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# Have the Health Gaps Between Indigenous and Non-Indigenous Australian Children Changed over Time? Results from an Australian National Representative Longitudinal Study

Lixin Ou · Jack Chen · Ken Hillman

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**Abstract** The purpose of this study was to evaluate the changes of health gaps between Indigenous and non-Indigenous children over time and to explore critical factors that contribute to the changes. We employed data consisting of two cohorts of Australian children: infant (0/1 year) and children (4/5 years) that are part of the Longitudinal Study of Australian Children. Health outcomes were measured by physical outcome index (POI) and parent-rated health during 2004, 2006 and 2008. We used first-order autoregressive modelling to examine the longitudinal relationship between the changes in health outcomes and possible contributing risk factors. The results showed that the trends of POIs between Indigenous and non-Indigenous children were closing, while the gap of parent-rated health between the two populations persisted. We found that health outcomes (both POI and parent-rated health) at an earlier time point ( $t - 1$ ) were significant predictors of the outcomes at the later time point ( $t$ ). Carer's depression status, socio-economic position and neighbourhood liveability had significant and consistent impacts on parent-rated health, but had only varying impacts on POIs

between Indigenous and non-Indigenous children as well as between the birth cohorts at different time periods. Similarly, low birth weight, carer's binge drinking behaviour and other risk factors showed such varying impacts at a particular time period. The study implied that appropriate interventions accompanied by monitoring of health outcomes are necessary in order to decrease the health gaps between Indigenous and non-Indigenous children.

**Keywords** Children · Health disparity · Indigenous · Socio-economic position · Life-course

## Introduction

Closing the gap in Indigenous health has been an ongoing national pursuit in Australia since the National Aboriginal Health Strategy agreed on directions for an Indigenous health policy in 1989 [1]. Since then, a number of strategic frameworks for bridging the gap in Indigenous health have been launched [2, 3]. The national strategy frameworks identified priority areas such as strengthening community controlled primary health care; reducing socio-economic disparities; promoting health behaviour change, such as absence from smoking and drinking during pregnancy; and improving health system delivery and resource allocation. A recent report by the National Indigenous Health Equality Council revealed that the reduction of the Indigenous gap in the child mortality rate was significant between 1998 and 2006 [4]. Despite this encouraging result, there were no national representative studies in Australian children regarding the gaps defined by broader health outcomes such as overall health well-being, body mass index (BMI) and health care needs for special medical conditions. Moreover, despite the well documented determinants of

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child health such as parental depression, marital status, socio-economic status, as well as neighborhood or community characteristics [5–10], there was no national data enabling the exploration of factors which contribute to the different developmental trajectories of health outcomes between Indigenous and non-Indigenous children in Australia. Thus, there is a need to understand both the changes in the gaps over time and the factors that may have contributed to or prohibited such changes.

This study aimed to answer two research questions: (1) how has the health gap between Indigenous and non-Indigenous children changed over time? And (2) what have been the crucial factors that contributed to those changes? We undertook this study using national representative data from the Longitudinal Study of Australian Children (LSAC), an ongoing program initiated and funded by the Australian Government Department of Families, Housing, Community Services and Indigenous Affairs (FaHCSIA) [11].

## Methods

### Study Sample Design

We drew data from Wave 1 (2004), Wave 2 (2006) and Wave 3 (2008) within the two cohorts of the LSAC. The B-cohort was aged 0–1, 2–3 and 4–5 years old and K-cohort was aged 4–5, 6–7 and 8–9 years in Wave 1, Wave 2 and Wave 3, respectively. The details of the study design and instruments used have been fully described elsewhere [12]. In brief, children from both cohorts were identified through the Health Insurance Commission (HIC) Medicare database that includes approximately 98% of all Australian infants and children as the sampling frame. The sample elements were firstly stratified by state or territory and then by urban or rural status. Within each stratum, approximately one of ten Australian postcodes was randomly included in the study as the primary sampling units to ensure proportional geographical representation. A total of 5,107 infants (230 Indigenous) and 4,983 children (189 Indigenous) were recruited to the first wave of the LSAC. The response rates were, in turn, 64.2 and 59.4%. For each participating child, written consent was obtained. The study was approved by the Australian Institute of Family Studies Ethics Committee.

### Data Collection

Trained professional interviewers undertook a face-to-face interview with the primary care-giving parent, mostly the biological mother (99.7%), but at times with the biological father, step parent, adoptive parent, guardian, or someone

who had a parental relationship to the child. The respondents also completed a written questionnaire as part of the main interview. The procedure was similar at each time point. The sample size throughout waves is displayed (Fig. 1).

