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Growing up in Australia: paradox of overweight/obesity in children of immigrants from low-and-middle -income countries

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Summary

Objective

Children of immigrants from low-and-middle-income countries show excess overweight/obesity risk relative to host populations, possibly due to socioeconomic disadvantage. The present study was conducted to estimate overweight/obesity prevalence and its association with the family socioeconomic-position in 2–11-year-old Australian-born children of immigrants and Australian-mothers.

Methods

A cross-sectional analysis of 10-year data from the Longitudinal Study of Australian Children was undertaken. Overweight/obesity was defined according to the International Obesity Taskforce, age-and sex-specific BMI cut-off-points.

Results

Approximately 24% children aged 2–3 years (22% sons, and 25% daughters), were overweight/obese with no significant difference between children of immigrants and Australian-mothers. Overweight/obesity prevalence consistently increased with age for sons of mothers from low-and-middle-income countries but not daughters. Adjusting for the family socioeconomic-position did not explain excess overweight/obesity in children of mothers from low-and-middle-income countries. The odds of overweight/obesity in sons were significantly higher at 8–9 years (OR 1.5; $p = 0.03$) and 10–11 years (OR 1.5; $p = 0.03$) and in daughters at 4–5 years (OR 1.7; $p = 0.002$) when the mothers were from low-and-middle-income countries.

Conclusion

Excess weight in children of immigrants is not due to socioeconomic disadvantage alone. Other social processes and interactions between immigrants and host cultures may be involved.

Keywords: childhood obesity, immigrants, low-and-middle-income countries, socioeconomic deprivation.

Introduction

Immigrants from low-and-middle-income countries have lower overweight/obesity and better health on arrival compared to their counterparts in high-income countries, however, this health advantage reverses in less than one generation (1). Children of immigrants, continue to have a disproportionately higher overweight/obesity risk compared to their counterparts in the host populations (2), even when the childhood overweight/obesity rates have plateaued in many European and high-income English speaking countries such as Australia (3,4). Overweight/obesity significantly increases the risk of chronic health conditions such as diabetes and cardiovascular disease, which increases premature mortality (5), and health costs from as early as 4–5 years of age (6). Approximately one-third of Australian children are children of immigrants; about half of them are from low-and-middle-income countries (7). However, little is known about the prevalence and

causes of overweight/obesity in these children, as they develop.

Better health of immigrants from low-and-middle-income countries on arrival is attributed to the low overweight/obesity prevalence in their origin countries (8), health screening on immigration and immigrant self-selection where healthiest and wealthiest individuals migrate (1). However, this health advantage does not extend to the children of immigrants who are born in high-income countries (2). Evidence from high-income countries with large immigrant populations is inconclusive on the reversal of this health advantage (2,9–16). Immigrant health deterioration in such short period is considered to be primarily due to the interrelationship of cultural, socioeconomic and environmental risk factors in the host society (for example, western-diet and sedentary lifestyle) and those carried over from the origin country (such as cultural preferences for large body size and low physical activity) (2,12).

Ethnicity and family socioeconomic-status (SES) measured by parental education, occupation, and income have complex relationship with childhood overweight/obesity. The association of SES with childhood overweight/obesity varies according to the economic development and the health/nutrition transition stages of the immigrant's origin country (17). An inverse relationship between childhood overweight/obesity and poverty in high-income countries is generally observed, but in low-and-middle-income countries this relationship is reverse (17,18). In many low-and-middle-income countries, overweight/obesity is widespread among middle and high-income families due to the global expansion of food markets, urbanization, and media exposure which has popularized the high-calorie and low activity Western lifestyle (17). Whilst attempts have been made to examine effects of SES and overweight/obesity in children of immigrants, small sample sizes and inconsistency of SES measures has resulted in equivocal evidence (9,12). Duration of stay in the host country (10), cultural, environmental, and family dynamics (11,13,14), also influence the association between immigrant status and childhood overweight/obesity.

