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# BMJ Open Differences in birth weight between immigrants' and natives' children in Europe and Australia: a LifeCycle comparative observational cohort study

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## ABSTRACT

**Objective** Research on adults has identified an immigrant health advantage, known as the 'immigrant health paradox', by which migrants exhibit better health outcomes than natives. Is this health advantage transferred from parents to children in the form of higher birth weight relative to children of natives?

**Setting** Western Europe and Australia.

**Participants** We use data from nine birth cohorts participating in the LifeCycle Project, including five studies with large samples of immigrants' children: Etude Longitudinale Française depuis l'Enfance—France (N=12 494), the Raine Study—Australia (N=2283), Born in Bradford—UK (N=4132), Amsterdam Born Children and their Development study—Netherlands (N=4030) and the Generation R study—Netherlands (N=4877). We include male and female babies born to immigrant and native parents.

**Primary and secondary outcome measures** The primary outcome is birth weight measured in grams. Different specifications were tested: birth weight as a continuous variable including all births (DV1), the same variable but excluding babies born with over 4500 g (DV2), low birth weight as a 0–1 binary variable (1=birth weight below 2500 g) (DV3). Results using these three measures were similar, only results using DV1 are presented.

Parental migration status is measured in four categories: both parents natives, both born abroad, only mother born abroad and only father born abroad.

**Results** Two patterns in children's birth weight by parental migration status emerged: higher birth weight among children of immigrants in France (+12 g,  $p<0.10$ ) and Australia (+40 g,  $p<0.10$ ) and lower birth weight among children of immigrants in the UK (–82 g,  $p<0.05$ ) and the Netherlands (–80 g and –73 g,  $p<0.001$ ) compared with natives' children. Smoking during pregnancy emerged as a mechanism explaining some of the birth weight gaps between children of immigrants and natives.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study includes data from nine cohorts in six countries, allowing for a comparison of varied national contexts and diverse immigrant groups.
- ⇒ Results are based on a large combined sample of more than 38 000 children.
- ⇒ The use of harmonised health outcomes and sociodemographic variables, as well as standardised statistical analyses enables a rigorous multinational comparative study.
- ⇒ Yet, some of the cohort samples are representative at the national level while others are at the local level, which limits the generalisability of the findings for certain cohorts.
- ⇒ Some of the most vulnerable, recently arrived immigrant groups may be underrepresented in certain cohorts, potentially biasing the results for these immigrant communities.

**Conclusion** The immigrant health advantage is not universally transferred to children in the form of higher birth weight in all host countries. Further research should investigate whether this cross-national variation is due to differences in immigrant communities, social and healthcare contexts across host countries.

## INTRODUCTION

Birth weight is an important health indicator that has been associated with lifelong development, morbidity and mortality.<sup>1–4</sup> Studies have found a U-shape relationship between birth weight and the risk of developing health problems, including cardiometabolic complications, with both low and high birth weight associated with a higher risk.<sup>4</sup>

Research on adults has identified an immigrant health advantage, known as the ‘immigrant health paradox’,<sup>5–7</sup> by which migrants appear to have better health outcomes, including lower morbidity and mortality as well as better mental health and fewer health risk behaviours, than their native counterparts, despite being on average more socioeconomically disadvantaged.<sup>8</sup> This health advantage has been hypothesised to be linked to positive premigration selectivity.<sup>7</sup> Studies using American data suggest that this health advantage can be transferred from parents to children, at least during the early years, finding healthier birth weight (ie,  $\geq 2500$  g and  $\leq 4500$  g) and lower probability of low birth weight among children of Hispanic immigrants in the USA<sup>4 9 10</sup> compared with native peers. This advantage does not appear to apply to second-generation parents and their children.<sup>11</sup>

There is a less research on these relationships in Europe, although the available evidence suggests similar patterns, that is, better birth health of children born to first-generation migrant mothers.<sup>12</sup> Little research has however investigated patterns in children’s birth weight by parental migration status through a cross-country comparative lens, particularly in Europe.<sup>13</sup> Investigating inequality in children’s birth weight according to parents’ migration status is important given its potential to inform social and health policies. Differences in national origin and host country contexts (social policies, health systems, economic opportunities, etc) are likely to shape inequalities in children’s birth outcomes as well as immigrant parents’ abilities to invest in their children’s health and transfer them health ‘capital’.<sup>2</sup> Thus, we expect that children’s birth weight by parental migrant status will vary across host countries.

Parental socioeconomic status is also an important determinant of children’s health outcomes,<sup>8 14 15</sup> and, hence, a potential confounder of the relationship between migration status and birth weight. Children of less educated parents and with low family incomes are more likely to exhibit lower birth weight.<sup>6 16 17</sup> This has led researchers to highlight the importance of considering parental socioeconomic background when investigating differences in birth outcomes according to migrant status.<sup>18</sup> Although immigrants in developed countries tend to be socioeconomically disadvantaged on average, the level of this disadvantage differs across host countries; it is therefore even more critical to consider socioeconomic status in comparative research.<sup>18</sup>

Parental health behaviours also constitute an important possible mechanism that may contribute to health inequality at birth.<sup>19</sup> The deleterious effects of mother’s smoking during pregnancy on children’s health at birth are well established in the literature.<sup>20–23</sup> Research indicates that immigrant mothers appear to have fewer health risk behaviours, such as less smoking and lower alcohol consumption.<sup>22</sup> We explore the role of maternal health behaviour (smoking during pregnancy) as a potential mechanism shaping inequalities in birth weight across migrant groups.

This study focuses on the differences in birth weight between children of natives and children of immigrants using recent data from eight European countries and Australia to investigate three questions. First, do children of immigrants exhibit higher or lower birth weight relative to children of natives? Second, how do these associations vary across host countries? Third, can maternal smoking during pregnancy explain any of these differences?

## METHODS

### Data

Data come from the Horizon 2020-funded LifeCycle Project-EU Child Cohort Network,<sup>24</sup> which comprises 19 pregnancy and childhood cohorts in Europe and Australia investigating early life health and its determinants, starting from pregnancy. LifeCycle cohorts collected data on demographic and socioeconomic characteristics, including maternal health, marital status, living arrangements, parental education, family income and parental health behaviours, among other variables.<sup>24</sup>

A total of nine cohorts collected data on migration status and were able to harmonise variables on socioeconomic and migrant status associated with health at birth. The results presented in the main text are based on five cohorts with a sufficiently large sample size ( $>1700$  children of immigrants) to conduct multivariate analyses. These cohorts include: the Etude Longitudinale Française depuis l’Enfance—ELFE (France), a nationally representative cohort study following 18 329 births in France to mothers aged 18 and over in 2011;<sup>25</sup> the Raine Study (Australia), a prospective study of 2788 babies collecting data starting in 1989 from pregnancy onwards;<sup>26</sup> the Born in Bradford—BiB study (UK) that includes data from 13 524 children born during 2007–2011 in Bradford;<sup>27</sup> the Amsterdam Born Children and their Development—ABCD study (Netherlands) including data from 11 474 pregnancies in Amsterdam between 2003 and 2004;<sup>28</sup> and the Generation R study (Netherlands) which enrolled 9153 mothers with a delivery date from April 2002 until January 2006, with a total of 9747 live born children.<sup>29</sup>

