



A longitudinal analysis of the effect of maternal region-of-birth on transitions in children's bodyweight status from early childhood to late adolescence in Australia: A population-based cohort study

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ARTICLE INFO

Keywords:

Bodyweight transitions
Overweight and obesity
Underweight
Multistate
Children and adolescence
Migrants
Australia

ABSTRACT

Although 49% of Australian residents have at least one overseas-born parent, little is known about children's longitudinal bodyweight transitions among the migrant population. This study examines the net associations between maternal region-of-birth and children's longitudinal bodyweight transitions between underweight, normal, and overweight/obese status from ages 2 to 17 years. A sample of 8889 children was drawn from seven waves of a national population-based cohort study, the Longitudinal Study of Australian Children, conducted between 2004 and 2016. A multistate approach was used to investigate (i) the net effect of mother's region-of-birth on children's bodyweight transitions, (ii) the net estimation of cumulative transition probabilities, and (iii) the net conditional bodyweight expectancy, controlling for child-, family-, and neighbourhood-factors associated with children's bodyweight. Our results showed children of Oceania and African mothers had unfavourable outcomes (i.e., lower remission from or higher incidence of underweight or overweight/obese status) than children of non-migrants. Toddlers with suboptimal bodyweight status (especially those from disadvantaged groups) had higher net cumulative probabilities of staying in that status as a 17-year-old adolescent unless they managed to transfer to normal weight in the primary school years. The 15-year bodyweight expectancy depended on the initial bodyweight status at age two years, with some children of migrant mothers affected longer by suboptimal bodyweight status. In Australia, region-of-birth related disparities in bodyweight started early and were of significant duration throughout development until late adolescence. Culturally tailored health programs should begin at least as early as two years of age.

1. Introduction

A significant number of children aged 5–19 years have suboptimal bodyweight status (underweight, overweight, and obese) globally (Abarca-Gómez et al., 2017) and in Australia (Australian Institute of Health and Welfare, 2020). Suboptimal bodyweight status is associated with higher health costs (Clifford et al., 2015) and adverse health outcomes (Black et al., 2013; Sahoo et al., 2015). It tends to track into

adulthood (Ng and Cunningham, 2020; Sjöholm et al., 2020), with the severity of the associated negative consequences being proportional to the duration of staying in the suboptimal bodyweight status (Barraclough et al., 2019).

The size of migrant populations are growing globally (International Organization for Migration, 2019), including in Australia (Australian Bureau of Statistics, 2020). Almost half of the Australian residents have at least one migrant parent (Australian Bureau of Statistics, 2017).

Abbreviations: AME, The Americas/Caribbean; AU, Australia; BMI, Body mass index; ESEA, East/South-East Asia; LSAC, Longitudinal study of Australian children; MENA, Middle East/North Africa; MSLT, Multistate life table; NWEU, North/West Europe; OCE, Oceania, excluding Australia; SCA, South/Central Asia; SEEU, South/East Europe; SSA, Sub-Saharan Africa; US, United States of America.

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<https://doi.org/10.1016/j.ypmed.2021.106832>

Received 18 April 2021; Received in revised form 11 September 2021; Accepted 3 October 2021

Available online 9 October 2021

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Children from some migrant groups, however, are disproportionately affected by suboptimal bodyweight status (O'Dea and Dibley, 2014). Hence, knowledge about childhood longitudinal bodyweight among migrant population is imperative for identifying at-risk children as early as possible. Such information is useful for designing suitable public health programs and prevention strategies to minimise the time spent in suboptimal bodyweight status, and taming both short- and long-term adverse health and financial outcomes.

More recent studies have reported disparities in children's and adolescents' longitudinal bodyweight status using conditional models, such as mixed and growth curve models (Ng and Cunningham, 2020; Becnel and Williams, 2019). For example, compared with the White background in the United States of America (US), adolescents of Black or Hispanic background had a higher risk of having unhealthy Body Mass Index (BMI) trajectory if they had initial normal weight status. Still, no group difference was found in initial obese status (Ng and Cunningham, 2020). Conditional models focus on sub-group trajectories within the population and investigate the effects of individual characteristics on identified group trajectories of BMI observations within children (Diggle et al., 2002). These models, however, do not portray the multistate transitions associated with lifetime bodyweight observations.

Multistate models study transitions into multiple states, allowing various episodes of entry into and exit from a given bodyweight status while assuming that current bodyweight status is influenced by previous bodyweight status (Namboodiri and Suchindran, 1987). Additionally, the predicted transition probabilities from the multistate model can be used to calculate cumulative probabilities and expected years of life spent in various bodyweight statuses conditional to (or controlling for) the state at the start of observation (Namboodiri and Suchindran, 1987). This descriptive information from the multistate model helps guide early detection and prevention of childhood suboptimal bodyweight status.

