Birth and Health Outcomes of Children Migrating With Parents: A Systematic Review and Meta-Analysis

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Objective: To examine the birth and health outcomes of children migrating with parents internationally and domestically, and to identify whether the healthy migration effect exist in migrant children.

Methods: Five electronic databases were searched for cross-sectional, case-control, or cohort studies published from January 1, 2000 to January 30, 2021 and written in English language, reporting the risk of health outcomes of migrant children (e.g., birth outcome, nutrition, physical health, mental health, death, and substance use). We excluded studies in which participants’ age more than 18 years, or participants were forced migration due to armed conflict or disasters, or when the comparators were not native-born residents. Pooled odd ratio (OR) was calculated using random-effects models.

Results: Our research identified 10,404 records, of which 98 studies were retrained for analysis. The majority of the included studies (89, 91%) focused on international migration and 9 (9%) on migration within country. Compared with native children, migrant children had increased risks of malnutrition [OR 1.26 (95% CI 1.11–1.44)], poor physical health [OR 1.34 (95% CI 1.11–1.61)], mental disorder [OR 1.24 (95% CI 1.00–1.52)], and death [OR 1.11 (95% CI 0.87–0.97)], while had a lower risk of adverse birth outcome [OR 0.92 (95% CI 0.87–0.97)]. The difference of substance use risk was not found between the two groups.

Conclusion: Migrant children had increased risk of adverse health outcomes. No obvious evidence was observed regarding healthy migration effect among migrant children. Actions are required to address the health inequity among these populations.

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Keywords: migrant children, health outcomes, meta-analysis, healthy migration effect, birth outcomes

INTRODUCTION

Migration is a global phenomenon with nearly one in seven individuals being a migrant (1). The majority are labor migrants who relocate to more developed areas, seeking employment opportunities, either internationally or domestically. Others are forced migrants because of wars, conflicts, or natural disasters. A growing number of children are compelled to migrate with their parents. According to the International Organization for Migration, the number of children...
migrating with their families beyond a country’s border reached 37.9 million in 2019 (1). Similarly, the number of children migrating within a country (e.g., from rural to urban) is also spiking. In China, about 20.8% of the migrant population in 2010 were children younger than 14 years old (2).

Migrants are usually at a relatively lower socioeconomic ladder and have less access to public welfare, such as healthcare services and education (3). However, migrant adults present similar or better health outcomes compared to native populations in multiple health indices, including pregnancy outcomes, self-reported health, and adult mortality (4, 5). This phenomenon, known as the “migrant paradox” or “healthy migrant effect,” has been much debated (6). Evidence regarding the impacts of migration on migrant children’s health status is inconsistent. Some migrant children experienced overall better health outcomes than the native-born children. In Portugal, children who migrated from other counties have a lower risk of being low birth weight (LBW) and small for gestational age (SGA) than native children (5). In contrast, the migratory process can generate unfavorable social and medical care conditions, placing the health of migrant children at risk. International migrant children in European and American countries have worse physical health (7), more mental health problems (8), and increased risks of fetal and infant mortality (9). These inconsistent observations may be related to population origins, migration types, and health indices used in the studies (10–12). Therefore, it is important to systematically examine the health status of migrant children and to understand the extent the health of these children is affected by migration and how the impacts may vary in regard to various health outcomes at birth and in later life.

No comprehensive assessment is available regarding the health status of migrant children across all the key areas of health. To address this study gap, we performed a systematic review and meta-analysis to evaluate the impact of migration on major health indicators, including children’s birth outcome, nutrition, physical health, mental health, death, and substance use. We also examined whether the migration type (international or internal) differentially influences the health of these children. This is in response to the debate regarding the migrant paradox among children populations.

METHODS

Search Strategy and Selection Criteria

For this systematic review and meta-analysis, we searched five electronic databases, including PubMed, Embase, Web of Science, Cochrane, and Scopus from January 1, 2000 to January 30, 2021. The full search strategy is provided in the Appendix. Based on literature review, we decided to investigate six categories of health outcomes: birth outcomes, nutrition, physical health, mental health, death, and substance use. We searched observational studies (e.g., cohort, case-control, or cross-section) reporting the risk of health outcomes that included migrant children aged 0–18 years. Both internal and international migrations were included. We defined international migrant children as those with at least one foreign-born parent, irrespective of the child’s birth place, including first-generation and second-generation immigrants (13). Internal migrant children refer to children who have lived in the host city for more than 6 months while holding a non-local household residency, such as rural-to-urban migration (14). The comparator group consisted of native-born children (e.g., children and both parents without migration background) (15). We excluded the studies on refugee children who migrated due to armed conflict, disasters, or political, religious or ethnic persecution. Those with a comparator group of non-natives were also excluded. The initial literature search and screening to assess eligibility was done by two reviewers (HQ and Y). Any discrepancies about study inclusion were resolved through discussion with RX. Data were extracted by two reviewers (RX and CN) and checked by two others (HQ and Y). Studies that reported results as odds ratios (ORs) or included data that enable the calculation of ORs were retained for analysis. This study is reported in accordance with the PRISMA guidelines (16) (Appendix).