## Measurement

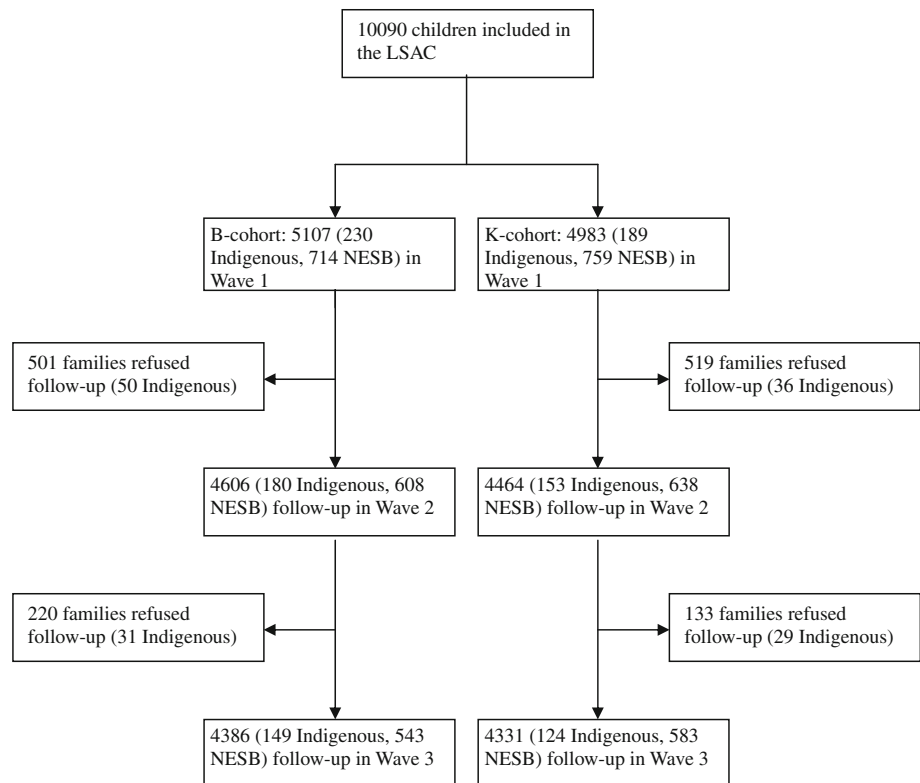
### Health Outcomes

Two health outcomes were measured in our analysis:

1. The global overall health rating of children was reported by the surveyed parents with a 5-point Likert scale ranging from excellent to poor. As our preliminary examination showed that only two percent of children were cited with fair or poor health at the baseline, we re-categorised the health rating as a dichotomous variable with “1 yes; 0 no” as an indication of very good or excellent rating.
2. Physical outcome index (POI) is a standardised composite health score (mean = 0, standard deviation = 1) which is calculated using cohort-specific standardised health-related subscale outcome measures [13], including “overall rating of health”, “special health care needs”, “health problems”, “weight status” [14, 15] and “Paediatric Quality of Life (PedsQL) physical health subscale summary” [16], and “gross motor co-ordination scale” [17] by age groups (Table 1). A lower score indicates a worse health outcome. The continuous POI was calculated in four steps. For the K-cohort: (1) it involved standardising all the outcome variables and combining them into sub-domain scores; (2) the sub-domain scores were standardised and combined into domain scores; (3) the domain scores were further standardised; (4) the final index was calculated through averaging the three domain scores. The calculation of the continuous POI for the B-cohort was in a similar but simpler three step fashion as no sub-domain was involved. All analyses and derivations involved use weighted data where appropriate. A detailed description of the methods and the distribution properties of the indices for both B- and K-cohort has been presented elsewhere [13].

### Potential Contributing Factors to the Changes of Health Outcomes

The potential contributing factors employed in this study included: individual risk factors, carer’s health behaviours, socio-economic status, and neighbourhood characteristics of the children and their families. Individual risk factors

**Fig. 1** Flow-chart for sample size throughout waves**Table 1** Domain of measure scales for calculating physical outcome index (POI)

Domain	Sub-domain	Age 0–1	Age 2–3	Age 4–5	Ages 6–7 and 8–9
Health/physical	Health	Overall rating of health	Overall rating of health	Overall rating of health	Overall rating of health
		Special health care needs	Special health care needs	Special health care needs	Special health care needs
		Health problems	Health problems	Health problems	Health problems
		Weight status	Weight status	Weight status	Weight status
	Motor		PedsQL physical health	PedsQL physical health	PedsQL physical health Gross motor coordination

*PedsQL* Paediatric Quality of Life

were identified as the child's sex and low birth weight (less than 2,500 g—yes/no), Indigenous status (yes/no), family type (both parents and single parent at home), and carer's depression scale. Carer's health behaviour included two variables "frequent binge drinking (yes/no)" and "smoking behaviour (yes/no)". Socio-economic position (SEP), the advantage and disadvantage index of Socio-Economic Indices for Areas (SEIFA) and home ownership were chosen as an indicator of socio-economic status. Two variables of "neighbourhood liveability" and "neighbourhood facilities" were included as indicators of community resources and supports.