The other participating cohorts with smaller sample sizes ( $<1700$  children of immigrants) included the NINFEA study (Italy),<sup>30</sup> the Piccolipiù study (Italy),<sup>31</sup> the Infancia y Medio Ambiente (Environment and Childhood) INMA study (Spain)<sup>32</sup> and the GECKO Drenthe study (Netherlands).<sup>33</sup> Because of smaller sample sizes, it is more difficult to draw conclusions from these cohorts, nevertheless, online supplemental appendix 1 presents the sample distribution and children’s birth weight by parental migration status and maternal region of birth for participating cohorts with a small number of children of immigrants. Model results for these smaller-sample cohorts are presented in online supplemental appendix 2.

## Patient and public involvement

Participants were recruited prior to and during pregnancy, as well as in childhood. All data have been deidentified. Ethical and legal responsibility for data management and security is maintained by the source studies or home institutions.<sup>24</sup>

## Measures

The dependent variable is the child's birth weight, a continuous variable measured in grams. Different specifications of our dependent variable are tested (see the Data analysis section). Children's migration status is measured in four categories: second-generation children, with both parents born abroad; 2.5 generation children with a mother born abroad, and native-born father; 2.5 generation children with a father born abroad and a native-born mother; and natives (reference), which included children with both parents born in the host country. Mothers' region of birth was measured in 10 categories: host country (reference for each cohort study), Western Europe, Eastern Europe, Other Europe and Central Asia, East Asia and Pacific, South Asia, Middle East and North Africa, sub-Saharan Africa, Latin America and the Caribbean, and North America.

Child characteristics at birth that were used as control variables included: the child's sex; a binary indicator for multiple births (single birth, multiple birth); birth order measured with continuous variables indicating the mother's parity; and the child's gestational age (in days).

Basic controls for mother's characteristics included maternal height (cm) and pre-pregnancy weight (kg), measured as continuous variables.

We consider two indicators of socioeconomic background: mother's education and household income at the child's birth. Mother's level of education was measured in three categories: high (reference), medium and low education. Household income quintile was measured using a cohort-specific log of the equivalised total disposable household monthly income in 2011, predicted using pan-European Union Statistics on Income and Living Conditions data.<sup>34</sup> The Australian Raine Study and the Dutch ABCD cohort used a household income quartile measure (the fourth quartile being the richest), collected at ages 1 and 5, respectively.

Finally, we included a binary indicator of mother's smoking behaviour during pregnancy (0=no smoking during pregnancy, 1=any smoking during the pregnancy). Each of the participating cohorts conducted the variable harmonisation for all the variables, following strict step-by-step protocols (see <https://pubmed.ncbi.nlm.nih.gov/33884544/>). Quality control checks were conducted to ensure the correct harmonisation of variables across cohorts.

## Data analysis

After descriptive statistics analyses, we selected our analytical sample following a complete-case analysis approach. We used ordinary least square and logistic regressions to

model different specifications of birth weight. First, we modelled birth weight as a continuous variable, including all births (DV1). Second, we excluded babies born with a birth weight higher than 4500 g (DV2) given their higher risk of negative health outcomes. Finally, we modelled low birth weight as a 0–1 binary variable where 1 indicates birth weight below 2500 g (DV3). As the results for these three models were very similar, only DV1 is presented in the Results section. Models using the other specifications are available as online supplemental appendices 3 and 4.

Analyses were conducted separately for each cohort. Each cohort conducted two sets of models for all three birth weight specifications. The first set predicted birth weight regressed on children's migration status, while the second set regressed birth weight on maternal region of birth. Each set of models included three nested models. Model 1 (M1) controlled for basic characteristics at birth, including the child's sex, birth order, gestational age, and the mother's height and pre-pregnancy weight. Model 2 (M2) additionally controlled for family socioeconomic characteristics, including the mothers' education and family income. Model 3 (M3) further adjusted for mothers' smoking during pregnancy.

## RESULTS

### Birth weight differences by parental migration status

Table 1 presents the sample distribution and the average birth weight for children by parental migration status and maternal region of birth for the five largest cohorts, as well as the distribution of cases excluded from the analysis due to missing values. As table 1 shows, immigrant group representation varies by cohort. The largest immigrant groups in the Raine Study (AU) come from Western European and East Asian and Pacific countries. For ELFE (FR) the largest groups are immigrants from Middle East and North Africa followed by sub-Saharan African. For BiB (UK) the largest group come from South Asia; whereas in ABCD (NL) and Generation R (NL) the groups with the largest representations come from Latin America, the Caribbean as well as Middle East and North Africa.

Table 2 presents the first set of models predicting birth weight regressed on children's migration status and figures 1 and 2 illustrate the results of table 2. We observed two distinct patterns regarding the disparities of children's weight at birth by parental migration status in the five largest cohorts (figures 1 and 2, table 2). The 'small sample' cohorts exhibited similar patterns, but the differences were not statistically significant, possibly due to small samples of children of immigrants (online supplemental appendix 2).

In the first pattern, depicted by two cohorts, ELFE (France) and Raine (Australia), children of immigrants exhibited on average higher weight at birth relative to children of natives, as shown in figure 1. For ELFE, M1 (grey bars) shows a slight tendency for children of immigrants to be born with higher weight than children with

**Table 1** Cohort sample distribution and children's birth weight (in grams) by migration status and mother's region of origin (large cohorts)