With a growing immigrant population, estimation of overweight/obesity risk in children of immigrants is imperative to drive age and culture-specific health promotion and preventive policies. The purpose of this study was to estimate the overweight/obesity prevalence and its association with the family socioeconomic position in two-yearly intervals in a cohort of 2–11-year-old Australian-born children of Australian-mothers and mothers from both high-income and low-and-middle-income countries. The study followed children as they developed, hypothesizing that children of mothers from low-and-middle-income countries have high overweight/obesity prevalence at every age, independent of family socioeconomic position.

Methods

Study population

Data from the birth (B) cohort of the ongoing nationally representative Longitudinal Study of Australian Children (LSAC) was used. The LSAC is a comprehensive study that explores the influence of the Australian social, economic and family environment on child wellbeing and development (19).

Details of the sampling design and study methodology are described elsewhere (19). Briefly, eligible children were identified from the Medicare Australia enrolment database, which contains details of the majority of Australian children. A two-stage clustered sampling technique was adopted, first selecting postcodes then children. The sample was stratified by both state/territories and metropolitan/non-metropolitan area. Postcodes were selected with probability proportional to size where possible, and with equal probability for small population postcodes. Children were randomly selected from the selected postcodes, with an approximately equal chance of selection for each child (about one in 25). Sampling weights were used to adjust for unequal probabilities of selection and for non-response.

The B cohort comprised of 5107 children aged 3–19 months born and recruited in 2003–04. Data are collected biennially. The sample size was 4606 (90%) children at 2–3 years (our study baseline), 4386 (86%) at 4–5 years, 4242 (83%) at 6–7 years, 4085 (80%) at 8–9 year and 3764 (74%) at 10–11 years. Data of 10–11-year-old children was the latest available data at the start of the present study.

Procedure

Trained interviewers conducted face-to-face interviews with the study child's primary caregiver (biological mother in 99% of cases) in the child's home, after obtaining informed written consent.

Measures

Child anthropometry

Children's weight and height were measured at each age. Children were weighed in light clothing to the nearest 50 g using Salter Australia bathroom scales (Code 79985; Springvale, Victoria, Australia). Height was measured to

the nearest 0.1 cm using a portable rigid stadiometer (Invicta, Leicester, UK, Model IPO955) (19).

Child weight, height, age, and sex were used to calculate age-and sex-specific Body Mass Index (BMI) scores as weight/height^2 (kg/m^2). The outcome variable, child weight status (overweight/obese and not overweight/obese), was classified according to the International Obesity Task Force (IOTF) age-and-sex-specific criteria which are based on and linked to the corresponding adult BMI cut-offs (20). The current analysis comprises data of children aged 2–3 years to 10–11 years of age. Data for children younger than 2 years were excluded as length/height and BMI of children was not measured.

Maternal immigrant status

Maternal immigrant status based on the economic development of her parent's birth country was the exposure variable. This derived variable was constructed in two steps (Figure 1). In the first step, mothers were classified as Australians if they were born in Australia or born-overseas with both Australian-born parents, according to the Australian Bureau of Statistics definition. Mothers with at least one overseas-born parent were classified as immigrants (21).

In the second step, immigrant mothers were classified according to the economic development of their parent's country of origin. Economic development was classified by the Human Development Index (HDI) criteria (22). The

HDI categorize countries into high-income and low-and-middle-income countries by comparing life expectancy, literacy, education, the standard of living and quality of life. According to the HDI criteria, low-and-middle-income countries include countries in Africa, Asia (except Japan), Latin America, the Caribbean, and Oceania (except Australia and New Zealand). The remaining countries are high-income (22).

Immigrant mothers with at least one parent born in a low-and-middle-income country were classified as mothers from low-and-middle-income countries. Mothers from high-income countries had at least one parent born in a high-income country. Mothers with mixed backgrounds had one parent from a low-and-middle-income and the other from a high-income country.

Covariates

Family socioeconomic position (SEP), neighbourhood liveability, duration of stay in Australia, area of residence and father's immigrant status were considered as covariates because of their previously demonstrated association with childhood overweight/obesity.

Family SEP developed Blakemore et al. in 2009 (23), is a composite continuous indicator which comprises combined annual family income, parents' employment status and education of both parents to summarize the social and economic capital available to families. The summary standardized SEP scores are divided into the lowest 25%, the middle 50%, and the highest 25%.