Unfortunately, only a few studies have used multistate models to study bodyweight transitions in children (Chen et al., 2016; Moreira et al., 2019; Tran et al., 2016). The transitions between underweight, normal weight, overweight, and obesity statuses were investigated for children aged 4–10 in Portugal, and knowledge for migrant children was not available (Moreira et al., 2019). On the other hand, studies involving minority populations excluded the underweight status (Chen et al., 2016; Tran et al., 2016). They found that children of Black and Hispanic backgrounds in the US were less likely to transition to healthier bodyweight status and more likely to transition to unhealthy bodyweight status between kindergarten and grade 5 than children of White or Asian backgrounds (Chen et al., 2016). Moreover, when children of Black and Hispanic groups were in overweight or obese status at age 3, their expected number of years persisting in overweight or obese status between age 3 and 15 was longer than those of the White group (Tran et al., 2016). Unfortunately, results from these two studies may not be generalised to broader populations since authors did not use a nationally representative sample, did not include transitions to and from underweight and did not control for extensive child-, family-, and neighbourhood-covariates known to influence children's bodyweight.

Due to the growth of migrant population and the differential burden in bodyweight status among children of migrants, our research aimed to fill the gap by investigating the longitudinal transitions between underweight, normal weight, and overweight/obese by mother's region-of-birth in a nationally representative sample of children in Australia, covering a much wider age range than the previous studies (i.e., early childhood to late adolescence), while controlling for known child, family, and neighbourhood factors associated with childhood bodyweight status. Specifically, we analysed secondary data using a multistate approach to answer the following research questions: (1) Do group differences occur in all types of bodyweight transitions or only in a selected few? (2) What are children's net probabilities of transitioning to each bodyweight status at the end of kindergarten, primary school, and secondary school periods, when their bodyweight status at the beginning of those periods and the mother's region-of-birth are known? (3)

What is the net region-specific estimated number of years, between age 2 to 17, that children can expect to occupy specific bodyweight status if their bodyweight status at early childhood is known?

People originating from the same region tend to share broad similarities in biological disposition, environment and cultural background shaping views and habits associated with bodyweight (Renzaho, 2004; Renzaho et al., 2012; Odeniyi et al., 2020; Stryjecki et al., 2018). Hence, we hypothesised that children's bodyweight transitions would differ by mothers' region-of-birth because of the underlying differences in shared biological, environmental, and cultural elements associated with children's bodyweight. We focused on mothers because previous studies show a strong association between mother's characteristics and children's bodyweight status (Morrissey et al., 2011; Chen, 2009), and in part, dictated by data availability. Information on mothers in our data was less likely to be missing than that of fathers.

2. Methods

2.1. Sample

The Longitudinal Study of Australian Children (LSAC) is an ongoing nationally representative population-based biennial survey of children in Australia, conducted since 2004. LSAC used a two-stage clustered sampling design (Soloff et al., 2005). Postcodes were sampled, stratified by state and urban/rural status, followed by a random selection of children from each postcode. Approximately 18,800 infants aged 0 to 1 (B-cohort) and kindergarten children aged 4 to 5 (K-cohort) were identified using Medicare (the database for the universal health insurance scheme, which covers all Australians and permanent residents), and 10,090 of them participated in Wave 1 (Soloff et al., 2005). Our analytical sample consisted of all children who had at least 2 data points on weight and height ($N = 9140$) between Wave 1 (2004) and Wave 7 (2016).

2.2. Ethical consideration

The Australian Institute of Family Studies Ethics Committee approved the study, and parents provided written informed consent. The Australian Data Archives and National Centre for Longitudinal Data permitted us to use LSAC data for research purposes. Since we used secondary data, we obtained an exemption from institutional ethical compliance.

2.3. Variables

2.3.1. Maternal region-of-birth

Maternal region-of-birth was used as a proxy of broad similarities in biological disposition and socio-cultural background of the migrant mothers. We used the Standard Australian Classification of Countries (Australian Bureau of Statistics, 2016) to group mothers' self-reported countries of birth into nine region-of-birth: Australia (AU, non-migrant as the reference category); Oceania, excluding Australia (OCE); North/West Europe (NWEU); South/East Europe (SEEU); The Middle East/North Africa (MENA); Sub-Saharan Africa (SSA); East/South-East Asia (ESEA); South/Central Asia (SCA); and the Americas/Caribbean (AME). After exclusions, we had 8889 children eligible for analysis (response rate of 88.10%). Further information on the justification of this variable and exclusions is provided in the Appendix, section A.