|                                      | Raine Study (AU) |             |             | ELFE (FR)     |             |             | BiB (UK)      |             |             | ABCD (NL)     |             |             | Gen R (NL)  |             |             |
|--------------------------------------|------------------|-------------|-------------|---------------|-------------|-------------|---------------|-------------|-------------|---------------|-------------|-------------|-------------|-------------|-------------|
|                                      | Freq.            | Weight      |             | Freq.         | Weight      |             | Freq.         | Weight      |             | Freq.         | Weight      |             | Freq.       | Weight      |             |
|                                      |                  | %           | Mean        |               | %           | Mean        |               | %           | Mean        |               | %           | Mean        |             | %           | Mean        |
| Children's migration status          |                  |             |             |               |             |             |               |             |             |               |             |             |             |             |             |
| 2nd generation                       | 697              | 25.0        | 3314        | 1289          | 7.0         | 3349        | 2488          | 18.5        | 3186        | 2165          | 18.9        | 3313        | 1887        | 19.4        | 3321        |
| 2.5 gen. (immigrant mother)          | 407              | 14.6        | 3303        | 918           | 5.0         | 3344        | 1595          | 11.7        | 3112        | 743           | 6.5         | 3393        | 767         | 7.9         | 3397        |
| 2.5 gen. (immigrant father)          | 437              | 15.7        | 3363        | 1159          | 6.3         | 3348        | 1831          | 13.5        | 3120        | 943           | 8.2         | 3362        | 1040        | 10.7        | 3318        |
| Natives                              | 1137             | 40.8        | 3288        | 13 257        | 72.3        | 3308        | 5224          | 38.7        | 3293        | 3957          | 34.5        | 3455        | 4588        | 47.1        | 3452        |
| Missing                              | 110              | 3.9         | 2677        | 1706          | 9.3         | 3243        | 2386          | 17.6        | 3162        | 3666          | 32.0        | 3368        | 1465        | 15.0        | 3309        |
| <b>Total</b>                         | <b>2788</b>      | <b>100</b>  | <b>3284</b> | <b>18 329</b> | <b>100</b>  | <b>3309</b> | <b>13 524</b> | <b>100</b>  | <b>3205</b> | <b>11 474</b> | <b>100</b>  | <b>3389</b> | <b>9747</b> | <b>100</b>  | <b>3387</b> |
| Mother's region of birth             |                  |             |             |               |             |             |               |             |             |               |             |             |             |             |             |
| Host country-born                    | 1608             | 57.7        | 3305        | 14 839        | 81.0        | 3307        | 7084          | 52.4        | 3247        | 4985          | 43.4        | 3435        | 5929        | 60.8        | 3419        |
| Western EU/EEA                       | 620              | 22.2        | 3344        | 278           | 1.5         | 3313        | 91            | 0.7         | 3256        | 401           | 3.5         | 3423        | 436         | 4.5         | 3408        |
| Eastern EU                           | 33               | 1.2         | 3414        | 101           | 0.6         | 3410        | 243           | 1.8         | 3388        | 67            | 0.6         | 3390        | 56          | 0.6         | 3333        |
| Other Europe and Central Asia        | 0                | 0           | 0           | 140           | 0.8         | 3341        | 27            | 0.2         | 3490        | 390           | 3.4         | 3384        | 587         | 6.0         | 3422        |
| East Asia and Pacific                | 300              | 10.8        | 3264        | 129           | 0.7         | 3354        | 121           | 0.9         | 3272        | 151           | 1.3         | 3409        | 200         | 2.1         | 3304        |
| South Asia                           | 55               | 2.0         | 3152        | 23            | 0.1         | 3162        | 3291          | 24.2        | 3118        | 145           | 1.3         | 3199        | 31          | 0.3         | 3393        |
| Middle East and North Africa         | 15               | 0.5         | 3298        | 858           | 4.7         | 3392        | 78            | 0.6         | 3423        | 729           | 6.4         | 3444        | 533         | 5.5         | 3531        |
| Sub-Saharan Africa                   | 60               | 2.2         | 3219        | 604           | 3.3         | 3297        | 219           | 1.7         | 3232        | 344           | 3.0         | 3226        | 363         | 3.7         | 3236        |
| Latin America and Caribbean          | 16               | 0.6         | 3320        | 125           | 0.7         | 3230        | 12            | 0.1         | 3011        | 666           | 5.8         | 3201        | 884         | 9.1         | 3200        |
| North America                        | 12               | 0.4         | 3404        | 18            | 0.1         | 3131        | 15            | 0.1         | 3354        | 67            | 0.6         | 3421        | 39          | 0.4         | 3391        |
| Missing                              | 69               | 2.5         | 2412        | 1214          | 6.6         | 3282        | 2343          | 17.3        | 3164        | 3529          | 30.8        | 3366        | 689         | 7.1         | 3300        |
| <b>Total</b>                         | <b>2788</b>      | <b>100</b>  | <b>3284</b> | <b>18 329</b> | <b>100</b>  | <b>3309</b> | <b>13 524</b> | <b>100</b>  | <b>3205</b> | <b>11 474</b> | <b>100</b>  | <b>3389</b> | <b>9747</b> | <b>100</b>  | <b>3387</b> |
| <b>Missing cases in analyses (n)</b> |                  |             |             |               |             |             |               |             |             |               |             |             |             |             |             |
| Birth weight                         | 80               | -           | -           | 503           | -           | 334         | -             | -           | 921         | -             | -           | -           | 90          | -           | -           |
| Child and mother's controls          | 112              | 2520        | 531         | 8097          | 3301        | 3307        | 3197          | 3307        | 3370        | 2376          | 3349        | 3349        | 3326        | 3341        | 3343        |
| Migration status                     | 44               | 3178        | 1495        | 2386          | 3239        | 3162        | 148           | 3304        | 3311        | 1768          | 3341        | 3341        | 3341        | 3341        | 3341        |
| Missing other variables              | 269              | 3286        | 3306        | 3564          | 3261        | 3068        | 3183          | 3068        | 3311        | 1768          | 3341        | 3341        | 3341        | 3341        | 3341        |
| Total excluded cases                 | <b>505</b>       | <b>2985</b> | <b>5835</b> | <b>9392</b>   | <b>3259</b> | <b>7444</b> | <b>3198</b>   | <b>7444</b> | <b>3344</b> | <b>4870</b>   | <b>3343</b> | <b>3343</b> | <b>3343</b> | <b>3343</b> | <b>3343</b> |

ABCD, Amsterdam Born Children and their Development; AU, Australia; BiB, Born in Bradford; EEA, European Economic Area; ELFE, Etude Longitudinale Française depuis l'Enfance; EU, European Union; Gen R, Generation R.

**Table 2** Ordinary least square regression coefficients of children's migration status on child's birth weight (large cohorts)