Figure 1 Sample Distribution by Maternal Immigrant Status at Baseline of B Cohort.

Neighbourhood liveability scale comprised the mean of the caregiver's responses to five statements about the condition of their neighbourhood such as safety, cleanliness, availability of parks and quality of street lighting on a four-point Likert scale. High liveability neighbourhoods scored 1 to 2.5 on the scale, while low liveability neighbourhoods had a score of 2.6 to 4 (24).

Maternal duration of stay in Australia was classified as $\leq$ 10 years and >10 years based on literature which showed that immigrants acculturate to the host practices in approximately 10 years (25). Area of residence was classified as metropolitan or remote. Father's immigrant status, was also defined and classified in a similar manner as maternal immigrant status.

The LSAC was approved by the Australian Institute of Family Studies Ethics Committee. The Australian National University's Human Research Ethics Committee approved the current analysis (Protocol No. 2015/421).

Statistical analysis

Data analysis was conducted in STATA 15 (StataCorp, College Station, Texas, USA, 2015). The results were considered statistically significant if $p < 0.05$. Basic descriptive characteristics (percentages for categorical variables, and mean and standard deviation for continuous variables) are presented for study child aged 2–3 years by maternal immigrant status. Exploratory data analysis indicated different trends in overweight/obesity over time for sons and daughters; therefore analysis was undertaken separately for sons and daughters.

Unadjusted logistic regression was conducted to examine the relationship of each variable with child overweight/obesity across different ages. Variables, significantly associated with overweight/obesity in unadjusted models in at least one age were tested in all cross-sectional multivariable logistic regression models. Separate cross-sectional analysis was carried-out to identify rates of overweight/obesity at each age. Due to a small number of observations in low neighbourhood liveability, it was excluded from the primary analysis; instead, it was included in sensitivity analysis. All analyses were adjusted for the sampling weights.

Results

Sample characteristics

The final sample consisted of 4,233 2–3 year old Australian-born children with known BMI and maternal immigrant status (51% sons; 49% daughters) (Table 1). Overseas-born children ($n = 17$), multiple-births ($n = 151$) and mothers with mixed immigrant background ($n = 75$) were excluded. Children of Australian-mothers included 178 children with Indigenous mothers. Data of 3553 (77%) children was available for at least four of the five follow-up studies. Missing data for child BMI ranged from 1.8% at baseline to 4.9% at 10–11 years. Most mothers from low-and-middle-income countries had South-East Asian, Middle-eastern, South-Asian, Southern-African and Papa New Guinea backgrounds. The majority of mothers from high-income countries were from Europe, the United Kingdom, NewZealand, Canada, and United States (data not shown).

Descriptive analysis at the baseline revealed little difference in tertiary education among mothers. However, significantly lowest percentage of mothers from low-and-middle-income countries and highest percentage from high-income countries were in the workforce ($P < 0.001$). Similarly, significant disparities were observed in SEP, with a higher percentage of mothers from low-and-middle-income countries in the lower SEP and a low percentage in the middle SEP quartiles compared to the other groups (P < 0.001). Approximately 94% of 2–3 years old children were living in neighbourhoods rated by their mothers as highly liveable with no significant difference between the groups.

The preliminary analysis showed high overweight and obesity rates in children of immigrants from low-and-middle-income countries at 4–7 years of age. However, across some ages, the sample of children of low-and-middle-income countries category was quite small. Further analysis showed, similar patterning of risk factors in children who were overweight and those who were obese, at all ages. Other studies have also shown that overweight and obesity are highly interrelated and children move in and out of these categories as they develop (26). It was therefore, decided to conduct analysis by combining overweight/obesity.

Prevalence of overweight/obesity

Approximately 24% children aged 2–3 years; (22% sons, and 25% daughters), were overweight/obese with no statistically significant difference between three maternal groups. From the age of 4–5 years, the overweight/obesity prevalence increased substantially in children of mothers from low-and-middle-income countries.