2.3.2. Children's transitions in bodyweight status

Objective anthropometric measure data were obtained from children aged two years and older, and detailed anthropometric data collection is available elsewhere (Australian Institute of Family Studies, 2018). Implausible height or weight data ($n = 74$) were assigned to 'missing', including heights that did not increase by age over time (except for girls aged 14 years and older) and zero weight. These valid anthropometric

data were converted to BMI categories ($n = 49,271$, mean of 5.5 BMI observations per child) using the age- and sex-specific BMI cut-off points of the International Obesity Taskforce, which correspond to the adult cut-off points for thinness (i.e., underweight), overweight and obesity, respectively (Cole et al., 2000; Cole et al., 2007). This standard was based on international samples (Cole et al., 2000; Cole et al., 2007), hence assumed to be suitable for the Australian multicultural population.

We had three outcome variables constructed by the pattern of transitions between 2 consecutive BMI category observations. Detailed constructions of these variables are in the Appendix section C. Our first binary variable was *remission from underweight*, a transition from underweight to normal weight (reference was staying underweight). The second binary variable was *remission from overweight/obese*, a transition from overweight/obese to normal weight (reference was staying overweight/obese). Lastly, a categorical variable with three categories: (1) *incidence of underweight*, which is a transition from normal weight to underweight, (2) *incidence of overweight/obese*, which is a transition from normal weight to overweight/obese, and (3) staying normal weight, as the reference. Sixty-six BMI observations were excluded from the analysis because they did not fit the above transitions (see Appendix section C). We also created a variable representing the duration of staying in a bodyweight status before transitioning. Given that our study methodology involves both increments and decrements of recurrent events, the incidence in our study does not necessarily mean new cases only (i.e., included re-entrants).

2.3.3. Child-, household-, and neighbourhood-specific covariates

Covariates were selected based on ecological theory (Harrison et al., 2011) and previous findings (Morrissey et al., 2011; Lobstein et al., 2004; Kimbro and Denney, 2013). Child-specific covariates included age (years), sex, birthweight (z-scores) (Kuczmarski et al., 2000), age first had food or drink except breastmilk (days), index of daily fruits and vegetables consumption, and daily total screen time (hours). Household-specific characteristics included mother's age (years), the weekly household median income (dollars), number of other children still living in the house and mother's average weekly total time spent working and studying (hours). The latter indicates the mother's ability to spend time with children. The neighbourhood-specific covariates were socioeconomic status (SES) and the concentration of non-migrants. The methods of constructing our covariates are described in the Appendix section D.

2.4. Statistical analysis

Our statistical analyses were performed as follows. *Step 1*: run two-level categorical regression models in the framework of discrete-time event history analysis (Steele, 2011) to answer the first research question. Descriptions of our discrete-time event history analysis are in the Appendix section E. Briefly, our two-level regression models were fitted without intercept, with the outcome variable as the first level and children as the second level. The models were adjusted for child-, household-, and neighbourhood-specific covariates because our interest was in the net effect of mother's region-of-birth. All variables were entered as time-varying variables, except for mother's region-of-birth, children's sex, birthweight and age first had food or drink except breastmilk; and treated as continuous variables, except for mother's region-of-birth and children's sex. The child's age was included through a third-degree polynomial which represented the best fit to the data. Lastly, sampling weights were applied in all statistical analyses. Sampling weights were provided in each LSAC data release, which accounted for unequal sampling, non-response, and loss-to-follow up (Soloff et al., 2006). Details of the LSAC sampling methods and weights are provided elsewhere (Soloff et al., 2006; Usback, 2018).

Step 2: predict the annual transition probabilities by mother's region-of-birth using models from step 1 and use these as the input of the multistate life table (MSLT) (Namboodiri and Suchindran, 1987) to

calculate the net cumulative transition probabilities for the second research question. We computed region-specific cumulative transition probabilities for each of the childhood and adolescent life-courses: (i) between 2 and 17 years; (ii) pre-primary school, which started at age two and ended just before turning six years; (iii) primary school, started at age six and ended just before turning 12 years; and (iii) secondary school, started at age 12 and ended just before turning 17 years.

Step 3: use MSLT to calculate the expected number of years between 2 and 17 years affected by each bodyweight status (we named this the "bodyweight expectancy") for the third research question. We calculated both the unconditional and the net conditional bodyweight expectancy. Further information on our MSLT is in the Appendix section F. The regression analyses were conducted using *gsem* in *svy* suite, and MSLT calculations were done in *lpxct_2* suite of commands in STATA/SE Release 16 (StataCorp LP, College Station, TX), with $p < .05$ considered statistically significant.