|                               | ELFE (FR)  |            |            | Raine Study (AU) |            |            | BIB (UK)       |            |            |
|-------------------------------|------------|------------|------------|------------------|------------|------------|----------------|------------|------------|
|                               | M1         | M2         | M3         | M1               | M2         | M3         | M1             | M2         | M3         |
| <b>DV1: birth weight</b>      |            |            |            |                  |            |            |                |            |            |
| Children's migration status   |            |            |            | Child controls   | SES        | Smoked     | Child controls | SES        | Smoked     |
| Natives (ref.)                |            |            |            |                  |            |            |                |            |            |
| 2nd generation                | 11.9       | 42.5*      | 13         | 39.8             | 34.4       | 16.7       | -81.5***       | -83.4***   | -118.8***  |
| 2.5 generation (mother)       | 47.6**     | 53.9***    | 43.2**     | 41.4             | 38         | 32.6       | -97.8***       | -94.7***   | -132.8***  |
| 2.5 generation (father)       | 3.2        | 16.7       | 11.6       | 48.1             | 46.7       | 38.2       | -117***        | -120.8***  | -147.8***  |
| Child controls                |            |            |            |                  |            |            |                |            |            |
| Female                        | -149.3***  | -149.2***  | -150.2***  | -130.2***        | -129.8***  | -123.3***  | -145.4***      | -143.5***  | -144.6***  |
| Plural birth†                 | -372.1***  | -374.2***  | -378***    | 0                | 0          | 0          | -311.2***      | -305***    | -309.9***  |
| Mother's parity (birth order) | 49.9***    | 54.9***    | 54***      | 64.8***          | 65.3***    | 64.7***    | 54.8***        | 62.7***    | 59.8***    |
| Gestational age               | 23.7***    | 23.6***    | 23.5***    | 20***            | 20***      | 20.1***    | 25.3***        | 25.3***    | 25.2***    |
| Mother controls               |            |            |            |                  |            |            |                |            |            |
| Height                        | 9***       | 8.5***     | 8.7***     | 11***            | 10.7***    | 11***      | 11.3***        | 10.9***    | 11.1***    |
| Pre-pregnancy weight          | 4.7***     | 5***       | 4.9***     | 5.6***           | 5.7***     | 5.5***     | 5.6***         | 5.6***     | 5.6***     |
| <b>SES</b>                    |            |            |            |                  |            |            |                |            |            |
| Education‡                    |            |            |            |                  |            |            |                |            |            |
| High (ref.)                   |            |            |            |                  |            |            |                |            |            |
| Medium                        |            | -11        | -2.7       |                  | 16.4       | 18.5       |                | -0.7       | 1.7        |
| Low                           |            | -34.8*     | -15.9      |                  | -1         | 19.5       |                | -24.9      | -21.9      |
| Household income quintiles§   |            |            |            |                  |            |            |                |            |            |
| 1st quintile (ref.)           |            |            |            |                  |            |            |                |            |            |
| 2nd quintile                  |            | 52.3***    | 44.9***    |                  | -6.2       | 4.9        |                | 1.7        | -9.7       |
| 3rd quintile                  |            | 50.2***    | 32.9*      |                  | -31.4      | -13.7      |                | -38        | -22.9      |
| 4th quintile                  |            | 57.3***    | 36.9*      |                  | -30.6      | 2.3        |                | -38.8      | -27.7      |
| 5th quintile                  |            | 60.8***    | 36.4*      |                  | -          | -          |                | -68.6**    | -31        |
| Mother smoked (pregnancy)     |            |            |            |                  |            |            |                |            |            |
| Constant                      | -5049.5*** | -4996.3*** | -4972.1*** | -4281.4***       | -4236.2*** | -4261.9*** | -5889.6***     | -5810.7*** | -5766.4*** |
| N                             | 12 494     | 12 494     | 12 494     | 2283             | 2283       | 2283       | 4132           | 4132       | 4132       |
| R <sup>2</sup>                | 0.358      | 0.361      | 0.369      | 0.379            | 0.38       | 0.393      | 0.489          | 0.492      | 0.498      |

Continued

Table 2 Continued

|                               | ABCD (NL)             |            |               | Gen R (NL)            |            |               |
|-------------------------------|-----------------------|------------|---------------|-----------------------|------------|---------------|
|                               | M1                    | M2         | M3            | M1                    | M2         | M3            |
| <b>DV1: birth weight</b>      | <b>Child controls</b> | <b>SES</b> | <b>Smoked</b> | <b>Child controls</b> | <b>SES</b> | <b>Smoked</b> |
| Children's migration status   |                       |            |               |                       |            |               |
| Natives (ref.)                |                       |            |               |                       |            |               |
| 2nd generation                | -80.1***              | -52.6*     | -66.5**       | -73.4***              | -33.6      | -50.2*        |
| 2.5 generation (mother)       | 14.6                  | 23.3       | 14.9          | 26.7                  | 42.5       | 36.4          |
| 2.5 generation (father)       | -78.3***              | -65.6**    | -61.5**       | -75.3***              | -53.9**    | -51.1**       |
| Child controls                |                       |            |               |                       |            |               |
| Female                        | -121.9***             | -123.4***  | -123.6***     | -106.8***             | -107.2***  | -108.2***     |
| Plural birth†                 | 0                     | 0          | 0             | -404.8***             | -408.5***  | -409.1***     |
| Mother's parity (birth order) | 82***                 | 84.3***    | 83.1***       | 109.3***              | 111.8***   | 109.3***      |
| Gestational age               | 25.7***               | 25.6***    | 25.6***       | 26.1***               | 26***      | 25.9***       |
| Mother controls               |                       |            |               |                       |            |               |
| Height                        | 10.4***               | 9.5***     | 9.5***        | 10.1***               | 9.2***     | 9.3***        |
| Pre-pregnancy weight          | 4.6***                | 5***       | 4.9***        | 4.5***                | 4.8***     | 4.7***        |
| <b>SES</b>                    |                       |            |               |                       |            |               |
| Education‡                    |                       |            |               |                       |            |               |
| High (ref.)                   |                       |            |               |                       |            |               |
| Medium                        |                       | -54.9***   | -44.1**       |                       | -10        | -7.3          |
| Low                           |                       | -59.7**    | -38.2         |                       | -30.7      | -23           |
| Household income quintiles§   |                       |            |               |                       |            |               |
| 1st quintile (ref.)           |                       |            |               |                       |            |               |
| 2nd quintile                  |                       | 2.7        | 5.9           |                       | 21.4       | 15.2          |
| 3rd quintile                  |                       | -3.9       | 5.9           |                       | 56.1*      | 42.9          |
| 4th quintile                  |                       | -30.6      | -18.1         |                       | 77.1*      | 56.4          |
| 5th quintile                  |                       | -          | -             |                       | 84.2*      | 63.1          |
| Mother smoked (pregnancy)     |                       |            | -135.5***     |                       |            | -79.5***      |
| Constant                      | -5733.5***            | -5573.2*** | -5550.5***    | -5951.2***            | -5823.6*** | -5780.1***    |
| N                             | 4030                  | 4030       | 4030          | 4877                  | 4877       | 4877          |