We summarized the health outcomes from all the included studies as follows. Birth outcomes included low birth weight (LBW), high birth weight (HBW), and preterm birth. Nutritional outcomes were overweight/obesity, underweight, and iron deficiency anemia. Physical health included oral, gastrointestinal, respiratory, allergic, and congenital diseases. Mental health covered depression, attention deficit hyperactivity disorder (ADHD), autistic spectrum disorder (ASD), schizophrenia, suicide attempt. Deaths referred to fetal, perinatal, neonatal, post-neonatal, and infant deaths. Substance use included tobacco, alcohol, and cannabis (Appendix).

Data Analysis

The quality assessment for all included studies was done independently by two reviewers (RX and HQ) using an adapted version of the Newcastle Ottawa Scale (Appendix). Studies with a high or unclear risk of bias across five or more domains were assessed as having high risk of bias. For each article ultimately included, we extracted data on the name of authors, publishing year, study country, study design, age of participants, sample size, and health outcomes using self-designed data extraction sheets. We also extracted ORs or recalculated pertinent ORs using available data.

We estimated pooled OR with 95% confidence intervals (CIs) for the risk of health outcomes using a random-effects model. The I² statistic was used to estimate the proportion of total variation among the pooled studies due to heterogeneity. We performed subgroup analyses of study region (e.g., Europe vs. non-Europe) to assess the source of heterogeneity. Subgroup analyses were also conducted per migration type if possible, and the risk of each health outcome was assessed by host countries (the countries with at least two studies in each selected health outcome). We explored the potential risk of publication bias using Begg’s and Egger’s tests. We used forest plots to show the OR and 95% CIs for each study and the pooled estimates. A sensitivity analysis was performed to assess the robustness of our conclusions by excluding studies with quality score less than five. We used meta-regression to assess the effect of sample
size (continuous), study design (cross-section vs. non-cross-section), publish year (<2010 vs. ≥2010), and participant’s age (continuous) on health outcomes. All statistical analyses were done using Stata (version 12.0). The study was registered with PROSPERO (number: CRD42021214115).

RESULTS

Characteristics of the Included Studies

Among 10,404 references identified through the literature search, full-text copies of 1,009 articles were retrieved and screened, with 98 articles selected for analysis. The PRISMA flow diagram and study characteristics were shown in Figure 1 and Table 1. Among the 98 included articles, 90.8% (89) involved international migration, 66.3% (65) studies were conducted in European countries, and 75.5% (74) were cross-sectional studies. Overall, 79.6% (78) of studies included children <10 years of age. The quality of the included studies varied, with 24.5% (24) studies bearing high or unclear risk of bias (Appendix). Birth outcomes were most commonly examined (n = 55), followed by physical health status (n = 34), nutrition status (n = 29), death (n = 28), mental health status (n = 16), and substance use (n = 8) (Appendix).