3. Results

3.1. Sample characteristics

The final data consisted of 94,676 person-year observations derived from 8889 children (51.01% boys; 49.78% B-cohort). Table 1 presents the description of the sample population by bodyweight status at the start of respective risk sets (i.e., the first BMI observation from each child, which marks the time when the data were included in the analysis), and Table A.3 at the Appendix shows top three mothers' countries of birth by regions and the associated proportions. Approximately 7% and 19% of the children were in underweight and overweight/obese categories. The highest proportion of children in underweight category had SCA mothers, while the highest proportion of children in overweight/obese category had MENA or AME mothers. Compared to children in underweight and normal weight categories, those in the overweight/obese category were mostly girls, had heavier birth weights, were introduced to food or drink (not breastmilk) earlier, spent more hours on screen-based activities, had mothers who spent more time outside the home, were from families with lowest weekly household incomes, and lived in the lowest SES neighbourhoods.

3.2. Mother's region-of-birth and children's bodyweight transition

The relationship between mother's region-of-birth and children's bodyweight transitions was significant even after accounting for all covariates (Model 2, 4, 6, and 8 of Table 2). For remission from underweight, children of OCE mothers were less likely, while those of SEEU were more likely, to converge to normal weight (Model 2) than children of non-migrant mothers. For remission from overweight/obese, children of MENA or SSA mothers had lower odds and children of NWEU or ESEA mothers had higher odds of remission than the reference children (Model 4). Further, higher odds of overweight/obese incidence were found in children of MENA (Model 8).

3.3. Mother's region-of-birth and children's cumulative probabilities in bodyweight transition

Our net cumulative probability (showed as nonagon in Fig. 1 and 95% CIs are in Table A.1 of the Appendix) indicates the net probability that a child would be in bodyweight state at age $t + n$, if the child was in a bodyweight state i at age t and the mother was from x region-of-birth. The global ideal would be a perfect-shaped-nonagon indicating no group difference and a persistent green line around the perimeter indicating higher likelihood in normal weight. Deviations from this, either in shape or colour, show the extent of the health challenge for the children from a specific migrant group. In general, children of OCE, MENA, ESEA, and AME mothers tended to have more unfavourable, and children of NWEU, SEEU and SCA were likely to have more favourable cumulative

Table 1
Sample characteristics by their bodyweight status at the start of risk sets^a.

Variable	Body mass Index ^b category ^c		
	Underweight	Normal weight	Overweight/obese
Total sample, %	6.87	74.53	18.6
Cohort, %			
Baby cohort	7.64	73.83	18.53
K-cohort	6.12	75.22	18.66
Mother's region-of-birth, %			
Australia (AU, non-migrant)	6.31	74.84	18.85
Oceania excluding Australia (OCE)	8.76	71.6	19.64
North and West Europe (NWEU)	6.85	78.74	14.41
South and East Europe (SEEU)	7.94	72.22	19.84
The Middle East and North Africa (MENA)	7.28	64.9	27.81
Sub-Saharan Africa (SSA)	9.24	78.15	12.61
East and South-East Asia (ESEA)	7.53	76.03	16.44
South and Central Asia (SCA)	20.93	64.53	14.53
The Americas and Caribbean (AME)	7.63	65.25	27.12
Male, %	51.23	52.02	46.94
Children's age, mean years (SD)	3.14 (1.01)	3.30 (1.08)	3.36 (1.09)
Birthweight, mean z-score (SD)	- 0.49 (1.05)	- 0.05 (1.05)	0.12 (1.09)
Age first had food or drink except breastmilk, mean days (SD)	108.17 (74.38)	102.58 (71.68)	93.40 (73.54)
Index of daily fruits and vegetables consumption, mean (SD)	1.71 (0.83)	1.79 (0.80)	1.84 (0.81)
Daily total screen time – at start of risk period, mean hours (SD)	0.57 (0.32)	0.60 (0.27)	0.64 (0.27)
Mother's age, mean age (SD)	33.91 (5.28)	34.17 (5.24)	34.03 (5.50)
Mother's average weekly total time spent on working and studying, mean hours (SD)	14.52 (16.94)	16.23 (17.29)	17.60 (18.61)
Number of other children living in the house, mean number (SD)	1.38 (0.94)	1.38 (1.02)	1.37 (1.06)
Weekly household income in AUD, mean income (SD)	1433.24 (1011.03)	1499.21 (1187.73)	1361.55 (898.25)
Neighbourhood socioeconomic status, mean z-score (SD)	0.04 (1.00)	0.05 (1.00)	-0.09 (0.98)
Proportion of non-migrants in the neighbourhood, mean proportion (SD)	85.71 (10.77)	85.07 (11.37)	85.47 (11.41)

Abbreviations: SD, standard deviation; AUD Australian Dollar.