Continued

Table 2 Continued

|   | ABCD (NL)      |       | Gen R (NL)     |      |
|---|----------------|-------|----------------|------|
|   | M1             | M2    | M1             | M2   |
| DV1: birth weight   | Child controls | SES   | Child controls | SES  |
| R <sup>2</sup>  | 0.401          | 0.404 | 0.46           | 0.46 |
| M1: basic child and mother's controls at birth. M2: M1 + socioeconomic status (SES) variables. M3: M2 + mother's smoking during pregnancy.<br>*p<0.05, **p<0.01, ***p<0.001.<br>†The ABCD and the Raine Study cohorts only included single births in their sample.<br>‡Level of education based on the highest ongoing or completed education when the child was 0 years old (between >–1 year and <1 year). If more than one education level is reported within the defined time frame, we used the highest recorded education level. Classification according to International Standard Classification of Education 97/2011 (ISCED-97/2011). High: short cycle tertiary, bachelor, masters, doctoral or equivalent (ISCED-2011: 5-8, ISCED-97: 5-6). Medium: upper secondary, post-secondary non-tertiary (ISCED-2011: 3-4, ISCED-97: 3-4). Low: no education; early childhood; pre-primary; primary; lower secondary or second stage of basic education (ISCED-2011: 0-2, ISCED-97: 0-2).<br>§European Union Statistics on Income and Living Conditions income quintiles for all cohorts except for Raine (AU) and ABCD (NL) that measured household income in quartiles.<br>ABCD, Amsterdam Born Children and their Development; AU, Australia; BiB, Born in Bradford; ELFE, Etude Longitudinale Française depuis l'Enfance; Gen R, Generation R. |                |       |                |      |

both native parents only among 2.5 generation, immigrant mothers (+48 g,  $p<0.001$ ). For the ELFE cohort, adjusting for socioeconomic characteristics in M2 (white bars), children of immigrants' weight *increased* compared with natives and was significant for the 2nd generation (+43 g,  $p<0.05$ ) and the 2.5 generation mother (+54 g,  $p<0.001$ ). By contrast, for the Raine Study, controlling for socioeconomic factors somewhat *decreased* children of immigrants' birth weight relative to children of natives, the few marginally significant differences became non-statistically significant. M3, which additionally controlled for mothers' smoking during pregnancy (black bars), showed a reduction in the magnitude of the coefficients for children of immigrants for both cohorts, which is still significant and positive for ELFE's 2.5 generation mother (+43 g,  $p<0.01$ ).

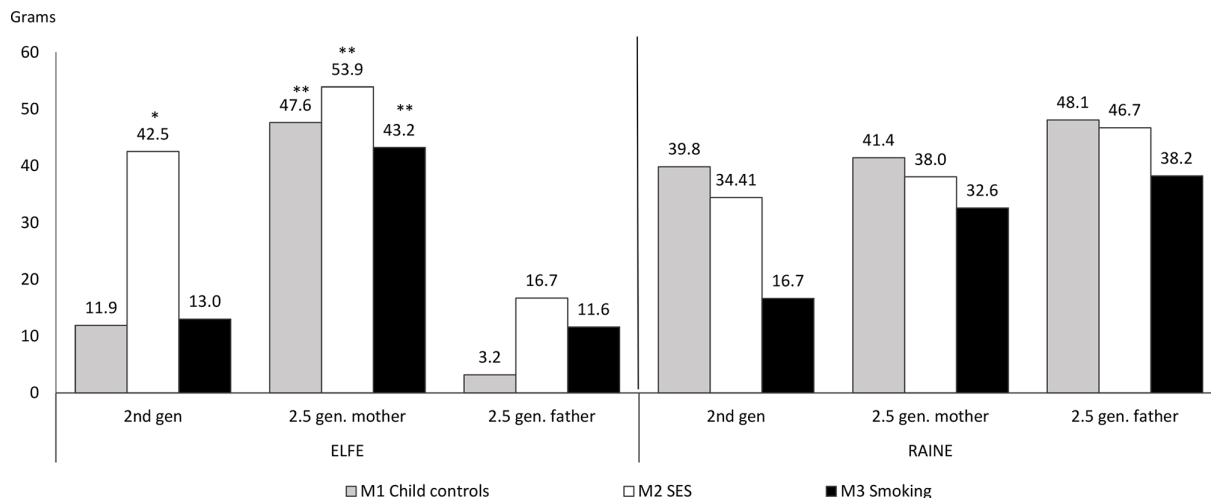
The opposite pattern is observed in [figure 2](#) M1, where children of immigrants exhibit lower birth weights compared with children of natives. This pattern characterises the BiB (Bradford, UK), the ABCD (Amsterdam, Netherlands) and the Generation R (Rotterdam, Netherlands) cohorts. Exceptions to this pattern are 2.5 generation children with an immigrant mother in the two Dutch cohorts, where no significant differences from natives' birth weight could be detected.

For the Dutch cohorts (ABCD and Generation R), the differences in birth weight for children with two immigrant parents and for those with one immigrant father are somewhat reduced after controlling for socioeconomic characteristics (M2), suggesting that the lower birth weight might be due to immigrants' disadvantaged socioeconomic position within the host country. By contrast socioeconomic factors do not seem to play an important role in explaining birth weight differences for the BiB (UK) cohort.<sup>35</sup>

As in the first group, mothers' smoking during pregnancy had a negative effect on children's birth weight. Despite mothers' lower prevalence of smoking during pregnancy, children of immigrants' still exhibit lower birth weight than children of natives after controlling for this variable. As shown in [figure 2](#), for BiB birth weight gaps tend to increase in magnitude after controlling for smoking during pregnancy (M3, 2nd generation –119 g,  $p<0.001$ , 2.5 gen-mother –133 g,  $p<0.001$  and 2.5 gen-father –148 g,  $p<0.001$ ), indicating that if immigrant mothers smoked as much as native mothers, children of immigrants' birth weight would be even lower. For ABCD and Gen R, smoking has a smaller effect, but it slightly increased the gap for the second generation (–67 g,  $p<0.01$  for ABCD, and –50 g,  $p<0.05$  for Gen R). The mothers' height and pre-pregnancy weight are positively and similarly associated with the child's birth weight for all cohorts.

In sum, we find higher birth weight for children of immigrants in our southern European studies, such as in France and in the smaller cohorts representing Italy and Spain, as well as in Australia; and lower birth weight for children of immigrants in central and northern





**Figure 1** Ordinary least square coefficients for cohorts in which children of immigrants exhibit higher birth weight (in grams). ELFE, Etude Longitudinale Française depuis l’Enfance; SES, socioeconomic status. \*p <0.05, \*\*p <0.01.