Carer's depression scale (K6) was the mean of 6-item subscales evaluating the degree of depression [18]. The subscales were rated by parents in regard to the way the individual had felt during the previous 4 weeks, including feeling nervous; hopeless; restless or fidgety; feeling that

everything was an effort; feeling so sad that nothing could cheer you up; and feeling worthless, using a 5-point Likert scale (1 = all of the time and 5 = none of the time). The SEP score was a z-score calculated using a combined information measure of parent educational attainments, their income and occupational prestige amongst all families [19]. The score positively indicates the family SEP. The SEIFA score is a composite measure from the 2001 census at the postcode of residence, and low values indicate an area of disadvantage [20].

Neighbourhood liveability consisted of five items that assessed the circumstances of the neighbourhood (i.e. safe; clean; parks, playground and play spaces; street lighting; footpaths and roads). The variable of the neighbourhood facilities was derived using a 3-item scale reflecting general neighbourhood satisfaction in terms of access to close, affordable, regular public transport; basic shopping

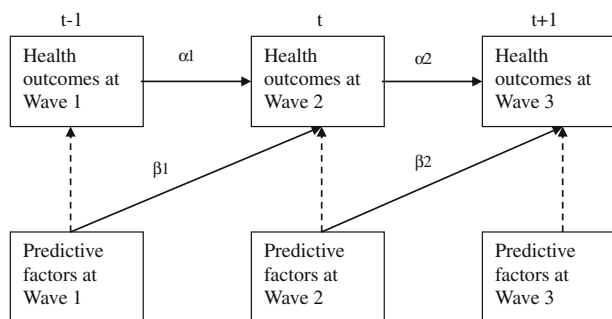
facilities; and basic services such as banks and medical clinics. For both neighbourhood characteristics scores, a higher score indicates lower satisfaction.

**Descriptive and Bivariate Analysis**

We analysed the data according to survey statistical principles and took into account the design features of the longitudinal study. Analyses were weighted for the multi-stage sampling design, allowing for unequal probabilities of selection into the sample and for no responses. First-order Taylor linearisation was used to obtain the estimates of standard error, taking into account the stratification and the correlation of responses within postcodes. Rao-Scott Chi-square was used to examine the distributional difference between Indigenous and non-Indigenous children for categorical variables. The total numbers included in the analyses were slightly varied due to missing values and non-responses to different items.

**Longitudinal Analysis**

We used first-order autoregressive modelling to examine the longitudinal relationship between the changes in the health outcomes and the possible contributing risk factors [21]. The model stipulates that an outcome at a time point is primarily affected by the same outcome measured at the early time period ( $t - 1$ ) as well as other predicting variables at the  $t - 1$  point [22]. The statistical approach employed enabled us to combine two separated before-after analyses (i.e. Wave 3 outcome regressed on Wave 2 predictors and Wave 2 outcome regressed on Wave 1 predictors) into a single model (Fig. 2). In our study, the predictor variables included time-independent covariates (sex, birth weight, and Indigenous status), and time-dependent covariates, such as carer’s health behaviour, socio-economic status and neighbourhood variables.



**Fig. 2** Illustration of autoregressive model for the longitudinal relationship between health outcomes and predictive factors over time

We analysed the data for B-cohort and K-cohort separately using the same framework. First we tested the interaction effect between  $t - 1$  dependent outcome and the Indigenous status and we then tested the interaction effect between  $t - 1$  dependent outcome and Wave indicator variable (1 = Wave 3, 0 = Wave 2). If any test was statistically significant, we then stratified the results by either the Indigenous status or data collection waves. The regression coefficient ( $\beta$ ) from this autoregressive model demonstrates the strength of the partial effect of the risk factors on the changes in the outcomes.

Statistical significance was calculated with 95% confidence intervals. All analyses were performed using Stata 10.1 (StataCorp., College Station, TX).

**Results**

A total of 8,584 children (4,393 in the B-cohort and 4,191 in the children cohort) were included in the baseline analysis, excluding 1,473 non-English speaking background children and 33 children whose language background was confidential. A detailed description of the sample attrition is presented (Fig. 1).