^a Refers to the first body mass index observation from each child, which marks the time when the data were included in the dataset.

^b Weight (kg)/height² (m).

^c Body mass index categories were defined using the international obesity taskforce cut-off points.

transition probabilities when compared with the reference children.

The transition probabilities over 15 years showed that most children in underweight at age 2 were very likely to transition to normal weight by age 17 (panel A, 2–17 age period). In contrast, those with initial normal weight (panel B) and overweight/obese (panel C) tended to stay in the same bodyweight status. Dividing the 15 years into smaller intervals, we could see the probabilities of being in suboptimal bodyweight status at age 17 increased or decreased depending on whether children stayed in suboptimal bodyweight status or moved to normal weight as children progressed through different age periods. Take children of non-migrants with initial overweight/obese at age 2. The probability of persisting in overweight/obese or transferring to normal weight at age 17 was almost equal, around 50% in 2–17 age period. The probability of persisting, however, increased to 80% (95% CI 0.79 to

0.81 in Table A.1 of the Appendix), and the probability of remission decreased to 19% (0.18 to 0.21) if at age 12 these children were still in overweight/obese status (secondary school period). If these children managed to transfer to normal weight at age 12, the probability of overweight/obese at age 17 became only 10% (0.09 to 0.11), while the probability of normal weight was 87% (0.86 to 0.88).

A perfect pentagon indicates no difference between groups. Given the bodyweight status at the start of the interval, the cumulative probability suggests the probability of transferring to a certain bodyweight status by the end of the age interval.

The preschool period starts at age 2, ends before turning age 6. Primary school begins at age 6, ends before turning age 12. The secondary school period begins at age 12, ends before turning age 17.

The cumulative probability was calculated using the Multistate Life Table, with predicted annual transition probabilities as the input (i.e., from models 2, 4, 6, and 8 in Table 2).

Abbreviation: OVOB overweight/obese; AU Australia (non-migrant); OCE Oceania excluding Australia; NWEU North/West Europe; SEEU South/East Europe; MENA Middle East and North Africa; SSA Sub-Saharan Africa; ESEA East/South-East Asia; SCA South/Central Asia; AME the Americas and the Caribbean.

3.4. Mother's region-of-birth and children's bodyweight expectancies

We calculated the unconditional bodyweight expectancy to show the impact of not including initial bodyweight status, region-of-birth, and covariates in the estimation. Results show that average children in Australia could expect to spend 1.7 years (95% CI, 1.6–1.7), 8.7 years (95% CI, 8.6–8.8), and 4.6 years (95% CI, 4.5–4.7) in underweight, normal weight, overweight/obese categories between the age of 2 and 17 years. Our net conditional bodyweight expectancy describes the average number of years (between 2 and 17) in bodyweight status *j* given the child was in bodyweight status *i* at age two and has a mother from *x* region, controlling for all covariates. The results in Fig. 2 (95% CIs are in Table A.2 of Appendix) are ranked by the number of years in normal weight. Our results suggest longer years living with suboptimal bodyweight status if children already had suboptimal bodyweight status at age 2, and these estimates differed by mother's region-of-birth. Given underweight at two years (panel A), the net conditional bodyweight expectancy in underweight for children of OCE mothers was almost twice as long (while that of SEEU mothers was shorter by nearly half) than the reference children. Suppose the initial was overweight/obese status. In that case, the conditional bodyweight expectancies in overweight/obese for OCE, MENA, and SSA groups were longer (whereas those of NWEU and ESEA groups were shorter) than the reference group (Panel C).

4. Discussion

Given the trend in the volume of immigration and the disparities in children's bodyweight status in the migrant population (O'Dea and Dibley, 2014), our study contributes to the body of knowledge which can be used for designing health programs and public health policy to reduce disparities in children's bodyweight categories among migrant and minority populations. To the best of our knowledge, our study is the first to analyse the net relationship between migrant mothers' origin and complete children's transitions in bodyweight status, (focusing on the transitions between underweight, normal weight, and overweight/obese statuses) as children go through major periods of life events (from pre-primary to primary and then to secondary school years), as well as the time in each bodyweight status, given prior bodyweight status and mother's origin.