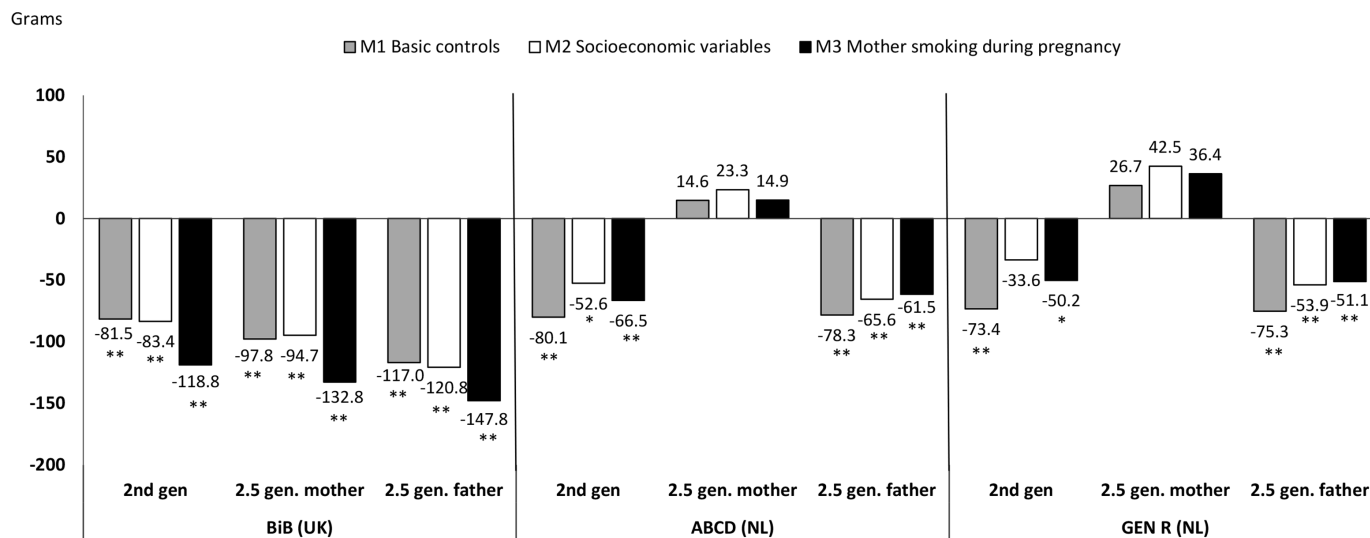
European countries, such as the UK and the Netherlands. These patterns could result from differences in the immigrants’ regions of origin across host countries. We therefore analyse birth weight differences by maternal region of origin in the next section.

**Birth weight differences by maternal region of birth**

Results from the models by mothers’ region of origin are presented in table 3. First, we observe heterogeneity in birth weight by immigrant mothers’ regions of birth. For ELFE (France), the pattern of birth weight ‘advantage’ and the changes across models are mostly driven by children of Middle East and North African immigrants, the largest immigrant group in France, as well as by children of East Asia and Pacific immigrants. However, children of sub-Saharan Africans, the second largest immigrant group in France do not appear to have statistically significantly different birth weights relative to children of

natives. Nonetheless, immigrant mothers exhibit lower smoking rates in most cohorts; thus, controlling for mother’s smoking during pregnancy (table 3) explained part of the weight ‘advantage’ for two groups (East Asia and Pacific: +132 g, p<0.01; Middle East and North Africa: +61 g, p<0.01).

In the Raine Study, children of Western Europeans, the largest immigrant group, showed slightly higher birth weight than natives, but differences were not statistically significant. Children of North American mothers also reported heavier weights at birth (M1: +374 g, p<0.01; M2: +373 g, p<0.01, M3: +355 g, p<0.01), although these estimates are based on small sample sizes. Children with a South Asian and sub-Saharan’s background tended to have lower birth weight than children of natives, but the difference was again not statistically significant.



**Figure 2** Ordinary least square regression coefficients for cohorts in which children of immigrants exhibit lower birth weight (in grams). ABCD, Amsterdam Born Children and their Development; BiB, Born in Bradford; Gen R, Generation R; SES, socioeconomic status. \*p <0.05, \*\*p <0.01.

**Table 3** Ordinary least square regression coefficients of mother's region of origin on child's birth weight (large cohorts)

| DV: birth weight              | ELFE (FR)      |           |           | Raine Study (AU) |           |           | BiB (UK)       |           |           |
|-------------------------------|----------------|-----------|-----------|------------------|-----------|-----------|----------------|-----------|-----------|
|                               | M1             | M2        | M3        | M1               | M2        | M3        | M1             | M2        | M3        |
|                               | Child controls | SES       | Smoked    | Child controls   | SES       | Smoked    | Child controls | SES       | Smoked    |
| Mother's region of origin     |                |           |           |                  |           |           |                |           |           |
| Host country-born (ref.)      |                |           |           |                  |           |           |                |           |           |
| Western EU/EEA                | 24.7           | 21        | 20.8      | 37.2             | 30.3      | 25.3      | 45.1           | 42.9      | 30.3      |
| Eastern EU                    | 97.9           | 94.6      | 85.2      | 38.1             | 37.5      | 29.9      | 44.1           | 34.6      | 29.5      |
| Other Europe and Central Asia | 5.7            | 13.8      | 1         |                  |           |           | -10.2          | 6.5       | -13.3     |
| East Asia and Pacific         | 145.3**        | 142.3**   | 131.8**   | 13.8             | 10.1      | -9        | 115.3          | 96.1      | 80.2      |
| South Asia                    | 211.9          | 211.1     | 244.7     | -51.2            | -54.2     | -87.4     | -74.1***       | -69.4***  | -94.4***  |
| Middle East and North Africa  | 60.4**         | 86.6***   | 61.2**    | 40.2             | 40.8      | 36.5      | -35.3          | -45       | -60.5     |
| Sub-Saharan Africa            | -38.5          | -9.8      | -40.1     | -35.8            | -46.9     | -67.9     | -53.8          | -58.1     | -82.1     |
| Latin America and Caribbean   | -7.1           | 8.7       | -14.5     | 165.7            | 165.7     | 126.6     |                |           |           |
| North America                 | -67.6          | -76.6     | -56.7     | 374.4**          | 373.1**   | 354.9**   | 108.7          | 86.4      | 70.2      |
| Child controls                |                |           |           |                  |           |           |                |           |           |
| Female                        | -149.5***      | -149.2*** | -150.3*** | -128.2***        | -128.3*** | -122.4*** | -143.1***      | -141.4*** | -141.9*** |
| Plural birth†                 | -372.7***      | -374.2*** | -378.6*** | 0                | 0         | 0         | -319.7***      | -313.2*** | -318.7*** |
| Mother's parity (birth order) | 50.3***        | 55.3***   | 54.2***   | 64.7***          | 65.1***   | 64***     | 52.8***        | 59.9***   | 57***     |
| Gestational age               | 23.7***        | 23.6***   | 23.5***   | 20.1***          | 20.2***   | 20.2***   | 25.4***        | 25.5***   | 25.3***   |
| Mother controls               |                |           |           |                  |           |           |                |           |           |
| Height                        | 9.1***         | 8.5***    | 8.8***    | 10.6***          | 10.3***   | 10.6***   | 11.9***        | 11.7***   | 11.9***   |
| Pre-pregnancy weight          | 4.7***         | 5***      | 4.9***    | 5.7***           | 5.8***    | 5.6***    | 5.6***         | 5.6***    | 5.6***    |
| <b>SES</b>                    |                |           |           |                  |           |           |                |           |           |
| Education‡                    |                |           |           |                  |           |           |                |           |           |
| High (ref)                    |                |           |           |                  |           |           |                |           |           |
| Medium                        |                | -11.8     | -3.2      |                  | 12.6      | 13.7      |                | 0.1       | 2.2       |
| Low                           |                | -34.4     | -15.1     |                  | -6.5      | 13.7      |                | -17.4     | -13.6     |
| Household income quintiles§   |                |           |           |                  |           |           |                |           |           |
| 1st quintile (ref.)           |                |           |           |                  |           |           |                |           |           |
| 2nd quintile                  |                | 51.2***   | 43.8***   |                  | -4.8      | 7.6       |                | 2.4       | -6.1      |
| 3rd quintile                  |                | 49.6***   | 32.2*     |                  | -35.3     | -15.1     |                | -44.4     | -33.5     |
| 4th quintile                  |                | 55.1***   | 34.4*     |                  | -37.1     | 2.3       |                | -43.7*    | -35.7     |
| 5th quintile                  |                | 58.4***   | 33.9*     |                  |           |           |                | -63.5**   | -32.2     |