**Distribution of Individual, Socio-Economic and Neighbourhood Variables at the Baseline**

Individual, socio-economic and neighbourhood characteristics by the groups of Indigenous and non-Indigenous children at the baseline are presented (Table 2). Compared with non-Indigenous children, Indigenous children had a lower birth weight ( $P < 0.001$ ) in both cohorts, were four times more likely to be living with a single parent in B-cohort, and were more than twice as likely to be living with a single parent in the K-cohort. Indigenous parents were more likely than non-Indigenous parents to have a lower depression score; to be a frequent binge drinker; and to be a current smoker in both cohorts. In comparison with non-Indigenous families, Indigenous families had a lower SEP and SEIFA score and a lower percentage of home ownership. Indigenous families were also more likely to live in a neighbourhood with poorer liveability in both cohorts ( $P < 0.001$ ) and poorer neighbourhood facilities in the K-cohort ( $P < 0.01$ ).

**Changes of Health Outcomes Between Indigenous and Non-Indigenous Groups**

In both cohorts, the mean POI scores for Indigenous children were lower than that for non-Indigenous children in the first two waves, but were similar in Wave 3 (Table 3). In the B-cohort, Indigenous children were less likely than

**Table 2** Percentage or mean (SE) [sample was weighted] of individual, socio-economic and neighbourhood characteristics by Indigenous status at the baseline

Characteristics	B-cohort (0–1 years)			K-cohort (4–5 years)		
	Non-Indigenous ( <i>n</i> = 4,159)	Indigenous ( <i>n</i> = 229)	<i>P</i> value	Non-Indigenous ( <i>n</i> = 4,001)	Indigenous ( <i>n</i> = 188)	<i>P</i> value
<b>Child</b>						
Child sex (male)	50.9	53.4	0.54	51.6	48.6	0.38
Mean birth-weight (SE)	3,425.3 (9.62)	3,239.2 (50.45)	<0.001	3,418.8 (10.88)	3,266.3 (49.66)	0.003
Birth-weight less than 2,500 g (yes)	5.0	11.6	<0.001	6.4	8.6	0.26
<b>Family type</b>						
Both parents	90.8	62.3	<0.001	85.7	67.6	<0.001
Single parent	9.2	37.7		14.3	32.4	
<b>Caregiver</b>						
Depression scale (SE)	4.4 (0.01)	4.2 (0.07)	<0.002	4.3 (0.01)	4.1 (0.07)	<0.001
Frequent binge drinking (yes)	6.8	10.4	0.03	13.6	26.3	<0.001
Smoke (yes)	19.6	43.0	<0.001	22.2	39.7	<0.001
<b>Socio-economic</b>						
Socio-economic position score (SE)	0.0	−1.1	<0.001	0.1 (0.03)	−0.7	<0.001
SEIFA score (SE)	1,008.4 (3.87)	962.1 (6.97)	<0.001	1,001.9 (4.44)	962.8 (7.86)	<0.001
Home ownership (Yes)	65.8	23.0	<0.001	70.5	28.4	<0.001
<b>Neighbourhood</b>						
Neighbourhood liveability (SE)	2.0 (0.01)	2.2 (0.04)	<0.001	2.0 (0.01)	2.2 (0.04)	<0.001
Neighbourhood facilities (SE)	2.0 (0.02)	2.1 (0.06)	0.09	2.0 (0.02)	2.2 (0.08)	0.009

SEIFA Socio-Economic Indices for Areas

non-Indigenous children to be rated with a very good or excellent health status over the three waves (Wave 1: 78.1% vs. 87.9%,  $P < 0.001$ ; Wave 2: 79.5% vs. 86.2%,  $P = 0.011$ ; Wave 3: 76.3% vs. 88.9%,  $P < 0.001$ ). In the K-cohort, significant differences in the health rating were observed between Indigenous and non-Indigenous children in the first two waves (Wave 1: 81.7% vs. 88.9%,  $P = 0.022$ ; Wave 2: 82.4% vs. 89.6%,  $P = 0.022$ ), but not in Wave 3. The closing trends of the mean POIs between Indigenous and non-Indigenous children in both cohorts are shown (Figs. 3, 4).

#### Autoregressive Analysis for POI

##### *B-Cohort*

The previously measured POIs were significant predictors of the POIs in the immediately following waves except for the Indigenous group in Wave 2 (Table 4). For the non-Indigenous group, prior lower carer's depression score was associated with worsening POIs at later waves (Wave 2:  $\beta = 1.79$ , 95% CI: 1.11–2.48; Wave 3:  $\beta = 1.48$ , 95% CI: 0.64–2.33). For the Indigenous group, worsening health outcomes were observed in Wave 2 when carers had binge drinking behaviour ( $\beta = -7.29$ , 95% CI: −13.05 to

−1.54), and when families lived in a place with poorer neighbourhood liveability ( $\beta = -5.91$ , 95% CI: −10.75 to 1.08) and poorer neighbourhood facilities ( $\beta = 3.21$ , 95% CI: 0.43–5.99) in Wave 1. No significant relationships were found with all confounding variables within the model at Wave 3.

