patterns by ethnicity.

CONCLUSION

Ethnic disparities in growth trajectories between young children of Chinese-born compared to Australian-born mothers living in Victoria were revealed in models adjusted for birthweight, sex and level of socioeconomic disadvantage. A clearer understanding of these ethnically patterned growth trajectories is important for identifying key opportunities to promote healthy feeding and growth in early life in children of different ethnic groups, particularly for Chinese immigrants. Strategies to promote optimal growth will need to consider sociocultural factors. Further research is required to examine ethnic differences in growth into early childhood, and the risk of adiposity and other long term health outcomes.

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CONTRIBUTORS

KJC conceived the study. KJC and KAB obtained access to the data. KAB supported data analysis and led the primary writing of the manuscript. MZ conducted the analysis of the data. KAB, PK, RL, KJC and MZ all contributed to interpretation of the findings and the development of the manuscript.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ETHICAL APPROVAL

Approval for this study was provided by the Deakin University Human Research Ethics Committee (2014-184). The local government area who was the custodian of the database provided written permission for analysis of the fully deidentified data.

DATA AVAILABILITY STATEMENT

Data may be obtained from a third party and are not publicly available. De-identified data was obtained by specific request to a local government area of Victoria. As we are not the custodian of the data, we cannot grant sharing of this data.

What is already known about this topic:

- Chinese immigrants are the third largest immigrant group in Australia
- Growth trajectories can indicate risk of overweight, obesity and disease risk later in life
- Growth trajectories of children of Chinese-born immigrants living in Australia is unknown

What this study adds:

- This is the first known comparison of growth trajectories from birth to 3.5 years in children of Chinese-born compared with Australian-born mothers living in Australia
- Ethnic disparities in growth trajectories between children of Chinese-born and Australian-born mothers were revealed in models adjusted for birthweight, sex and level of socioeconomic disadvantage
- Early, sharp accelerated growth was observed for children of Chinese-born mothers (0.5-2 months) compared to a longer acceleration in infants of Australian-born mothers (2-18 months)

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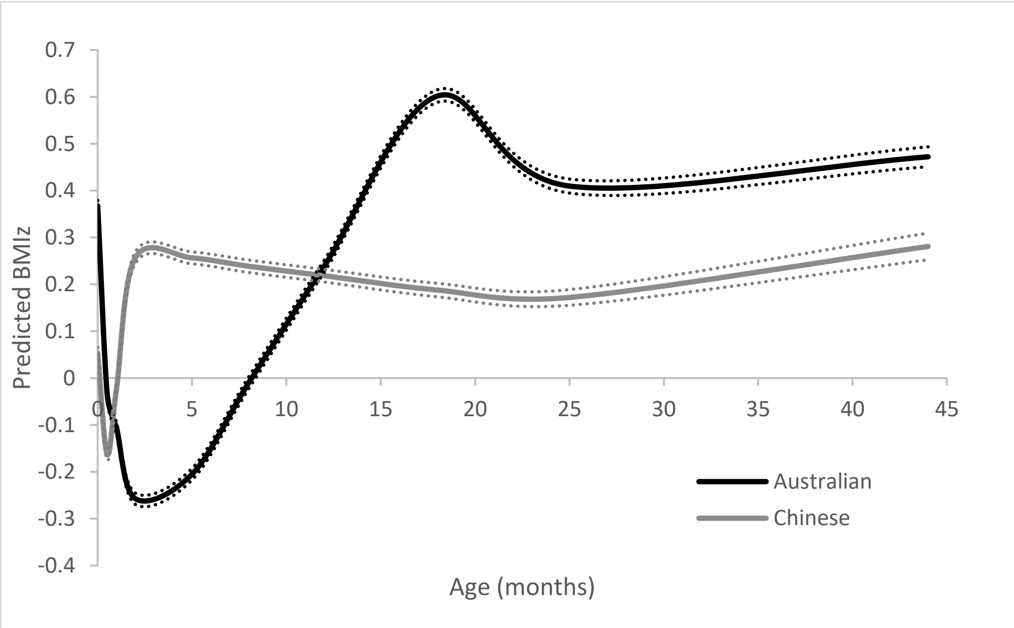
Figure caption

Figure 1: Average predicted zBMI trajectory by ethnicity from multilevel spline model with adjustment for covariates