Different trends in overweight/obesity over time for sons and daughters were observed (Table 2). Comparison of overweight/obesity prevalence in sons showed little difference across maternal groups until after the age of 4–5 years. From 6 to 7 years, the overweight/obesity prevalence was highest in sons of mothers from low-and-middle-income countries but this difference was significant only at 8–9 years (30%; $p = 0.05$). A

Table 1 Participant characteristics at Baseline by Maternal Immigrant Status

Maternal ethnic background	Mother from LMIC (N = 529)	Mother from HIC (N = 1,270)	Australian mothers (N = 2,434)	P Value X^2 test
Girls (n %)	246 (46)	656 (51)	1,207 (49)	0.2
Overweight children	92(18)	226(18)	449(19)	0.5
Obese children	33(6)	59(5)	107(5)	
Overweight/obese children (n %)	128 (24)	288(23)	571 (24)	0.6
Mother tertiary educated (n %)	191 (30)	459 (30)	809 (27)	0.1
Mother in workforce (n %)	241 (40)	735 (56)	1397(54)	< 0.001
Mothers born in Australia (n %)	114(20)	869(68)	2450(99)	<0.001
Mother living in Australia for >10 years (n %)	259(51)	149(11)	0	< 0.001
SEP Low 25% (n %)	164 (37)	268(25)	622(31)	< 0.001
Middle 50% (n %)	230(40)	693(53)	1243 (48)	
High 25% (n %)	142(22)	325(22)	605(20)	
Live in Metropolitan area (n %)	477 (90)	886(70)	1290(51)	< 0.001
Low neighbourhood liveability (n %)	27(8)	62(7)	103(6)	0.2
	Mean (SD)	Mean (SD)	Mean (SD)	P Value ANOVA
Maternal age (years)	33.7 (0.2)	33.8 (0.1)	33.0(0.1)	< 0.001
Child age[years]	2.3(0.008)	2.3(0.01)	2.3(0.02)	0.8
Child BMI (kg/m^2)	16.8 (0.09)	16.8(0.07)	16.9 (0.02)	0.7

Percentages may not total exactly 100% due to rounding. Data are weighted

Abbreviations: LMIC, Low-Middle-Income Countries; HIC, High-Income Countries; SEP, family socio-economic position, The measure of SEP, developed by Blakemore, Strazdins, and Gibbings (2009), uses information about combined annual family income, educational attainment of parents and parents' occupational status to summarize the social and economic resources available to families. The standardized SEP scores have been divided into groups as shown in the table.

* $p<0.05$ * $p<0.01$ ** $p<0.001$***

continuous upward trend was observed in the overweight/obesity prevalence in sons of mothers from low-and-middle-income countries with age, a pattern not demonstrated in other groups (Figure 2A.). Daughters of mothers from low-and-middle-income countries had the highest overweight/obesity prevalence at most ages compared to the other groups, however, the difference was only significant at 4–5 years (35%, $p = 0.002$) (Figure 2B). Overweight/obesity prevalence in daughters of mothers from low-and-middle–income countries did not demonstrate the same strength of upward trend with age, as shown for sons.

Factors associated with overweight/obesity

In the unadjusted cross-sectional analysis, maternal and paternal immigrant status, gender, family SEP and, neighbourhood liveability were significantly associated with child overweight/obesity in at least one age, and were included in final models. In the final multivariable cross-sectional regression models, fathers' immigrant status was excluded, being highly correlated with maternal immigrant status. Multivariable cross-sectional regression models showed that the overweight/obesity odds were higher in sons of mothers from low-and-middle-income countries, compared to the sons of Australian-mothers, at 8–9 years (OR 1.5; $p = 0.03$) and

10–11 years (OR 1.5; $p = 0.03$), after adjusting for family SEP. The overweight/obesity odds were higher for daughters of mothers from low-and-middle-income countries, compared to the daughters of Australian-mothers, at most ages, but this was statistically significant only at 4–5 years (OR 1.7; $p = 0.002$). The overweight/obesity odds in sons and daughters of mothers from high-income countries were generally similar to children of Australian-mothers (Table 3). Results from sensitivity analysis including neighbourhood liveability were similar to the primary analysis except that the relationship between maternal immigrant status and overweight/obesity in sons was statistically significant at 6–7 years (OR 1.4; $p = 0.04$) (Supplementary table).