Birth Outcomes

Migrant children had a lower risk of adverse birth outcome [OR 0.92 (95% CI 0.87–0.97)] than non-migrant children, including lower risk of LBW [OR 0.86 (95% CI 0.79–0.94)] and preterm birth [OR 0.90 (95% CI 0.84–0.97)] (Figure 2A).
| Author [reference] | Year | Country | Design  | Age | No. of migrants | No. of controls | Health outcome | Measurement/Instrument |
|-------------------|------|---------|---------|-----|----------------|----------------|----------------|-----------------------|
| Kana et al. (5)   | 2019 | Portugal | CS      | —   | 386            | 8,171          | Birth outcome (LBW, Preterm birth) | LBW: birth weight <2,500 g Preterm birth: delivered at < 37 completed weeks |
| Gillet et al. (9) | 2014 | Belgium  | CS      | —   | 129,200        | 261,566        | Birth outcome (LBW, Preterm birth) Death (Neonatal death, Post-neonatal death, Infant death) | LBW: birth weight <2,500 g Preterm birth: Gestational age (week)<37 Infant death was defined as the sum of early neonatal (death at 0–6 days), late neonatal (7–27 days), and post-neonatal (28–364 days) deaths. |
| Cebolla-Boado and Salazar (17) | 2016 | Spain    | CS      | —   | 71,758         | 287,153        | Birth outcome (LBW, HBW) | LBW: birth weight ≤2,500 g HBW: birth weight >4,000 g |
| Forna et al. (18) | 2003 | US       | Cohort  | —   | 13,465         | 36,439         | Birth outcome (LBW, Preterm birth) | LBW: birth weight <2,500 g Preterm birth: delivery before 37 weeks’ gestation |
| Sandra et al. (19) | 2015 | Spain    | CS      | —   | 72,567         | 599,660        | Birth outcome (LBW, HBW) | LBW: birth weight <2,500 g HBW: birth weight >4,000 g |
| Beesharat et al. (20) | 2014 | Sweden   | Cohort  | —   | 336            | 2,181          | Birth outcome (LBW, HBW, Preterm) | LBW: birth weight <2,500 g HBW: birth weight (gram) ≥ 4,000 g Preterm birth: delivered at < 37 completed weeks |
| Racape et al. (21) | 2016 | Belgium  | CS      | —   | 334,150        | 1,029,471      | Birth outcome (LBW, Preterm birth) Death (Perinatal death) | LBW: birth weight <2,500 g Perinatal death: fetal deaths from 22 weeks of gestation until 7 days after birth |
| Lehti et al. (22) | 2013 | Finland  | CC      | —   | 347            | 5,300          | Birth outcome (LBW, Preterm) Mental health (ASD) | LBW: birth weight <2,500 g Preterm birth: Gestational age <37 weeks ASD: clinical assessment ICD-9/ICD-10 |
| Milewski and Peters (23) | 2014 | Germany  | Cohort  | —   | 427            | 1,214          | Birth outcome (LBW, HBW) | LBW: birth weight <2,500 g HBW: birth weight >4,000 g |
| Ratnasiri et al. (24) | 2020 | US       | CS      | —   | 446,724        | 611,253        | Birth outcome (LBW, Preterm birth) Death (Neonatal death, Post-neonatal death) | LBW: birth weight <2,500 g Preterm birth: Gestational age <38 Neonatal death: death before 28 days of age Post-neonatal death: death at 28d-1year |
| Hessol and Fuentes-Afflick (25) | 2014 | US       | CS      | —   | 410,284        | 231,190        | Birth outcome (LBW, HBW, Preterm birth) | LBW: birth weight <2,500 g HBW: birth weight ≥4,000 g Preterm birth: <37 completed weeks’ gestation |
| Castello et al. (26) | 2012 | Spain    | CS      | —   | 5,926          | 15,782         | Birth outcome (LBW, Preterm birth) | LBW: birth weight <2,500 g Preterm birth: Gestational age <37 weeks |
| Juarez and Revueltas-Eugercios (27) | 2014 | Spain    | CS      | —   | 323,856        | 1,061,924      | Birth outcome (LBW, Preterm birth) | LBW: birth weight <2,500 g HBW: macrosomia ≥4,500 g Preterm birth: <37 completed gestational weeks |
| Fuster et al. (28) | 2014 | Spain    | CS      | —   | 412,906        | 1,874,913      | Birth outcome (LBW, preterm) Death (fetal death) | LBW: birth weight <2,500 g Preterm birth: gestational age <38 week Fetal death: the number of late fetal deaths per 1,000 deliveries (both live births and fetal deaths) |
| Racape et al. (29) | 2010 | Belgium  | Cohort  | —   | 56,061         | 74,767         | Birth outcome (LBW, Preterm birth) Death (Fetal mortality, Neonatal mortality, Post-neonatal mortality) | LBW: birth weight <2,500 g Preterm birth: Gestational age <37 weeks Fetal mortality: fetal deaths of 22 or more weeks of gestation; Neonatal mortality: death at 0–27 days of life per 1,000 live births; Post-neonatal mortality: death at 28–364 days of life per 1,000 live births |
| Glick et al. (30) | 2009 | US       | Cohort  | —   | 2,300          | 7,300          | Birth outcome (LBW) | LBW: birth weight <2,500 g |

(Continued)
| Author [reference] | Year | Country | Design | Age | No. of migrants | No. of controls | Health outcome | Measurement/Instrument |
|-------------------|------|---------|--------|-----|----------------|----------------|---------------|----------------------|
| Farre (31)        | 2013 | Spain   | CS     | —   | 233,518        | 1,773,102      | Birth outcome (LBW, Preterm birth, Death (Perinatal death)) | LBW: birth weight <2,500 g Preterm birth: Gestational age (week) <38 Perinatal death: death within 24 h after birth |
| Nancy et al. (32) | 2015 | US      | CS     | —   | 305            | 1,361          | Birth outcome (LBW) | LBW: Birth weight <2,500 g |
| Lehti et al. (33) | 2016 | Finland | CC     | —   | 1,730          | 47,803         | Birth outcome (LBW, Preterm) Mental health (ADHD) | LBW: birth weight <2,500 g Preterm birth: gestational age <37 weeks ADHD: clinical assessment ICD-9/ICD-10 |
| Gissier et al. (34) | 2003 | Sweden  | CS     | —   | 34,357         | 110,008        | Birth outcome (LBW) Death (Fetal death, Neonatal death, Perinatal death) | LBW: birth weight <2,500 g Neonatal deaths: death before 28 days of age per 1,000 live births Post-neonatal deaths: 28 days to 1 year of age |
| Madan et al. (35) | 2006 | US      | CS     | —   | 2,418,501      | 4,005,671      | Birth outcome (LBW) Death (Neonatal death, Post-neonatal death) | LBW: birth weight <2,500 g Neonatal deaths: death before 28 days of age |
| Auger et al. (36) | 2008 | Canada  | CS     | —   | 43,396         | 54,954         | Birth outcome (LBW, Preterm birth) | LBW: birth weight <2,500 g Preterm birth: delivery at <37 completed weeks of gestation |
| Bastola et al. (37) | 2020 | Finland | CS     | —   | 31,454         | 350,548        | Birth outcome (LBW, HBW, Preterm birth) Death (Post-neonatal death, Neonatal death, Fetal death) | LBW: birth weight <2,500 g HBW: birth weight >4,000 g Preterm birth: <36 weeks + 6 days Post-neonatal death: 28 days to 1 year of death Neonatal mortality: death of a live-born child within the first 28 days of life |
| Marcon et al. (38) | 2011 | Italy   | CS     | 3–14 years | 641 | 2,980 | Birth outcome (LBW, HBW) Physical health (Pneumonia, Eczema) | LBW: birth weight <2,500 g HBW: birth weight >4,000 g Pneumonia and Eczema: Self-reported symptoms |
| Besharat Pour et al. (39) | 2017 | Sweden  | Cohort | —   | 299            | 1,979          | Birth outcome (HBW, Preterm birth) | HBW: Birth weight >4,000 g Preterm birth: Gestational age <38 weeks |
| Reeske et al. (40) | 2013 | Germany | Cohort | —   | 384            | 903            | Birth outcome (HBW) | HBW: Birth weight >4,000 g |
| Choi et al. (41)  | 2019 | Australia | Cohort | —   | 601,299        | 1,735,724      | Death (Neonatal death, Fetal death) Birth outcome (Preterm birth) | Death <28 days among livebirths Preterm birth: Gestational age <37 weeks |
| Essen et al. (42) | 2000 | Sweden  | CS     | —   | 5,211          | 10,784         | Birth outcome (Preterm birth) Death (Perinatal death) | Preterm birth: Gestational age <37 weeks Perinatal death: stillbirth (fetus >28 weeks of gestation) and death within the first week of life |
| Vik et al. (43)   | 2019 | Norway  | CS     | —   | 198,520        | 115,644        | Death (fetal death) Birth outcome (Preterm birth) | Stillbirth: a pregnancy loss at ≥22 weeks of gestation or with a birthweight ≥500 g if data on gestational age were missing Moderately preterm: gestational age 28–36 weeks |
| Anil Kumar (44)   | 2016 | India   | CS     | 0–4 years | 11,327 | 2,488 | Nutrition (Overweight/obesity, Anemia) Physical health (Diarrhea) | Overweight/obesity: BMI scores Anemia: blood hemoglobin level Diarrhea: self-reported |
| Liu et al. (45)   | 2016 | China   | CS     | 5–12 years | 3,057 | 6,860 | Nutrition (Overweight/Obesity) | World Health Organization reference 2007 Overweight: +1 SD < BMI-for-age z-score ≤ +2 SD; Obesity: BMI-for-age z-score > +2 SD |