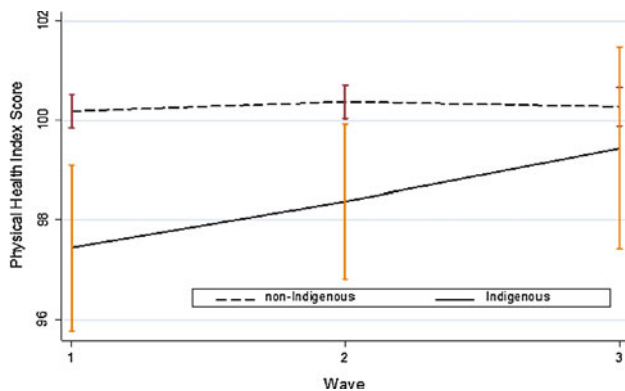
##### *K-Cohort*

The previous POIs were significant predictors of the POIs at the immediate following waves for both Indigenous and non-Indigenous groups (Table 5). For the non-Indigenous group, prior lower SEPs were associated with worsening POIs for the following waves (Wave 2:  $\beta = 0.78$ , 95% CI: 0.37–1.19; Wave 3:  $\beta = 0.66$ , 95% CI: 0.32–1.00). In addition, lower birth weight ( $\beta = -1.51$ , 95% CI: −2.65 to −0.38); poorer neighbourhood liveability ( $\beta = -0.70$ , 95% CI: −1.36 to −0.04); and poorer neighbourhood facilities ( $\beta = 0.60$ , 95% CI: 0.17–1.03) in Wave 1 were significant predictors of worsening POIs in Wave 2. The carer's depression scale ( $\beta = 0.86$ , 95% CI 0.21–1.50) and frequent binge drinking status ( $\beta = 0.89$ , 95% CI: 0.07–1.71) in Wave 2 were significant predictors for POIs in Wave 3. For the Indigenous group in Wave 2, previously owning a home was a strong predictor of better health

**Table 3** Comparison of changes in health outcomes over time

Indigenous status	N	Mean POI score (SE)	P value	Health rating as very good or excellent	P value
<b>B-cohort</b>					
0–1 years					
Indigenous	229	97.5 (0.86)	0.002	78.1	<0.001
Non-Indigenous	4,159	100.2 (0.17)		87.9	
2–3 years					
Indigenous	180	98.4 (0.82)	0.015	79.5	0.011
Non-Indigenous	3,806	100.4 (0.17)		86.2	
4–5 years					
Indigenous	140	99.5 (1.04)	0.422	76.3	<0.001
Non-Indigenous	3,580	100.3 (0.20)		88.9	
<b>K-cohort</b>					
4–5 years					
Indigenous	188	98.2 (0.83)	0.008	81.7	0.022
Non-Indigenous	4,000	100.4 (0.17)		88.9	
6–7 years					
Indigenous	153	98.2 (0.74)	0.003	82.4	0.022
Non-Indigenous	3,639	100.4 (0.18)		89.6	
8–9 years					
Indigenous	122	98.6 (1.10)	0.106	84.1	0.096
Non-Indigenous	3,476	100.4 (0.20)		90.1	

POI physical outcome index

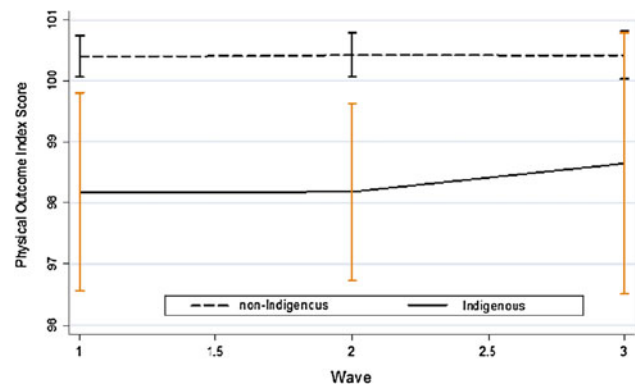


**Fig. 3** The average score of physical outcome index (B-cohort)

outcome ( $\beta = 5.86$ , 95% CI: 2.70–9.01). In Wave 3, there was an inverse relationship between previous SEIFA score and current POI for Indigenous children. No significant relationships were detected with other predictor variables.

Autoregressive Analysis for Global Health Rating

Table 6 shows the results of autoregressive analysis for parent-reported health rating of their children (yes or no for very good or excellent health status). The results were



**Fig. 4** The average score of physical outcome index (K-cohort)

displayed by Odds Ratio (OR) with 95% CI. No significant interactions were found for a time-lag health rating with waves, or with Indigenous status. Therefore, we did not separate the models by wave or Indigenous status.