We found three important findings. Firstly, the odds of bodyweight transitions were not equally shared among groups, even after controlling for extensive covariates, i.e., some groups were more affected by transitions between normal and overweight/obese and others were more

Table 2

Odds ratios and 95% confidence intervals of the remissions from and incidences of underweight and overweight/obese in children aged 2–17 years in Australia, by mother's region-of-birth.

Region-of-birth [#]	Remission from underweight		Remission from overweight/ obese		Incidence of underweight		Incidence of overweight/obese	
	Model 1 ^a	Model 2 ^b	Model 3 ^a	Model 4 ^b	Model 5 ^c	Model 6 ^d	Model 7 ^c	Model 8 ^d
	OR	OR	OR	OR	OR	OR	OR	OR
	(95% CI)	(95% CI)	(95% CI)	(95% CI)	(95% CI)	(95% CI)	(95% CI)	(95% CI)
Oceania excluding Australia (OCE)	0.42* (0.21 to 0.85)	0.44* (0.20 to 0.95)	0.58* (0.34 to 0.99)	0.63 (0.37 to 1.09)	0.45** (0.25 to 0.79)	0.61 (0.32 to 1.16)	0.99 (0.70 to 1.41)	1.42 (0.94 to 2.13)
North/West Europe (NWEU)	0.93 (0.63 to 1.38)	1.08 (0.69 to 1.71)	1.37 (0.96 to 1.94)	1.70** (1.15 to 2.54)	0.8 (0.54 to 1.17)	1.17 (0.75 to 1.81)	0.67** (0.53 to 0.86)	0.97 (0.73 to 1.29)
South/East Europe (SEEU)	2.27** (1.29 to 3.97)	2.68** (1.42 to 5.09)	1.52 (0.76 to 3.01)	1.79 (0.89 to 3.58)	0.59 (0.30 to 1.15)	0.76 (0.36 to 1.60)	0.76 (0.46 to 1.28)	0.95 (0.50 to 1.79)
Middle East/ North Africa (MENA)	0.87 (0.55 to 1.37)	1.14 (0.72 to 1.83)	0.44* (0.21 to 0.91)	0.40* (0.18 to 0.87)	0.54 (0.17 to 1.66)	0.49 (0.16 to 1.55)	1.49 (0.87 to 2.54)	2.12* (1.09 to 4.12)
Sub-Saharan Africa (SSA)	1.38 (0.70 to 2.75)	1.74 (0.90 to 3.38)	0.33* (0.13 to 0.83)	0.28* (0.10 to 0.79)	1.51 (0.81 to 2.82)	1.79 (0.85 to 3.80)	0.9 (0.57 to 1.42)	1.45 (0.82 to 2.58)
East/South-East Asia (ESEA)	0.81 (0.48 to 1.35)	1.2 (0.65 to 2.22)	1.4 (0.92 to 2.14)	2.08** (1.27 to 3.41)	0.89 (0.55 to 1.42)	1.09 (0.64 to 1.86)	0.65** (0.48 to 0.88)	0.82 (0.56 to 1.19)
South/Central Asia (SCA)	0.71 (0.46 to 1.11)	0.84 (0.52 to 1.34)	0.94 (0.44 to 2.00)	1.06 (0.49 to 2.29)	1.2 (0.70 to 2.05)	1.29 (0.65 to 2.56)	0.83 (0.54 to 1.27)	1.06 (0.63 to 1.79)
The Americas/Caribbean (AME)	0.89 (0.34 to 2.28)	0.9 (0.36 to 2.29)	0.55 (0.27 to 1.11)	0.53 (0.25 to 1.10)	1.34 (0.65 to 2.77)	1.87 (0.81 to 4.30)	0.94 (0.54 to 1.64)	1.26 (0.64 to 2.46)

Abbreviations: OR, odds ratio; CI, confidence interval.

[#] Reference category was non-migrant mothers.

^a Two-level logistic analysis of discrete-time event history model with intercept removed, adjusted for child's age and duration of staying in the origin state.

^b Two-level logistic analysis of discrete-time event history model with intercept removed, adjusted for child's age, duration of staying in origin state, child's sex, birthweight, age first had food or drink except breastmilk, index of daily fruits and vegetables consumption, daily total screen time, mother's age, weekly household median income, number of other children living in the house, mother's average weekly total time spent working and studying, neighbourhood SES, the proportion of non-migrant residents in the neighbourhood.

^c Two-level multinomial logistic analysis of discrete-time event history model with intercept removed, adjusted for child's age and duration of staying in the origin state.