(Continued)
| Author [reference] | Year | Country | Design | Age | No. of migrants | No. of controls | Health outcome | Measurement/Instrument |
|--------------------|------|---------|--------|-----|----------------|----------------|---------------|-----------------------|
| Ji et al. (14)      | 2016 | China   | CS     | 10.7 ± 0.94 years | 991            | 650            | Nutrition (Overweight/Obesity) Physical health (Caries experience, Diarrhea) | Overweight/obesity: based on cutoff of the Working Group on Obesity of China. Caries: referred to those in both deciduous and permanent teeth. Diarrhea: Parents reported symptom. |
| Lin et al. (46)     | 2011 | Taiwan  | CS     | 7–12 years       | 157            | 519            | Nutrition (Overweight) Mental health (Depression) | Overweight: BMI ≥ 85th percentile based on Department of Health criteria, Taiwan, ROC. Depression: The “Depression Screen Scale for Children and Adolescents” developed by Kao-Fin Chang. |
| De Carli et al. (47) | 2018 | Italy   | CS     | 11–12 years      | 353            | 847            | Nutrition (Overweight/obesity, Underweight) | The International Obesity Task Force cut-offs. |
| Zulfiqar et al. (48) | 2018 | Australia | Cohort | 2–11 years       | 1,799          | 2,434          | Nutrition (Overweight/obesity) | The International Obesity Task Force standard. |
| Maximova et al. (13) | 2011 | Canada  | CS     | 11.2 ± 1.1 years | 5,261          | 1,131          | Nutrition (Overweight/obesity) | The International Obesity Task Force standard. |
| Lindstrom et al. (49) | 2014 | Sweden  | CS     | 15–16 years      | 2,423          | 7,195          | Nutrition (Overweight/obesity) | Boy: overweight/obesity 23.29–28.29/28.30; girl: 23.94–29.10/29.11 |
| Esteban-Gonzalo et al. (50) | 2014 | Spain   | CS     | 13–17 years      | 335            | 1,742          | Nutrition (Overweight/obesity) Mental health (Depression) Substance use (Tobacco use) | Overweight/obesity: using the BMI age- and gender-specific cut-offs proposed by Cole et al. 27. Depression: self-reported medical diagnosis of depression. Tobacco use: self-reported questionnaire. |
| Besharat Pour et al. (51) | 2014 | Sweden  | Cohort | 8 years          | 561            | 2,028          | Nutrition (Overweight/obesity) | Overweight: 85th–95th BMI percentile Obesity: ≥ 95th BMI percentile International Obesity Task Force (IOTF) |
| Furthner et al. (52) | 2017 | Austria | CS     | 13.8 years       | 827            | 2,103          | Nutrition (Overweight/obesity) | |
| Burgi et al. (53)   | 2010 | Switzerland | CS    | 5.1 ± 0.60 years | 391            | 151            | Nutrition (Overweight/obesity) | |
| Igucel et al. (54)  | 2018 | Spain   | Cohort | 2.0–9.9 years    | 1,156          | 7,427          | Nutrition (Overweight/obesity) | |
| Khanolkar et al. (55) | 2013 | Sweden  | CS     | 4–5 years        | 1,286          | 9,342          | Nutrition (Overweight/obesity) | |
| Thi et al. (56)     | 2019 | Germany | CS     | 5–7 years        | 1,080          | 2,623          | Nutrition (Overweight/obesity) | |
| Will et al. (57)    | 2006 | Germany | CS     | 6–7 years        | 258            | 265            | Nutrition (Overweight/obesity) | |
| Zhou et al. (58)    | 2018 | Germany | CS     | —               | 19,245         | 31,441         | Nutrition (Overweight/obesity) | |
| Méroc et al. (15)   | 2019 | Belgium | CS     | 10–11 years      | 2,319          | 553            | Nutrition (Overweight/obesity) | |
| Labree et al. (59)  | 2015 | Finland | CS     | 8–9 years        | 397            | 1,546          | Nutrition (Overweight/Obesity, Underweight) | |