The previous health ratings were significant predictors of the ratings in the immediately following waves in both cohorts, and the effect in the K-cohort was stronger than that in the B-cohort. In both cohorts, carer’s depression scale, SEP and neighbourhood liveability at earlier time

**Table 4** Autoregressive models ( $\beta$ , 95% CI) for physical outcome index (POI) by Indigenous status and waves (B-cohort)

Previous measured variables	Non-Indigenous group		Indigenous group	
	Wave 2	Wave 3	Wave 2	Wave 3
Previous POI	0.23** (0.19 to 0.28)	0.47** (0.42 to 0.51)	0.05 (−0.09 to 0.19)	0.54* (0.06 to 1.01)
Time-independent				
Male vs. female	−0.55 (−1.27 to 0.18)	−0.27 (−0.94 to 0.41)	0.89 (−2.76 to 4.54)	−5.15 (−12.89 to 2.59)
Low birth-weight vs. normal	−0.99 (−3.20 to 1.22)	−1.31 (−3.22 to 0.61)	2.99 (−3.85 to 9.84)	1.32 (−3.93 to 6.57)
Time-dependent				
Both parents vs. single	1.81 (−0.02 to 3.65)	−0.50 (−2.16 to 1.16)	2.01 (−2.46 to 6.47)	−0.93 (−9.47 to 7.61)
Carer's depression score	1.79** (1.11 to 2.48)	1.48** (0.64 to 2.33)	2.81 (−0.27 to 5.89)	3.41 (−0.16 to 6.98)
Carer's frequent binge drinking behaviour (yes vs. no)	0.96 (−0.53 to 2.44)	0.27 (−1.00 to 1.55)	−7.29* (−13.05 to −1.54)	4.03 (−3.17 to 11.23)
Carer's smoking behaviour (yes vs. no)	−0.67 (−1.68 to 0.35)	−0.16 (−1.16 to 0.83)	−1.34 (−5.05 to 2.38)	3.69 (−0.63 to 8.02)
Socio-economic position	0.02 (−0.40 to 0.43)	0.25 (−0.20 to 0.69)	0.10 (−2.28 to 2.48)	0.32 (−3.67 to 4.31)
SEIFA score	−0.01 (−0.01 to 0.00)	−0.00 (−0.01 to 0.00)	−0.01 (−0.04 to 0.02)	−0.04 (−0.10 to 0.01)
Home ownership (yes vs. no)	0.45 (−0.35 to 1.25)	0.75 (−0.09 to 1.59)	−0.41 (−4.17 to 3.35)	0.47 (−3.30 to 4.25)
Neighbourhood liveability	−0.79 (−1.66 to 0.07)	−0.48 (−1.48 to 0.52)	−5.91* (−10.75 to −1.08)	0.72 (−4.04 to 5.48)
Neighbourhood facilities	−0.05 (−0.61 to 0.51)	−0.19 (−0.75 to 0.38)	3.21* (0.43 to 5.99)	1.05 (−2.56 to 4.66)
Constant	74.43** (65.78 to 83.08)	52.63** (44.03 to 61.23)	97.05** (51.32 to 142.79)	71.68* (14.12 to 129.23)
Observations	3,371	2,838	114	70

SEIFA Socio-Economic Indices for Areas; \*  $P < 0.05$ ; \*\*  $P < 0.01$

**Table 5** Autoregressive models ( $\beta$ , 95% CI) for physical outcome index (POI) by Indigenous status and waves (K-cohort)