^d Two-level multinomial logistic analysis of discrete-time event history model with intercept removed, adjusted for child's age, duration of staying in origin state, child's sex, birthweight, age first had food or drink except breastmilk, index of daily fruits and vegetables consumption, daily total screen time, mother's age, weekly household median income, number of other children living in the house, mother's average weekly total time spent working and studying, neighbourhood SES, the proportion of non-migrant residents in the neighbourhood.

* $p < .05$.

** $p < .01$.

affected by transitions between normal and underweight. Secondly, the net cumulative probability of persisting in suboptimal bodyweight status at age 17 could be decreased substantially if children with initial suboptimal bodyweight status at two years managed to transfer to normal weight before the secondary school year, with the extent of the persistence differed by region-of-birth. Thirdly, the net estimated conditional bodyweight expectancy in a suboptimal bodyweight status between 2 and 17 years of age increased if the children already had a suboptimal bodyweight status at two and were part of the disadvantaged group.

Our findings strengthen previous findings in childhood bodyweight transitions (Chen et al., 2016; Tran et al., 2016) and provide new knowledge. We found lower odds of remission from (1) underweight category for children of OCE and (2) overweight/obese category for children of mothers from MENA and SSA countries. Our finding in remission from overweight/obese was similar to the previous result on US children of non-Hispanic Black (Tran et al., 2016).

The cumulative transition probability of children in the general population during the primary school period shows a greater likelihood to remain in their initial bodyweight status, except for those with initial underweight status (Chen et al., 2016). Our results supported this finding, except in children of OCE. With initial underweight status, children of OCE had an almost equal chance to stay underweight or move to normal weight status. We also added new knowledge of region-specific cumulative transition probabilities from 4 different childhood and adolescent life-course periods.

Our bodyweight expectancies for children affected by overweight/obese and had mothers from MENA and SSA were comparable with the

previous finding using a non-Hispanic Black sample (Tran et al., 2016). We also added new information on the region-specific conditional bodyweight expectancy involving underweight.

Differences between our findings and previous findings exist, especially findings of disparities in children of Hispanic and Asian backgrounds (Tran et al., 2016). For the former, the difference was likely due to our North and South American countries' grouping into one due to low numbers of mothers from these countries. Additionally, the previous study investigated the transitions between overweight and obese (Tran et al., 2016), which we did not do. They found children of Asian background tended to have an unfavourable transition in this space (Tran et al., 2016).

Biological, environmental and socio-cultural factors are important predictors of childhood suboptimal bodyweight (Stryjecki et al., 2018; Harrison et al., 2011; Lobstein et al., 2004), and mothers from the same region-of-birth tend to share these factors (Renzaho, 2004; Stryjecki et al., 2018). Accordingly, the observed difference in children's bodyweight transitions was likely the manifestation of the difference in shared biological, environmental exposure, cultural views, and habits related to children's bodyweight between mothers' region-of-birth.

Our study also contributes to the theoretical understanding of children's bodyweight in migrant population. In the Six-Cs model of childhood overweight/obesity (Harrison et al., 2011), cultural and social norms shape society's views and habits associated with bodyweight. In our study, the mothers originated from 9 regions-of-birth (which represents broad cultural background). Our findings are aligned with this theoretical framework, reinforcing the applicability of the Six-Cs framework in the Australian setting.



(caption on next page)

Fig. 1. Children's net cumulative bodyweight transition probabilities by age, periods of life events and mother's region-of-birth.

A perfect pentagon indicates no difference between groups. Given the bodyweight status at the start of the interval, the cumulative probability suggests the probability of transferring to a certain bodyweight status by the end of the age interval. The preschool period starts at age 2, ends before turning age 6. Primary school begins at age 6, ends before turning age 12. The secondary school period begins at age 12, ends before turning age 17.

The cumulative probability was calculated using the Multistate Life Table, with predicted annual transition probabilities as the input (i.e., from model 2, 4, 6, and 8 in Table 2)

Abbreviation: OVOB overweight/obese; AU Australia (non-migrant); OCE Oceania excluding Australia; NWEU North/West Europe; SEEU South/East Europe; MENA Middle East and North Africa; SSA Sub-Saharan Africa; ESEA East/South-East Asia; SCA South/Central Asia; AME the Americas and the Caribbean

**Fig. 2.** Children's net conditional bodyweight expectancy showing the number of years affected by different bodyweight status between ages 2 and 17 by mother's region-of-birth, if their initial status at two years of age was (a) underweight, (b) normal weight, or (c) overweight/obese category.