Figure legend

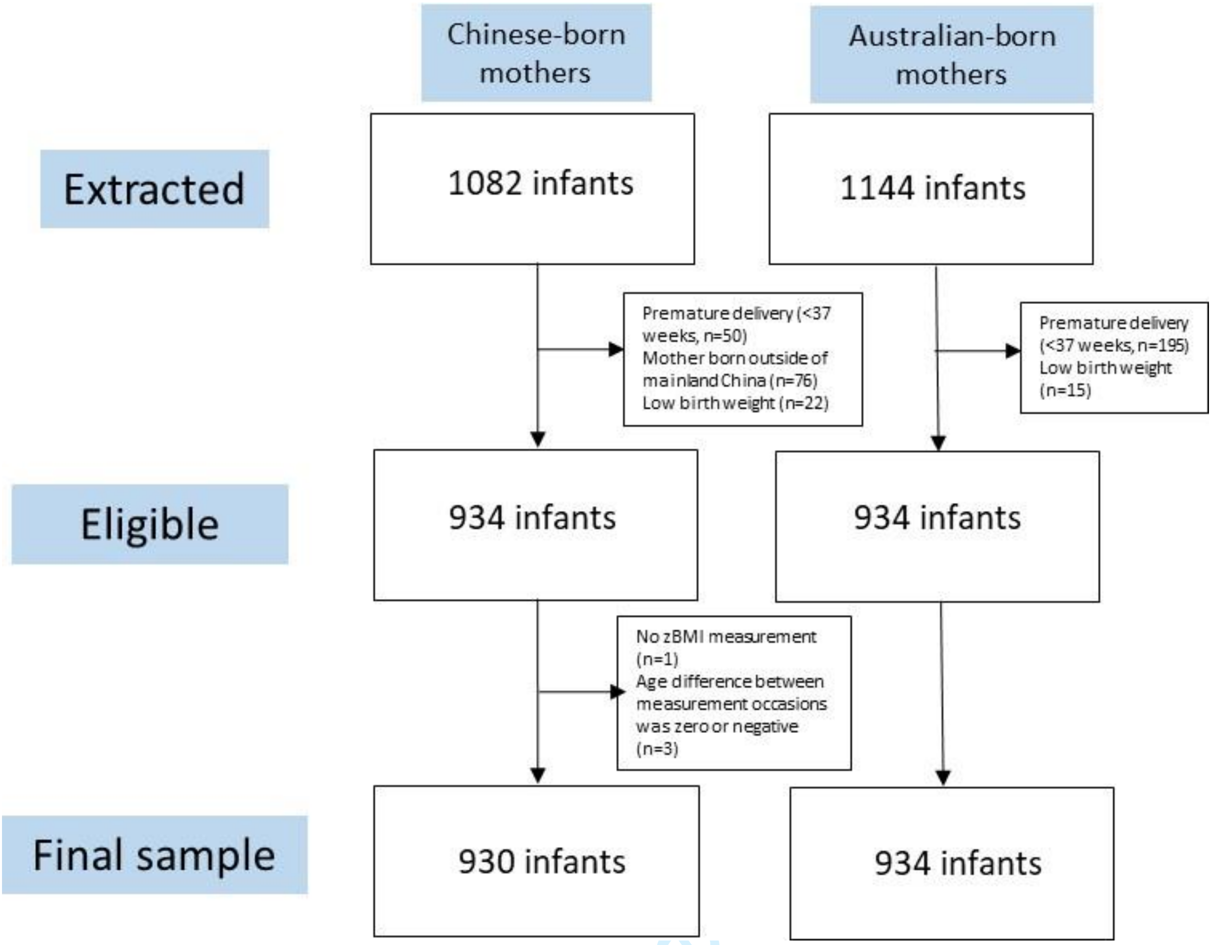
Model adjusted for child sex, Indigenous status, gestational age, marital status, delivery method, smoking status, level of socioeconomic disadvantage. Dotted lines are 95%CI.

Figure 1: Average predicted zBMI trajectory by ethnicity from multilevel spline model with adjustment for covariates



Model adjusted for child sex, Indigenous status, gestational age, marital status, delivery method, smoking status, level of socioeconomic disadvantage. Dotted lines are 95%CI.

Supplementary Figure 1: Flow chart on sample used in study



Comparison of predicted zbmi with observed zbmi (without adjustment for covariates)

Variable	Mean
occ1	
Observed	0.2086425
Predicted	0.209714
occ2	
Observed	-0.101197
Predicted	-0.096614
occ3	
Observed	-0.043072
Predicted	-0.069322
occ4	
Observed	-0.011793
Predicted	-0.017073
occ5	
Observed	0.0019412
Predicted	0.0104354
occ6	
Observed	0.1131697
Predicted	0.110819
occ7	
Observed	0.2743041
Predicted	0.2352158
occ8	
Observed	0.3946953
Predicted	0.4190389
occ9	
Observed	0.3109904
Predicted	0.308776
occ10	
Observed	0.3917944
Predicted	0.3968195

Std. Dev.
1.035767
0
0.860479
0.059064
0.851252
0.060021
0.945789
0.062781
1.016129
0.062017
0.932578
0.064933
0.918348
0.064639
0.892657
0.067522
0.970479
0.076902
0.876338
0.078665