Discussion

The present study, using repeated cross-sectional analysis of a large population-based cohort, observed that children of mothers from low-and-middle-income countries in Australia have an excess overweight/obesity risk compared to the children of Australian-mothers. This excess risk increased as children grew older. This trend was consistently observed among sons, but not among daughters. The positive associations between maternal immigrant status and overweight/obesity among children from 4 to 11 years persisted after adjustment for family

Table 2 Sex-specific mean raw BMI scores and percentage of overweight /obese sons and daughters by maternal immigrant status at each age of B cohort

Child age	2–3 years		4–5 years		6–7 years		8–9 years		10–11 years	
	BMI (mean) (95% CI)	OW/ OB n (%)	BMI (mean) (95% CI)	OW/ OB n%	BMI (mean) (95% CI)	OW/ OB n%	BMI (mean) (95% CI)	OW/ OB n%	BMI (mean) (95% CI)	OW/ OB n%
Sons										
Australian- mothers	16.9 (16.8,17.0)	275 (22)	16.4 (16.3, 16.5)	246 (21)	16.4 (16.3, 16.6)	214 (20)	17.6 (17.4, 17.8)	240 (23)	18.7 (18.5,18.9)	239 (25)
Mothers from HIC	17.0 (16.9,17.1)	137 (23)	16.5 (16.3, 16.6)	134 (23)	16.5 (16.4, 16.8)	103 (19)	17.7 (17.4, 18.0)	115 (22)	19.1 (18.7, 19.5)	121 (26)
Mothers from LMIC	16.8 (16.6, 17.1)	57 (21)	16.4 (16.1,16.7)	58 (23)	16.8 (16.3,17.3)	58 (25)	18.0 (17.5, 18.5)	66 (30)	19.3 (18.7, 19.9)	57 (33)
P		0.8		0.8		0.1		0.05		0.07
Number of observations		2162		2083		2024		1921		1714
Daughters										
Australian mothers	16.8 (16.7,16.9)	281 (25)	16.3 (16.2, 16.4)	266 (24)	16.6 (16.4,16.8)	228 (22)	17.7 (17.5,17.9)	249 (25)	19.0 (18.8,19.3)	214 (25)
Mothers from HIC	16.6 (16.4,16.7)	148 (22)	16.2 (16.1,16.4)	148 (24)	16.5 (16.3, 16.7)	117 (21)	17.4 (17.2,17.7)	117 (21)	18.8 (18.4,19.1)	125 (25)
Mothers from LMIC	16.9 (16.6,17.1)	68 (29)	16.6 (16.3,17.0)	72 (35)	16.5 (16.0,17.0)	51 (24)	17.9 (17.5,18.3)	53 (26)	19.3 (18.7,19.8)	49 (30)
p		0.2		0.002		0.6		0.2		0.3
Number of observations		2071		1975		1899		1823		1632

Abbreviations: BMI, Body mass index (Kilograms/meters^2); OW/OB, overweight/ obese; LMIC, Low-Middle-Income Countries; HIC, High-Income Countries.

SEP and neighbourhood liveability. These effects were only evident if mothers had a low-and-middle-income country background and did not apply to mothers from high-income countries, suggesting it is not immigrant status *per se* that is the cause of excess overweight/obesity. Further, sons and daughter showed different risk patterning in mothers from low-and-middle-income countries at different ages. Taken together these results challenge a simple socioeconomic or genetic explanation, instead, they point to a likely interplay between cultures of food, weight, gender and health and the experience of immigrant status in a developed, western country.