(Continued)
| Author [reference] | Year | Country | Design | Age | No. of migrants | No. of controls | Health outcome | Measurement/Instrument |
|--------------------|------|---------|--------|-----|----------------|----------------|---------------|-----------------------|
| Brettschneider et al. (60) | 2011 | Germany | CS 11–17 years | 518 | 2,949 | Nutrition (Overweight) | BMI >90th percentile based on the national German reference |
| Vorwieger et al. (61) | 2018 | Germany | CS 7.57 ± 0.42 years | 245 | 508 | Nutrition (Abdominal obesity) | WHtR >0.5 |
| Nagel et al. (62) | 2009 | Germany | CS 7.6 ± 0.4 years | 317 | 762 | Nutrition (Overweight/obesity) | The International Obesity Task Force standard |
| Beyerlein et al. (63) | 2014 | Germany | CS 3–17 years | 474 | 8,507 | Nutrition (Overweight) | International Obesity Task Force (IOTF) |
| Prusty and Keshri (64) | 2015 | India | CS 0–69 months | 13,220 | 5,617 | Nutrition (Underweight) | WFA-Z< -2SD |
| Saunders et al. (65) | 2016 | Canada | CS 12–72 months | 1,244 | 1,268 | Nutrition (Anemia) | Hemoglobin level <110 g/L (WHO recommendation) |
| Hu et al. (66) | 2014 | China | CS 6–23 months | 667 | 321 | Nutrition (Anemia) | Hemoglobin level <110 g/L (WHO recommendation) |
| Julihn et al. (67) | 2010 | Sweden | Cohort 13–19 years | 5,134 | 10,404 | Physical health (Caries experience) | Clinical examination of DMFT |
| Christensen et al. (68) | 2010 | Denmark | CS 5–15 years | 3,571 | 9,058 | Physical health (Caries experience) | Clinical examination of DMFT |
| van Meijeren et al. (69) | 2019 | Netherlands | Cohort 9 years | 611 | 2,510 | Physical health (Caries experience) | Clinical examination of DMFT |
| Ferrazzano et al. (70) | 2019 | Italy | CS 12–14 years | 183 | 370 | Physical health (Caries experience) | Clinical examination of DMFT |
| van der Tas et al. (71) | 2016 | Netherlands | CS 4.96 years | 1,403 | 2,957 | Physical health (Caries experience) | Clinical examination of DMFT |
| Almerich-Silla and Montiel-Company (72) | 2007 | Spain | CS 12–15 years | 54 | 825 | Physical health (Caries experience) | Clinical examination of DMFT |
| Bissar et al. (73) | 2014 | Germany | CS 4.1 ± 0.8 years | 265 | 698 | Physical health (Caries experience) | Clinical examination of DMFT |
| Baggio et al. (74) | 2015 | Switzerland | CS 36–71 months | 398 | 457 | Physical health (Caries experience) | Clinical examination of DMFT |
| Bardin et al. (75) | 2019 | Italy | Cohort 0–14 years | 21,817 | 191,345 | Physical health (Gastroenteritis, Pneumonia, Asthma) | ICD-9 |
| Charania et al. (76) | 2020 | New Zealand | CS 0–6 years | 125,511 | 567,408 | Physical health (Gastroenteritis, Pneumonia) | Hospitalization event |
| Li et al. (77) | 2019 | China | CS 12–15 years | 3,477 | 2,213 | Physical health (Gastroenteritis, Pneumonia, Asthma) | Physician-diagnosed |
| Migliore et al. (78) | 2007 | Italy | CS 6–7/13–14 years | 1,012 | 28,293 | Physical health (Pneumonia, Asthma, Food allergy) | Self-reported questionnaire |
| Keet et al. (79) | 2012 | US | CS 11.4 years | 341 | 3,209 | Physical health (Asthma, Eczema, Food allergy) | Physician-diagnosed |
| Svendsen et al. (80) | 2009 | US | CS 9–11 years | 2,026 | 4,370 | Physical health (Asthma, Food allergy) | Physician-diagnosed |
| Radhakrishnan et al. (81) | 2019 | Canada | Cohort 0–18 years | 422,305 | 968,256 | Physical health (Asthma) | ICES (institute for clinical Evaluation Sciences) database |
| Apfelbacher et al. (82) | 2011 | Germany | CS 0–17 years | 2,550 | 14,640 | Physical health (Eczema) | Physician-diagnosed |