Continued

Table 3 Continued

|                               | ELFE (FR)        |           |           | Raine Study (AU) |          |           | BiB (UK)       |           |           |
|-------------------------------|------------------|-----------|-----------|------------------|----------|-----------|----------------|-----------|-----------|
|                               | M1               | M2        | M3        | M1               | M2       | M3        | M1             | M2        | M3        |
| <b>DV: birth weight</b>       | Child controls   | SES       | Smoked    | Child controls   | SES      | Smoked    | Child controls | SES       | Smoked    |
| Mother smoked (pregnancy)     |                  |           | -119.8*** |                  |          | -157.5*** |                |           | -108.9*** |
| Constant                      | -5043***         | -4992***  | -4965***  | -4264***         | -4212*** | -4220***  | -6050***       | -5990***  | -5984***  |
| N                             | 12 419           | 12 419    | 12 419    | 2310             | 2310     | 2310      | 4141           | 4141      | 4141      |
| R <sup>2</sup>                | 0.358            | 0.36      | 0.369     | 0.38             | 0.38     | 0.4       | 0.485          | 0.488     | 0.492     |
|                               | <b>ABCD (NL)</b> |           |           |                  |          |           |                |           |           |
|                               | <b>M1</b>        |           |           | <b>M2</b>        |          |           | <b>M3</b>      |           |           |
| <b>DV: birth weight</b>       | Child controls   | SES       | Smoked    | Child controls   | SES      | Smoked    | Child controls | SES       | Smoked    |
| Mother's region of origin     |                  |           |           |                  |          |           |                |           |           |
| Host country-born (ref.)      |                  |           |           |                  |          |           |                |           |           |
| Western EU/EEA                | 7.8              | 10.5      | 0.8       |                  |          | 32.3      | 40.5           | 34.3      |           |
| Eastern EU                    | -99.4            | -83.2     | -90.1     |                  |          | 68.3      | 99.1           | 78.7      |           |
| Other Europe and Central Asia | 28.8             | 67.7      | 68.5      |                  |          | 11.5      | 58.5           | 52.2      |           |
| East Asia and Pacific         | 121.3*           | 134.5*    | 122.7*    |                  |          | 124**     | 143.3**        | 127.5**   |           |
| South Asia                    | -174.8**         | -144.3*   | -170.9**  |                  |          | 11.4      | 35.8           | 9.4       |           |
| Middle East and North Africa  | -6.2             | 25.7      | 1.7       |                  |          | 20.5      | 63.3           | 38.8      |           |
| Sub-Saharan Africa            | -54.6            | -19.9     | -41.1     |                  |          | -115.8**  | -68.5          | -86.9*    |           |
| Latin America and Caribbean   | -89.7**          | -63*      | -73.3*    |                  |          | -71.5**   | -37.1          | -49.8*    |           |
| North America                 | -148.5           | -143.1    | -151      |                  |          | -62.5     | -64.6          | -74.8     |           |
| Child controls                |                  |           |           |                  |          |           |                |           |           |
| Female                        | -121.7***        | -123.4*** | -124***   |                  |          | -107.8*** | -108.2***      | -109.1*** |           |
| Plural birth†                 | 0                | 0         | 0         |                  |          | -404.5*** | -409***        | -409.4*** |           |
| Mother's parity (birth order) | 80.3***          | 83.5***   | 82.3***   |                  |          | 107.1***  | 110.9***       | 108.7***  |           |
| Gestational age               | 25.7***          | 25.5***   | 25.5***   |                  |          | 26.1***   | 25.9***        | 25.9***   |           |
| Mother controls               |                  |           |           |                  |          |           |                |           |           |
| Height                        | 10.9***          | 9.7***    | 9.7***    |                  |          | 11.4***   | 10.2***        | 10.2***   |           |
| Pre-pregnancy weight          | 4.7***           | 5.3***    | 5.2***    |                  |          | 4.6       | 5***           | 4.9***    |           |
| <b>SES</b>                    |                  |           |           |                  |          |           |                |           |           |
| Education‡                    |                  |           |           |                  |          |           |                |           |           |
| High (ref)                    |                  |           |           |                  |          |           |                |           |           |
| Medium                        |                  | -66.3***  | -54.7***  |                  |          |           | -1.9           | -0.1      |           |

Continued

Table 3 Continued

|                             | ABCD (NL)             |            |               | Gen R (NL)            |            |               |
|-----------------------------|-----------------------|------------|---------------|-----------------------|------------|---------------|
|                             | M1                    | M2         | M3            | M1                    | M2         | M3            |
| <b>DV: birth weight</b>     | <b>Child controls</b> | <b>SES</b> | <b>Smoked</b> | <b>Child controls</b> | <b>SES</b> | <b>Smoked</b> |
| Low                         |                       | -78.3***   | -56*          |                       | -49.7      | -43.6         |
| Household income quintiles§ |                       |            |               |                       |            |               |
| 1st quintile (ref.)         |                       |            |               |                       |            |               |
| 2nd quintile                |                       | 0.5        | 3.9           |                       | 23.9       | 18            |
| 3rd quintile                |                       | -10.9      | -0.5          |                       | 57.2**     | 44.8*         |
| 4th quintile                |                       | -37.9      | -23.5         |                       | 93.6**     | 73.4*         |
| 5th quintile                |                       |            |               |                       | 100.9**    | 79.6*         |
| Mother smoked (pregnancy)   |                       |            | -140.1***     |                       |            | -77.3***      |
| Constant                    | -5827**               | -5598***   | -5571***      | -6189***              | -6004***   | -5962***      |
| N                           | 4072                  | 4072       | 4072          | 5123                  | 5123       | 5123          |
| R <sup>2</sup>              | 0.398                 | 0.402      | 0.408         | 0.456                 | 0.461      | 0.465         |