The role of SES in overweight/obesity in children of immigrants is not clearly established. The present study complemented the evidence which showed that the difference in overweight/obesity in children of immigrants cannot be simply explained by SES (16), in contrast to the studies where social class explained the difference (10,27). Our age-specific cross-sectional regression models showed that after controlling for family SEP and neighbourhood liveability, children of mothers from low-and-middle income countries had higher overweight/obesity odds at most ages, although these were statistically significant at 6–7 (sensitivity analysis), 8–9 and 10–11 years for sons and 4–5 years for daughters. Comparing SES across studies is challenging due to the array of indicators used for measurement, however, in the present study family SEP was used, which is considered a robust measure of the social and economic resources available to family members and addresses many challenges of using individual variables (23). Using a similar SES measure in a large cohort study, researchers in the United-States revealed higher BMI at kindergarten age and higher BMI growth in children from low-and-middle-income countries who arrived in infancy and early childhood. The reverse was true for immigrant children from high-income countries and the host country (13). In the present study, all children were Australian-born and there were no significant differences in children's BMI at 2–3 years among maternal groups. However, a higher overweight/obesity prevalence was found in children of mothers from low-and-middle-income countries relative to the other groups at all ages.

The results of the present study, using a representative sample of Australian children, confirmed previously reported prevalence of 21–25% overweight/obesity in 2–18-year-old Australian children (28,29). The decline in the overweight/obesity prevalence at 6–7 years in all groups (except sons of mothers from low-and-middle-income countries) may either be due to increase in physical activity in school-aged children or perhaps due to a normal growth phase of rapid height gain relative to weight (30). It is, however, difficult to explain the reason
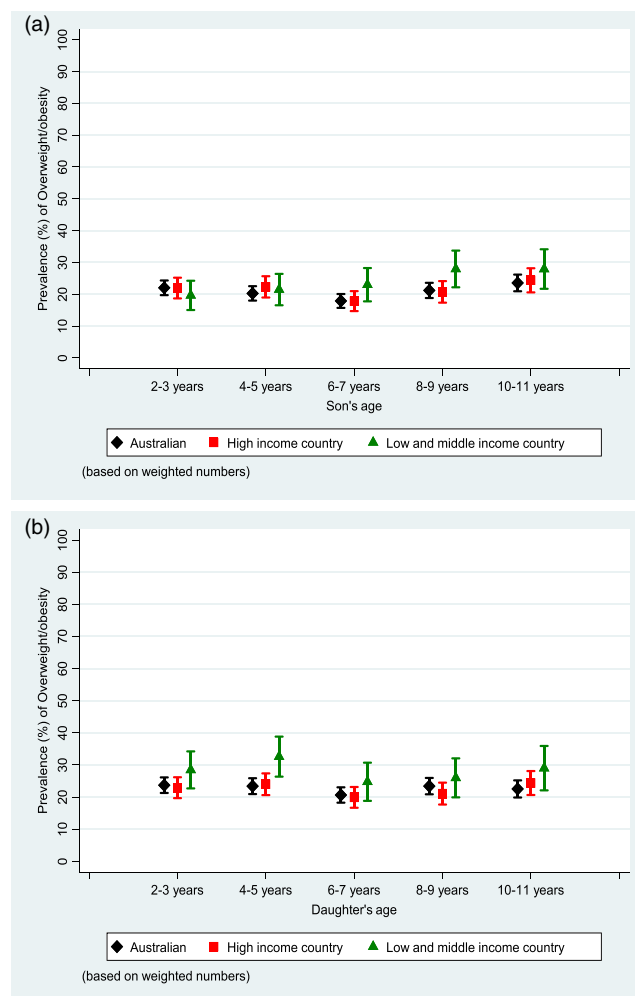
(a)

(b)

Figure 2 A & 2B. Age and Sex-specific Overweight/Obesity Prevalence in children of B Cohort by Maternal Immigrant Status.

for the absence of such decline in sons of mothers from low-and-middle-income countries. The results of the present study also support evidence that the differences in overweight/obesity in children of immigrants and hosts emerge after middle childhood (6–12 years). This is a developmental period when adiposity rebounds and BMI increases dramatically after an initial decline (30).