(Continued)
| Author [reference] | Year | Country | Design | Age | No. of migrants | No. of controls | Health outcome | Measurement/Instrument |
|--------------------|------|---------|--------|-----|----------------|----------------|---------------|-----------------------|
| Koplin et al. (83)  | 2014 | Australia | Cohort | 11–15 months | 535 | 3,023 | Physical health (Food allergy) | Food allergy to egg, peanut or sesame was defined as a positive oral food challenge in sensitized infants (SPT wheal ≥ 2 mm or specific IgE ≥ 0.35 ku/l) |
| Ramadhani et al. (84) | 2009 | US | CC | — | 575 | 539 | Physical health (Heart defects, Neural tube defect) | Surveillance registries system |
| Kang et al. (85) | 2016 | China | CS | 6–13 years | 325,940 | 214,634 | Physical health (Heart defects, Neural tube defect) | Clinical cardiovascular examination |
| Velie et al. (86) | 2006 | US | CC | — | 265 | 606 | Physical health (Neural tube defect) | California Birth Defects Monitoring system |
| Kim et al. (87) | 2018 | US | CS | 8–18 years | 1,013 | 1,361 | Mental health (Depression) | MFQ (Mood and Feelings Questionnaire) |
| Fuhrmann et al. (88) | 2014 | US | CS | 6.2 ± 0.4 years | 118 | 535 | Mental health (Depression) | PFC (Preschool Feelings Checklist) |
| Adriaanse et al. (89) | 2014 | Netherlands | CS | 12.9 ± 1.8 years | 576 | 702 | Mental health | The Strengths and Difficulties Questionnaire (SDQ) |
| Wang et al. (90) | 2017 | China | CS | 11.04 ± 0.04 years | 731 | 451 | Mental health | SDQ |
| van der Ven et al. (91) | 2013 | Netherlands | Cohort | — | 26,599 | 80,354 | Mental health (ASD) | DSM-IV diagnosis |
| Wandell et al. (92) | 2020 | Sweden | Cohort | <18 years | 1,149,504 | 2,873,645 | Mental health (ASD) | DSM-IV diagnosis |
| Magnusson et al. (93) | 2012 | Sweden | CC | 0–17 years | 9,396 | 34,567 | Mental health (ASD) | DSM-IV diagnosis |
| Weiser et al. (94) | 2008 | Israel | CS | 7.7 ± 3.7 years | 639,203 | 22,589 | Mental health (Schizophrenia) | ICD-9 and ICD-10 |
| Hjern et al. (95) | 2004 | Sweden | CS | — | 87,988 | 1,056,225 | Mental health (Schizophrenia) | ICD-9/ICD-10 |
| Pedersen et al. (96) | 2012 | Denmark | Cohort | — | 202 | 1,639 | Mental health (Schizophrenia) | ICD-10 |
| Lu et al. (97) | 2020 | China | CS | 13.67 ± 1.52 years | 1,858 | 2,359 | Mental health (Suicide attempt) | Self-injurious thoughts and behaviors (SITBs) |
| Vazsonyi et al. (98) | 2017 | Switzerland | CS | 17.85 ± 1.21 years | 741 | 6,546 | Mental health (Suicide attempts) | Self-reported questionnaire |
| Villadsen et al. (99) | 2010 | Northern Europe | CS | — | 265,135 | 9,649,736 | Death (Neonatal mortality, Fetal death) | Death within 0–27 days of birth |
| Barona-Var et al. (100) | 2014 | Spain | CS | — | 40,834 | 162,043 | Death (Perinatal death) | The number of fetal and neonatal deaths per 1,000 total births |
| Vang (101) | 2016 | Canada | CS | — | 514,247 | 2,856,394 | Death (Post-neonatal death, Neonatal death) | Neonatal death: 0 to 27 days and Post-neonatal death: 28 to 364 days |
| Rosenberg et al. (102) | 2002 | US | CS | — | 72,293 | 130,681 | Death (Infant death) | Death before first birthday |
| Landale et al. (103) | 2006 | US | CS | — | 4,342 | 715 | Death (Infant death) | Died before reaching the age of 1 year |
| Troe et al. (104) | 2007 | Netherlands | CS | — | 30,331 | 3,838 | Death (Infant death) | Died before reaching the age of 1 year |
| Abebe et al. (105) | 2015 | Norway | CS | 14–17 years | 2,932 | 8,002 | Substance use (Cannabis use, Tobacco use, Alcohol use) | Self-report questionnaire |
TABLE 1 | Continued

| Author [reference] | Year | Country | Design | Age | No. of migrants | No. of controls | Health outcome | Measurement/Instrument |
|--------------------|------|---------|--------|-----|----------------|----------------|-----------------|-----------------------|
| Slonim-Nevo et al. (106) | 2006 | Russia | CS     | 15–17 years | 396            | 127            | Substance use (Tobacco use, Alcohol use) | Self-report questionnaire |
| Donath et al. (107)    | 2016 | Germany | CS     | 14.88 ± 0.74 years | 2,277          | 7,235          | Substance use (Cannabis use) | Self-report questionnaire |