M1: basic child and mother's controls at birth. M2: M1 + socioeconomic status (SES) variables. M3: M2 + mother's smoking during pregnancy.  
 \*p<0.05, \*\*p<0.01, \*\*\*p<0.001.  
 †The ABCD and the Raine Study cohorts only included single births in their sample.  
 ‡Level of education based on the highest ongoing or completed education when the child was 0 years old (between >-1 year and <1 year). If more than one education level is reported within the defined time frame, we used the highest recorded education level. Classification according to International Standard Classification of Education 97/2011 (ISCED-97/2011). High: short cycle tertiary, bachelor, masters, doctoral or equivalent (ISCED-2011: 5-8, ISCED-97: 5-6), Medium: upper secondary, post-secondary non-tertiary (ISCED-2011: 3-4, ISCED-97: 3-4), Low: no education; early childhood; pre-primary; primary; lower secondary or second stage of basic education (ISCED-2011: 0-2, ISCED-97: 0-2).  
 §European Union Statistics on Income and Living Conditions income quintiles for all cohorts except for Raine (AU) and ABCD (NL) that measured household income in quartiles.  
 ABCD, Amsterdam Born Children and their Development; AU, Australia; BIB, Born in Bradford; EEA, European Economic Area; ELFE, Etude Longitudinale Française depuis l'Enfance; EU, European Union; Gen R, Generation R.

For BiB, the observed pattern is driven by children of South Asian immigrants, the largest immigrant group in Bradford, who weighed less at birth than children of natives (M1: -74 g,  $p < 0.001$ , M2: -69 g,  $p < 0.001$ , M3: -94 g,  $p < 0.001$ ). By contrast, children of European and East Asia and Pacific as well as North American immigrants showed a higher, but non-significant, birth weight than children of natives. The weight disadvantage among children of South Asian immigrants was partly explained by socioeconomic status. Adjusting to mother's smoking during pregnancy exacerbated this disadvantage.

For ABCD, children of women from South Asia and Latin America and Caribbean exhibited significantly lower birth weight, even after controls. Children of East Asian mothers had a significantly higher birth weight after controlling for socioeconomic variables and mother's smoking.

For Generation R (Rotterdam, the Netherlands), both patterns also coexist: children of women born in sub-Saharan Africa and Latin America and Caribbean exhibited significantly lower birth weight, even after controls. Children of East Asian and of other European and Central Asian mothers had, on the contrary, significantly higher birth weights.

## DISCUSSION

Research in developed countries has identified an immigrant health advantage among adults,<sup>5 7</sup> yet, evidence on whether immigrants can transfer this health advantage to their children is mixed, and remains particularly scarce in the European context.<sup>4 8 11 12</sup> This study investigates whether children of first-generation immigrants exhibit a health advantage on weight at birth, comparing eight European countries and Australia.

Prior studies on the role of immigration on birth weight have focused on Latin-American immigrants in the USA, providing mixed evidence, for example, finding lighter birth weight among Mexican and Cuban babies and heavier birth weight among Puerto Rican babies relative to US-born white women.<sup>8 9</sup> Our research extends this area of research to European countries and Australia. The first aim of this study was to evaluate whether children of immigrants exhibit a higher or lower birth weight relative to children of natives, using recent harmonised panel data of rich host countries. Two broad patterns emerged: we found higher birth weight for immigrants' children in southern European and Australian cohort studies, and lower birth weights in northern European studies, relative to natives'. This finding questions, at least when considering birth health, whether the 'healthy migrant' narrative applies to all contexts, and calls for a more nuanced approach to study this phenomenon.

Our second aim was to explore in more detail birth weight variation by mother's country of origin, controlling for the mother's height and pre-pregnancy weight. Previous studies indicate that geographic origins could be associated with children of immigrants' birth weight.

For example, previous work has highlighted higher birth weights for infants born in Spain to African and Latin-American mothers,<sup>12 36</sup> while lower mean birth weights were observed for infants born in China to Asian Indian mothers.<sup>37</sup> One of the most interesting findings in our study is that children of South Asian mothers showed consistently lower birth weights, in both BiB-UK (where south Asian immigrants represent the largest immigrant group), ABCD-NL and to a lesser extent in the Raine Study-AU. South Asia bears half of global low birth weight burden; children of South Asian parents were consistently shown to have lower birth weight than natives in UK,<sup>38</sup> Australia and Netherlands. Another group that stands out includes East Asian and Pacific mothers' babies, who were significantly heavier at birth in three cohorts, France and the two Dutch cohorts. In France, the largest immigrant group, immigrants from the Middle East and North Africa, showed the strongest advantage in birth weight, mirroring similar results previously found in Belgium.<sup>18 39</sup> Birth weights of children with Latin-American and Caribbean mothers were significantly lower in the Dutch cohorts, in contrast to findings in previous work in Spain.<sup>12 36</sup>

Our third aim was to evaluate the impact of mother's smoking during her pregnancy. Our results seem to go in the same direction as previous studies,<sup>20 22</sup> finding that mother's smoking during pregnancy has a negative effect on birth weight, as tobacco being a vasoconstrictor reduces placental circulation. Immigrant mothers' lower prevalence of smoking during pregnancy in all study cohorts had therefore a protective effect, favouring their children's health at birth across countries.

The strength of our work lies in the use of the recent and harmonised cross-country EU Child Cohort Network data.<sup>24</sup> We are however not able to empirically measure other important contextual factors (potential confounders) that might drive some of these patterns and that differ across countries, such as access to health services, in both origin and host countries, access to employment, exposure to discrimination and to other health risk factors. Another methodological limitation is that the cohort samples are not all representative of the general population at the national level; some are local samples and some exclude specific groups (such as preterm babies in the Piccolipiù or ELFE cohorts). In addition, the most vulnerable and recently arrived immigrant groups, who are likely to have language difficulties and limited access to health institutions, may be under-represented in some cohort samples. If children in these groups are lighter at birth,<sup>18 39</sup> the current study may under-report low birth weight for children of immigrant, and thus overestimate their average birth weight. As a result, our findings can be better generalised to the largest nationally representative samples and longer established immigrant groups, and may be more limited for smaller and locally based samples, and newly arrived immigrant groups. Finally, the relationship between parental migration status and children's birth weight may change over time. This change is unlikely to meaningfully affect the

comparability of our findings between cohorts, as all our cohorts include births in the 2000s and early 2010s, except for the Raine Study in which babies were born in 1989. Therefore, given the large difference in data collection period, the comparison between the European and Australian (Raine Study) results should be interpreted with caution.

## CONCLUSION

The patterns of birth weight of children of first-generation immigrants relative to natives differ across host countries. Some of this cross-country variation seems to be due to the diverse composition of immigrant communities across Europe and Australia. Further research should investigate whether these variations are also partly driven by the different social and health policies in host countries. Improving access to healthcare, especially during pregnancy, and more inclusive social policies are needed to reduce the inequalities in birth weight, especially for disadvantaged immigrant groups, while supporting positive parental health behaviours. Our results confirm the protective effects of not smoking during pregnancy for child's birth weight, highlighting the importance of maintaining immigrants' healthier practices.

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