The present study found important sex-specific variations in the overweight/obesity prevalence with age. The evidence is mixed on gendered variations in BMI of children of immigrants and varies according to the child's age and ethnicity (9,14,15,31). The age-specific trends of overweight/obesity for sons and daughters of mothers from low-and-middle-income countries shown in the present study, have not been previously reported. Explaining these inconsistencies in overweight/obesity of sons and daughters is challenging and somewhat speculative, given the heterogeneous population of immigrants in our sample. Excess weight in sons may be

explained by the cultural norms grounded in the socially constructed gender roles in some immigrant populations from low-and-middle-income countries, where sons are favoured to be big, muscular and strong (9). Similar societal norms in the host country may also contribute to excess weight (32). Excess weight in daughters is more difficult to explain due to its distinct pattern (high initially, but then rates converged after 6–7 years). The societal norms for daughters in the host and many immigrant populations are "slimness or thinness" (32). Previous evidence revealed that sedentary lifestyle in daughters of some immigrants groups were due to higher restrictions on social and after-school activities (33). The change in daughter's weight status before and at school-age in the present study also suggest different gender norms operating relative to boys, at both home and at school.

The present study is the first Australian study examining the association between maternal immigrant status based on the economic development of her parent's

Table 3 Association of Maternal Immigrant Status with overweight /obesity in sons and daughters at each age of B Cohort.

Child age Models	2–3 years		4–5 years		6–7 years		8–9 years		10–11 years	
	Model1 Odds ratio (95% CI)	Model2 Odds ratio (95% CI)	Model1 Odds ratio (95% CI)	Model2 Odds ratio (95% CI)	Model1 Odds ratio (95% CI)	Model2 Odds ratio (95% CI)	Model1 Odds ratio (95% CI)	Model2 Odds ratio (95% CI)	Model1 Odds ratio (95% CI)	Model2 Odds ratio (95% CI)
Sons										
Maternal immigrant status (ref = Australian-mothers)										
Mothers from HIC	1.0 (0.8, 1.3)	1.1 (0.8, 1.4)	1.1 (0.8, 1.4)	1.1 (0.7, 1.5)	0.9 (0.7, 1.2)	0.9 (0.7, 1.3)	0.9 (0.7, 1.2)	1.0 (0.7, 1.3)	1.1 (0.8, 1.4)	1.1 (0.8, 1.4)
Mothers from LMIC	0.9 (0.6, 1.3)	0.9 (0.6, 1.3)			1.4 (0.9, 1.9)	1.4 (0.9, 2.0)	1.5* (1.0, 2.0)	1.4* (1.0, 2.0)	1.5* (1.0, 2.1)	1.5* (1.0, 2.2)
Family Socioeconomic position (ref = middle 50%)										
Lowest 25%		1.4** (1.1, 1.8)		1.1 (0.8, 1.4)		1.1 (0.8, 1.4)		1.5** (1.1, 1.9)		1.4* (1.0, 1.8)
Highest 25%		0.9 (0.6, 1.1)		0.7 (0.6, 1.0)		0.6** (0.5, 0.9)		0.6** (0.4, 0.8)		0.6* (0.5, 0.9)
Observations	2162	2154	2083	2074	2024	2010	1921	1901	1714	1696
Daughters										
Mothers from HIC	0.9 (0.7, 1.1)	0.9 (0.7, 1.1)	1.0 (0.8, 1.3)	1.0 (0.8, 1.3)	0.9 (0.7, 1.2)	0.9 (0.7, 1.2)	0.8 (0.6, 1.0)	0.8 (0.6, 1.1)	1.0 (0.8, 1.3)	1.1 (0.8, 1.4)
Mothers from LMIC	1.2 (0.9, 1.7)	1.2 (0.9, 1.7)	1.7** (1.2, 2.4)	1.8** (1.2, 2.5)	1.1 (0.8, 1.6)	1.1 (0.7, 1.6)	1.0 (0.7, 1.5)	1.0 (0.7, 1.5)	1.3 (0.9, 2.0)	1.3 (0.9, 2.0)
Lowest 25%		1.2 (.09, 1.5)		1.2 (0.9, 1.6)		1.3* (1.0, 1.8)		1.3 (0.9, 1.7)		1.7*** (1.3, 2.4)
Highest 25%		0.7* (0.5, 0.9)		1.0 (0.8, 1.3)		0.9 (0.7, 1.3)		0.7* (0.5, 0.9)		0.7* (0.5, 0.9)
Observations	2071	2060	1975	1965	1899	1891	1823	1805	1632	1618

Model 1 is adjusted for maternal ethnicity. Model 2 is also adjusted for neighbourhood liveability and socio-economic position at each age [wave].