Abbreviations: AU Australia (non-migrant); OCE Oceania excluding Australia; NWEU North/West Europe; SEEU South/East Europe; MENA Middle East and North Africa; SSA Sub-Saharan Africa; ESEA East/South-East Asia; SCA South/Central Asia; AME the Americas and Caribbean.

Elsewhere, culturally tailored preventions for obesity-related conditions were found effective (Renzaho et al., 2009). In Australia, culturally tailored obesity prevention programs have been developed for adolescents (Renzaho, 2008; Renzaho et al., 2015). Our study shows the merit of extending these programs to pre-primary age groups to reduce their probability of staying in suboptimal bodyweight status at late adolescence and the number of years affected by suboptimal bodyweight status. Reducing the number of years in suboptimal bodyweight status may reduce the severity of individual's and the public health systems' health and financial outcomes. Although more children in our sample were affected by unfavourable bidirectional transitions between normal weight and overweight/obese than between normal weight and underweight, we still recommend programs for children affected by underweight due to distinct underlying mechanisms and health consequences (Black et al., 2013). Lastly, this study could be extended to compare bodyweight transitions of migrant children with those from the source countries. Applying this study to children in different countries would (i) clarify the extent of the dual burden of underweight and overweight/obesity in each country, (ii) identify the optimum age for starting the prevention program, and (iii) collectively support the epidemiological research of global burden of underweight and overweight/obesity among children. Lastly, our paper did not focus on the effect of time (e.g., length of residence or age on arrival) on children's bodyweight transition. We suggest a future study investigating this research question to enrich our understanding of the disparities in childhood bodyweight transitions.

4.1. Strengths and limitations

The strength of this study was the use of representative longitudinal data of children in Australia, covering their lives from ages 2–17 years. We focused on the complete transition between underweight, normal weight, and overweight/obese from pre-primary to the last years of secondary years. This study also provided, as novel perspectives, region-specific cumulative transition probabilities at different age periods and region-specific conditional bodyweight expectancies, which are valuable descriptive information for prevention and intervention programs.

Our study was limited by the absence of father's region-of-birth in the analysis due to the high level of missing data from fathers. Secondly, we were aware that mothers from different countries are likely to have different belief systems and habits; hence we did not want to combine the country-of-birth into a highly aggregated category. We were also informed that the patterns of transitions for children with initial overweight status might differ from children with initial obese status (Chen et al., 2016; Moreira et al., 2019; Tran et al., 2016). However, since our focus was to examine the influence of region-of-birth, we chose less aggregated region-of-birth and went without investigating transitions between overweight and obese to maintain adequate sample sizes in outcome variables for stability in the statistical analyses.

5. Conclusions

Many children in our study were disproportionately affected, while others had better transition patterns than children of non-migrant mothers. Hence, our findings provide strong justification for culturally tailored programs and health policy to address suboptimal bodyweight, aimed at families with children from as young as 2. The study also

demonstrated the value of using a transition-based approach, rather than group-based growth trajectories approach, to understand how region-of-birth influenced longitudinal bodyweight transitions. Future studies on transitions between overweight and obese status involving a more nuanced category of migrant families, the role of father's region-of-birth, time aspect of migration, and cross-country comparison are necessary.

Contributors

SH conducted a literature search. TC involved in the early discussion on project conception and methods. SH and YK conceptualised the study, developed the study design and analytical strategy. SH and YK identified relevant data. TN and YK guided data analysis plan. SH obtained the data from Data Custodian and analysed data. SH and YK interpreted the results. TN involved in discussion and interpretation of results. YK guided manuscript structure, TC supported with drafting the manuscript, and SH drafted the manuscript. SH, TC, TN, and YK critically reviewed manuscripts for important intellectual content and approved the final version. SH and YK agree to be accountable for all aspects of the work. All authors have read and approved the paper for submission, and our work complies with the journal's Ethical Policies and has been conducted after relevant ethical review.

Funding statement

We did not receive any funding in conducting this study.

Disclaimer

Findings and views reported in this manuscript are solely those of the authors.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

we used the anonymised data from the Longitudinal Study of Australian Children, a project initiated and funded by the Australian Government, and conducted in partnership with the Department of Social Services, the Australian Institute of Families Studies, and the Australian Bureau of Statistics, with advice provided by a consortium of leading researchers. Benedict Sheehy, PhD (University of Canberra), contributed to the editing of the manuscript. We also thank the Health Research Institute staff (University of Canberra) for their valuable inputs during the study's initial conceptualisation. Lastly, we were grateful for the constructive comments and suggestions provided by the reviewers and editors of the Preventive Medicine.

Appendix. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jpmed.2021.106832>.

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