Observed zBMI (mean+/-SD) by ethnicity

Australian					
Observed Mean	0.379977	-0.00967	-0.1233629	-0.26108	-0.28466
Observed SD	1.022225	0.879043	0.8897417	0.945071	0.96647
chinese					
Observed Mean	0.037542	-0.20766	0.0390395	0.240203	0.307542
Observed SD	1.020498	0.825905	0.8014898	0.877332	0.977037

0.050578	0.325542	0.533728	0.413059	0.471836
0.925623	0.910637	0.869838	0.973539	0.86189
0.183285	0.214319	0.235207	0.185517	0.250095
0.93435	0.923365	0.892298	0.952802	0.884166

Number of BMIz/visits by ethnicity

Chinese

numocc	Freq.
1	4
2	14
3	20
4	40
5	53
6	75
7	133
8	217
9	250
10	124
Total	930

Australian

numocc	Freq.
1	3
2	8
3	11
4	19
5	35
6	45
7	72
8	171
9	293
10	276
Total	933

Mean age, weight, height, zbmi of the ten time points

Variable	Obs	Mean	Std. Dev.	Min	Max
agemo1	1868	0	0	0	0
agemo2	1825	0.521673	0.101873	0.262839	1.379906
agemo3	1825	1.002443	0.123173	0.624243	1.774165
agemo4	1803	1.960939	0.192903	0.952792	3.416911
agemo5	1718	4.687989	0.542687	2.956942	7.195226
agemo6	1617	8.074319	0.58684	5.815319	11.20352
agemo7	1565	12.27149	0.625418	10.51357	17.08455
agemo8	1416	18.47839	0.869638	14.88328	23.68839
agemo9	1169	24.80121	1.418262	21.81566	37.15891
agemo10	580	44.01752	1.526461	38.17741	51.31937

Variable	Obs	Mean	Std. Dev.	Min	Max
weight1	1772	3.441378	0.443821	2.5	5.55
weight2	1657	3.74538	0.477283	2.4	5.855
weight3	1786	4.374936	0.529175	2.975	6.355
weight4	1783	5.379862	0.681251	3.22	8.435
weight5	1703	7.194056	0.939571	4.63	11.31
weight6	1612	8.573535	1.004722	5.83	12.68
weight7	1555	9.786886	1.099306	6.71	14.4
weight8	1396	11.26762	1.250243	7.78	15.6
weight9	1153	12.62936	1.424476	8.61	19.2
weight10	575	16.36439	1.896913	10.85	23

Variable	Obs	Mean	Std. Dev.	Min	Max
height1	1772	50.05703	2.093673	38.4	59
height2	1657	52.41147	1.931184	46.5	61
height3	1786	54.44367	1.971795	48	61.5
height4	1783	57.85048	2.144256	51	64.5
height5	1703	64.78585	2.540678	55.8	73.5
height6	1612	70.37339	2.623116	62	80.5
height7	1555	75.80071	2.745138	66.7	85
height8	1396	82.56791	3.045006	73.5	94
height9	1153	88.05759	3.334728	77	99
height10	575	101.2346	4.149762	86.5	115.5

Variable	Mean	Std. Dev.	Min	Max	
zbmi1	1772	0.207794	1.035332	-3.45	5.8
zbmi2	1657	-0.10156	0.860226	-4.16	3.61
zbmi3	1786	-0.04289	0.85081	-3.22	3.23
zbmi4	1783	-0.01142	0.945552	-4.28	3.51
zbmi5	1703	0.002572	1.015441	-4.08	3.3
zbmi6	1612	0.113474	0.931841	-3.12	3.4

zbmi7	1555	0.273042	0.918053	-2.8	3.96
zbmi8	1396	0.39409	0.892623	-2.28	4.4
zbmi9	1153	0.310043	0.970427	-2.99	3.64
zbmi10	575	0.390852	0.875866	-2.16	3.27

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Content under: *Study setting and participants; Maternal and child demographic factors* Page 5-6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Content under *Maternal and child demographic factors* Page 6 and *Anthropometric measures* page 6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Content under: *Study setting and participant* page 5, *Maternal and child demographic factors* Page 6; *Anthropometric measures* page 6
Bias	9	Describe any efforts to address potential sources of bias	Content under *Statistical analysis* page 6-7
Study size	10	Explain how the study size was arrived at	*Study setting and participant* page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4 paragraphs in the methods

			section detailing this, page 5-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, explain how loss to follow-up was addressed (*e*) Describe any sensitivity analyses	4 paragraphs in the methods section detailing this, page 6-8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8, Table 1 Suppl.Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	Table 1
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table 2 Table 3 Figure 1 Supplementary File 1

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Table 2 Table 3 Figure 1 Supplementary File 1
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	See methods pg. 7-8
Discussion			
Key results	18	Summarise key results with reference to study objectives	Paragraph 1, page 12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Last paragraph, pg 16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 12-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	Last paragraph, pg 16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Funding, pg 17

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.