CS, cross-sectional; CC, case-control; LBW, low birthweight; HBW, high birthweight; ADHD, attention deficit hyperactivity disorder; ASD, autistic spectrum disorder. — represents the data cannot be obtained

Although high statistical heterogeneity across birth outcomes was observed, it was reduced after subgroup and sensitivity analysis. In the subgroup analyses by region (Table 2), although no significant difference of overall adverse birth outcomes was found between migrant children and native ones in European countries [OR 0.95 (95% CI 0.90–1.02)], a lower risk of low birthweight was identified. In non-European countries, migrant children had a lower risk of overall adverse birth outcome [OR 0.84 (95% CI 0.75–0.94)] and preterm birth [OR 0.81 (95% CI 0.71–0.92)]. All the studies targeting birth outcomes were performed among international migrant children and the effect of domestic migration on birth outcomes cannot be unexplored. Sensitivity analysis of excluding studies with quality score less than five did not alter the above results (Appendix).

Nutrition
Migrant children had an increased risk of malnutrition [OR 1.26 (95% CI 1.11–1.44)], including higher risk of overweight/obesity [OR 1.33 (95% CI 1.13–1.57)] and iron-deficiency anemia [OR 1.37 (95% CI 1.01–1.87)]; while no difference was identified regarding underweight [OR 0.90 (95% CI 0.77–1.04)] between migrant and non-migrant children (Figure 2B). Heterogeneity between the estimates was low for overweight and high for overweight/obesity. Subgroup analyses by region (Table 2) revealed that migrant children in European countries had a significantly increased risk of malnutrition [OR 1.51 (95% CI 1.29–1.78)] such as overweight/obesity [OR 1.62 (95% CI 1.39–1.90)], while no significant differences were found between migrant children and native ones in the non-European countries. We also explored the effect of migration way on children’s nutrition, which showed that international migrant children had an increased risk of overweight/obesity than non-migrant children [OR 1.47 (95% CI 1.28–1.68)], but the result was opposite for internal migrant children [OR 0.67 (95% CI 0.60–0.74)]. When the studies with quality score less than five were excluded, the risk of malnutrition was not altered (Appendix).

Physical Health
Migrant children had a significantly increased risk of poor physical health [OR 1.34 (95% CI 1.11–1.61)] compared with non-migrant children, including higher risk of oral disease [OR 2.56 (95% CI 2.11–3.11)] and gastrointestinal disease [OR 1.56 (95% CI 1.18–2.07)] (Figure 2C). Although high statistical heterogeneity was identified across the selected physical health outcomes, a reduction trend was found by using subgroup and sensitivity analysis. Subgroup analyses by region (Table 2) suggested that migrant children had poorer physical health than non-migrant children both in the European countries [OR 1.48 (95% CI 1.02–2.14)] and non-European countries [OR 1.20 (95% CI 1.03–1.41)]. The insufficient number of studies did not allow for analyses of the risk of physical health outcomes among internal migrant children. Sensitivity analyses by excluding studies of quality score less than five did not change the results related to physical health outcomes (Appendix).

Mental Health
Migrant children had a marginally higher risk of psychological problems [OR 1.24 (95% CI 1.00–1.52)] than the controls, including higher risk of depression [OR 1.29 (95% CI 1.00–1.65)], schizophrenia [OR 1.79 (95% CI 1.50–2.14)], and suicide attempt [OR 1.31 (95% CI 1.10–1.56)] (Figure 2D). Statistical heterogeneity across the mental health outcomes was moderate between estimates. Subgroup analyses by region (Table 2) showed that migrant children in European had an increased risk of schizophrenia; while in non-European countries had higher risk of depression. Given the limited number of studies on internal migrant children, we did not assess the effect of migration way on the risk of mental health outcomes. Sensitivity analyses by excluding studies with quality score less than five did not change the mental health outcomes (Appendix).