Previous measured variables	Non-Indigenous group		Indigenous group	
	Wave 2	Wave 3	Wave 2	Wave 3
Previous POI	0.60** (0.56 to 0.65)	0.70** (0.66 to 0.73)	0.38** (0.19 to 0.56)	0.70** (0.42 to 0.99)
Time-independent				
Male vs. female	−0.22 (−0.81 to 0.37)	−0.15 (−0.71 to 0.40)	2.37 (−0.02 to 4.76)	−1.39 (−5.39 to 2.62)
Low birth-weight (yes vs. no)	−1.51** (−2.65 to −0.38)	0.04 (−1.20 to 1.27)	0.94 (−4.76 to 6.64)	3.13 (−2.63 to 8.89)
Time-dependent				
Both parents vs. single	−0.57 (−1.56 to 0.42)	1.01 (−0.11 to 2.12)	0.26 (−2.56 to 3.08)	1.74 (−5.23 to 8.71)
Carer's depression score	0.39 (−0.22 to 1.00)	0.86** (0.21 to 1.50)	0.79 (−1.45 to 3.03)	0.61 (−2.35 to 3.57)
Carer's frequent binge drinking behaviour (yes vs. no)	0.86 (−0.03 to 1.76)	0.89* (0.07 to 1.71)	0.59 (−3.75 to 4.93)	4.44 (−1.27 to 10.14)
Carer's smoking behaviour (yes vs. no)	−0.19 (−1.00 to 0.62)	−0.38 (−1.12 to 0.37)	−2.65 (−5.78 to 0.49)	−2.56 (−8.49 to 3.37)
Socio-economic position	0.78** (0.37 to 1.19)	0.66** (0.32 to 1.00)	−1.29 (−3.26 to 0.67)	1.93 (−1.10 to 4.97)
SEIFA score	0.00 (−0.00 to 0.00)	0.00 (−0.00 to 0.01)	−0.00 (−0.03 to 0.02)	−0.04** (−0.06 to −0.01)
Home ownership (yes vs. no)	0.20 (−0.55 to 0.94)	0.37 (−0.39 to 1.13)	5.86** (2.70 to 9.01)	2.17 (−4.15 to 8.49)
Neighbourhood liveability	−0.70* (−1.36 to −0.04)	−0.32 (−0.91 to 0.28)	−2.45 (−5.55 to 0.65)	2.12 (−1.65 to 5.88)
Neighbourhood facilities	0.60** (0.17 to 1.03)	0.02 (−0.38 to 0.42)	−0.16 (−1.84 to 1.52)	−1.57 (−4.57 to 1.44)
Constant	38.37** (31.98 to 44.76)	24.68** (18.12 to 31.23)	63.55** (39.64 to 87.46)	61.81** (18.13 to 105.48)
Observations	3,098	2,634	94	57

SEIFA Socio-Economic Indices for Areas; \*  $P < 0.05$ ; \*\*  $P < 0.01$

points were significantly associated with the health rating at later time points. In addition, lower birth weight (OR = 0.66, 95% CI 0.47–0.93) predicted worsening

health rating in the following waves in the B-cohort. No significant relationships were observed with Indigenous status and other variables in both cohorts.



**Table 6** Autoregressive models (OR, 95% CI) for parent-rated health status by cohorts

Previous measured variables	B-cohort	K-cohort
Previous health rating	1.11** (0.90 to 1.33)	1.75** (1.49 to 2.00)
Time-independent		
Male vs. female	−0.07 (−0.26 to 0.12)	−0.01 (−0.20 to 0.18)
Low birth-weight vs. normal	−0.41* (−0.75 to −0.07)	−0.16 (−0.54 to 0.23)
Indigenous status(yes)	−0.27 (−0.66 to 0.13)	0.09 (−0.47 to 0.65)
Time-dependent		
Both parents vs. single	0.23 (−0.07 to 0.52)	0.12 (−0.17 to 0.42)
Carer's depression score	0.24** (0.10 to 0.37)	0.41** (0.23 to 0.59)
Carers' frequent binge drinking(yes)	0.44* (0.10 to 0.78)	0.14 (−0.17 to 0.45)
Carers' smoking behaviour (yes)	0.04 (−0.03 to 0.11)	0.02 (−0.05 to 0.09)
Socioeconomic position	0.11* (0.01 to 0.21)	0.20** (0.08 to 0.32)
SEIFA score	0.00 (−0.00 to 0.00)	−0.00 (−0.00 to 0.00)
Home ownership (yes)	0.18 (−0.00 to 0.37)	0.17 (−0.05 to 0.39)
Neighbourhood liveability	−0.23* (−0.43 to −0.03)	−0.25* (−0.47 to −0.03)
Neighbourhood facility	−0.03 (−0.16 to 0.10)	0.02 (−0.15 to 0.19)
Constant	0.09 (−1.44 to 1.62)	−0.52 (−2.42 to 1.39)
Observations	6,406	5,894

SEIFA Socio-Economic Indices for Areas; \*  $P < 0.05$ ; \*\*  $P < 0.01$

## Discussions

The present study uses the longitudinal data from an Australian national representative sample in order to provide a comprehensive description of changes in health disparities between Indigenous and non-Indigenous Australian children aged between 0 and 9 years. We used two health indicators—the POI based on broad physical functioning as well as the parent-rated health status, and examined health disparity and its contributing factors at two follow-up periods in the two birth cohorts. Our study showed that a plethora of potential risk factors may contribute to the improvement or worsening of the health outcomes over an extended period of time.

Composite health outcomes between Indigenous and non-Indigenous children were narrowed over time between Waves 1 and 3. Despite the argument that there are inadequate or misdirected efforts in many aspects, the narrowing gap over time may be encouraging [23–25]. However, the persistent gap in parent-rated health outcomes was still alarming. The differential results between the POI and parent-rated health status may be attributed to the content and the scales of both measures. For the POI, it is a standardised index based on multiple domains such as special health care needs, health problems, weight status, PedsQL, as well as parent-rated health status measured in a 5-point Likert scale. In contrast, parent-rated health status in the present study was collapsed into a dichotomous variable for simplicity. There are a few caveats when interpreting the positive gap narrowing results. First, the

wide confidence interval for the result in Wave 3 is as a result of the small sample size for Indigenous children. Thus, we may have low power for detecting the difference. Second, those families from a lower SEP background and non-Indigenous background were more likely to drop out of the study which may introduce a selection bias [26, 27]. It is possible that the health gap between Indigenous and non-Indigenous children was underestimated at the time point of Wave 3.