Abbreviations: ref, referent category; LMIC, Low-Middle-Income Countries; HIC, High-Income Countries

The measure of SEP, developed by Blakemore, Strazdins, and Gibbings (2009), uses information about combined annual family income, educational attainment of parents and parents' occupational status to summarize the social and economic resources available to families. The standardized SEP scores have been divided into groups as shown in the table.

Odds Ratio; 95% Confidence Interval

* $p<0.05$ * $p<0.01$ ** $p<0.001$***

origin country and overweight/obesity prevalence in a large, nationally representative longitudinal cohort of Australian children. Anthropometric measurement by trained interviewers and high study retention rates were also strengths of our study.

The study has several limitations which caution extrapolation of results to the Australian and other populations. The LSAC underrepresents children from disadvantaged areas, non-English speaking backgrounds and single-parent families, and over-represents children with mothers who completed year 12 education. Sample weights were applied to adjust for unequal probabilities of sample selection and for non-response.

The choice of cross-sectional analysis of longitudinal data could be considered another limitation, however, as the study aimed to investigate the differences in the overweight/obesity prevalence in children at different ages, this study design was considered more appropriate. The present study also found, in agreement to other reports, that overweight/obesity prevalence and the nature and strength of the relationship with risk factors change profoundly with age (34). Longitudinal analysis may have obscured such age-specific developmental differences.

Economic development of immigrant's countries of origin has been measured by different methods in studies (13). The HDI criteria in the present study was used to measure economic development as it is a comprehensive measure to group countries on a similar context of economic growth. The HDI criteria was also considered as a better measure of stages of health/nutrition transition of the country of origin and host country (13,17,35). Grouping of countries by economic development may have concealed some differences in this diverse group of immigrants, however, the small sample size in the low-and-middle-income country category made analysis by country/region of origin difficult.

Immigrant status has been classified in many ways in literature. The classification used in this study helped in differentiating between mothers with Australian-born parents and those who were Australian-born to immigrant parents or who immigrated as children with immigrant parents. Another way to classify mothers could have been by maternal generations. However, majority of mothers from low-and-middle-income countries in the LSAC were first-generation Australians (overseas-born); a very small percentage were second-generation (Australia-born to immigrant parents). The preliminary analysis showed little difference in maternal characteristics by generation and the risk of child overweight/obesity, therefore it was decided to classify them based on their parental birthplace in order to preserve cell sizes. It is argued that the children born to

mothers with both immigrant parents may be raised in a cultural environment closer to their origin country than children who were born to multigenerational Australian parents and grandparents (36). A similar approach was adopted in other studies also (37).

The present study found a distinct gendered pattern in overweight/obesity in children of mothers from low-and-middle-income countries. The results showed that factors explaining higher overweight/obesity risks are much more complex than either socioeconomic position or genetics. These factors may include cultural practices and beliefs from the country of origin of the immigrants in addition to the other multilevel influences in the host environment. Future research is recommended to understand the elements which increase overweight/obesity risk in children of immigrants at different growth stages. Understanding these factors will help in developing targeted age, sex and culture-specific interventions for children of immigrants.

Conflict of interest

The authors declare no conflict of interest.

Contributors

TZ developed the original idea and plan the study. TZ led the writing and analysis. LS contributed to the idea and planning. CDE and HD contributed to analysis. CDE, LS contributed to writing and interpretation of results. LS, CDE, HD and CB reviewed and approved the final manuscript.

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Supporting Information

Additional Supporting Information may be found online in the supporting information tab for this article.

Table S1. Sensitivity analysis with neighbourhood liveability, maternal immigrant status and overweight /obesity in sons and daughters at each wave of B Cohort.