Previous literature identified the carer's depression scale, carer's health behaviour, SEP, and neighbourhood characteristics as significant predictors for concurrent health outcome [5, 6, 10], as well as for a longer lasting effect on later adult health [5, 6, 8–10, 28]. The literature also showed that excessive consumption of alcohol or cigarettes among Indigenous carers, to some extent, led to financial or depression problems and resulted in poor care for their children [29, 30]. Our findings support the hypothesis that the previous carer's depression scale, SEP and neighbourhood liveability and facilities predict later POIs, despite the influence varying across the time-periods between the study populations and the birth cohorts. The results suggest different focuses and intervention strategies to improve POI. Further, the understanding of the critical and sensible time period effects may benefit policy decision-making in health interventions targeting the improvement of health outcomes during the life-course [31, 32].

In contrast to the varying effects on the composite health outcome, the significant impact of carer's depression status, SEP and neighbourhood liveability on parent-rated

health were remarkably consistent across time-periods, between study groups and birth cohorts, except for the impacts of low birth weight and carer's binge drinking behaviour on parent-rated health which were more pronounced in the B-cohort. These results reflect the fact that children's early health experiences are primarily influenced by the family environment, such as the carer's depression and SEP, as well as by the neighbourhood liveability.

We found that low birth weight had no impact on the change of POI for both Indigenous and non-Indigenous groups in the B-cohort but had an earlier effect on the K-cohort for non-Indigenous group, implying a possible lasting adverse effect on health outcomes among earlier periods of childhood. Literature demonstrates that low birth weight adversely affects health outcomes such as being associated with low-grade inflammation, a higher chance of obesity in early adulthood, and a negative impact on cardiovascular diseases [33]. A recent study also showed an interwoven, trans-generational effect of poorer SEP and low birth weight on later life health outcomes [34]. These findings further suggest the importance of monitoring and specific policy interventions for Indigenous children with low birth weight in early childhood in order to avoid its deleterious adverse effects in later life.

Evidence for the roles of individual, socio-economic and neighbourhood characteristics in moulding a child's health in its early life-course is fairly strong in the study. Our study was based on the life-course epidemiology concept [28, 35–37]. The life-course perspective concentrates on understanding early-life experiences and how they can shape health across an entire lifetime and potentially across generations by systematically concentrating on the role of context, including the social and physical context along with biological factors, over time. This approach is particularly relevant to understanding and addressing health disparities as many social and physical contextual factors such as socio-economic status and neighbourhood liveability may play a role in the early childhood period.

To our knowledge, this is the first national longitudinal study to explore the issues of health disparity between the two populations, which covered individual, socio-economic and neighbourhood characteristics in an Australian setting. Our study is unique in that it is the first of its kind in terms of the study sample, research focus, theoretical conceptualisation and the analytic approach to assist in understanding the changing health gap between Indigenous and non-Indigenous children in Australia. Previous studies, with respect to Indigenous child health, may suffer from the limitations of being mostly cross-sectional analyses which did not adequately address the developmental outcomes [38] and were limited in drawing causal inferences [39].

Our study has its limitations. One limitation of the current study is that it has not included the information

regarding the important historical factors such as colonialism and oppression that may have adversely influenced the health outcomes of Indigenous children [40]. While employing the longitudinal data from a national representative study, the interpretations were inevitably limited by its missing values due to non-response at follow-up. Also, the subsample for Indigenous children was relatively small which may be less representative for an Indigenous child population. In addition, the current analysis employing only three-wave data may have limited power to explain the long-term causal relationships. Further study is needed to identify the robust causal pathways in closing Indigenous health gaps over time.

## Conclusion

The health gap between Indigenous and non-Indigenous children is closing for the composite health outcome measure but not for parent-rated health. Carer's depression status, SEP and neighbourhood liveability had a significant and consistent impact on later parent-rated health but had varying impacts on the composite health outcome across time-periods, between study populations and birth cohorts. Low birth weight, carer's binge drinking behaviour and other risk factors showed such varying impacts at a particular time period. The study implies that appropriate interventions accompanied by monitoring of health outcomes are necessary in order to decrease the gaps in health outcomes between Indigenous and non-Indigenous children. Continuing efforts are needed to monitor a broad array of health outcomes and to identify unique intervention opportunities in a life-course perspective.

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