Deaths
All the studies on mortality focused on international migrant children. Migrant children were at a higher risk of death than the controls [OR 1.11 (95% CI 1.01–1.21)], including fetal death [OR 1.24 (95% CI 1.07–1.45)], perinatal death [OR 1.25 (95% CI 1.04–1.50)], and neonatal death [OR 1.10 (95% CI 1.02–1.19)] (Figure 2E). Statistical heterogeneity between estimates varied substantially across death outcomes, with the exception of neonatal death. Subgroup analyses by region (Table 2) on fetal death [OR 1.33 (95% CI
|                  | Migrant (n/N) | Control (n/N) | OR (95% CI) | %Weight |
|------------------|---------------|---------------|-------------|---------|
| **Overweight/obesity** |               |               |             |         |
| Kumar (2016) [44] | 85/11327      | 32/2488       | 0.58 (0.38, 0.90) | 2.98    |
| Liu (2016) [45]  | 436/3057      | 1370/6860     | 0.66 (0.59, 0.75) | 4.32    |
| Ji (2016) [14]   | 241/991       | 198/650       | 0.73 (0.58, 0.92) | 3.86    |
| Lin (2011) [46]  | 56/157        | 223/519       | 0.73 (0.49, 1.08) | 3.14    |
| De (2018) [47]   | 174/353       | 459/847       | 0.82 (0.65, 1.06) | 3.74    |
| Zulfiqar (2018) [48] | 416/1799     | 571/2434      | 0.98 (0.84, 1.13) | 4.15    |
| Maximova (2011) [13] | 1618/5261   | 326/1131      | 1.09 (0.94, 1.26) | 4.16    |
| Lindstrom (2014) [49] | 412/2423     | 1061/7195     | 1.18 (1.04, 1.34) | 4.21    |
| Esteban-Gonzalo (2014) [50] | 66/335      | 296/1742      | 1.19 (0.87, 1.62) | 3.52    |
| Besharat (2014) [51] | ---           | ---           | 1.33 (1.07, 1.66) | 3.91    |
| Furthner (2017) [52] | 223/827      | 437/2103      | 1.40 (1.16, 1.70) | 4.01    |
| Burgi (2010) [53] | 39/391        | 11/151        | 1.41 (1.08, 1.84) | 1.77    |
| Iguacl (2018) [54] | 329/1156     | 1597/7427     | 1.45 (1.26, 1.67) | 4.17    |
| Khanolkar (2013) [55] | ---           | ---           | 1.52 (1.08, 2.14) | 3.38    |
| Thi (2018) [56]  | 147/1080      | 203/2623      | 1.75 (1.39, 2.21) | 3.86    |
| Will (2005) [57] | 46/258        | 29/265        | 1.76 (1.04, 3.02) | 2.55    |
| Zhou (2018) [58] | 2452/19245    | 2154/1441     | 1.78 (1.26, 2.51) | 3.37    |
| Merco (2019) [15] | ---           | ---           | 1.84 (1.46, 2.32) | 3.86    |
| Labree (2015) [59] | 114/397       | 205/1546      | 2.17 (1.22, 3.87) | 2.38    |
| Brettschneider (2011) [60] | ---         | ---           | 2.36 (1.28, 4.34) | 2.26    |
| Vonwieger (2018) [61] | ---           | ---           | 2.47 (1.68, 3.62) | 3.19    |
| Nagel (2009) [62] | 88/287        | 104/689       | 2.48 (1.76, 3.48) | 3.39    |
| Beyelerin (2014) [63] | 44/183        | 219/2096      | 2.71 (1.83, 3.95) | 3.19    |
| Subtotal (I-squared = 78.0%, p = 0.013) |              |               | 1.33 (1.13, 1.57) | 79.30   |
| **Underweight**  |               |               |             |         |
| De (2018) [47]   | 58/353        | 181/847       | 0.72 (0.51, 1.01) | 3.38    |
| Labree (2015) [59] | 22/397        | 100/1546      | 0.85 (0.50, 1.40) | 2.64    |
| Prusty (2015) [64] | ---           | ---           | 0.95 (0.65, 1.39) | 4.26    |
| Subtotal (I-squared = 17.2%, p = 0.299) |              |               | 0.90 (0.77, 1.04) | 10.29   |
| **Anaemia**      |               |               |             |         |
| Saunders (2017) [65] | 22/1244      | 26/1268       | 0.93 (0.54, 1.62) | 2.49    |
| Kumar (2016) [44] | 8032/11327    | 1628/2488     | 1.28 (1.17, 1.41) | 4.29    |
| Hu (2014) [66]   | 244/667       | 60/321        | 1.86 (1.40, 2.47) | 3.64    |
| Subtotal (I-squared = 63.6%, p = 0.033) |              |               | 1.37 (1.01, 1.87) | 10.42   |
| **Overall (I-squared = 80.9%, p = 0.000)** |              |               | 1.26 (1.11, 1.44) | 100.00  |

**FIGURE 2 | Continued**
### FIGURE 2 | Continued

#### Oral diseases

| Suboutcome                  | Migrant(N) | Control(N) | OR (95% CI) | %Weight |
|-----------------------------|------------|------------|-------------|---------|
| Julious (2010) [67] Caries  | 396/5314   | 3610/10404 | 1.64 (1.53, 1.76) | 3.16    |
| Christiansen (2018) [68]    | Caries     | ---        | 2.00 (1.90, 2.10) | 3.15    |
| Li (2016) [74]               | Caries     | 235/691    | 2.39 (1.26, 3.00) | 2.94    |
| Van Meijeren (2019) [69]     | Caries     | 179/611    | 2.39 (1.50, 2.90) | 3.04    |
| Ferrazzano (2019) [70]       | Caries     | 142/183    | 2.72 (1.79, 4.18) | 2.72    |
| van der (2016) [71]          | Caries     | 642/1403   | 2.85 (1.48, 3.28) | 3.11    |
| Almeirich (2007) [72]        | Caries     | 40/54      | 3.23 (1.66, 6.52) | 2.23    |
| Bisar (2014) [73]            | Caries     | 48/625     | 3.63 (2.72, 5.83) | 2.63    |
| Baggio (2013) [74]           | Caries     | 154/598    | 4.61 (3.22, 6.64) | 2.83    |
| Subtotal (I-squared = 61.1%, p = 0.043) |          |            | 2.56 (2.31, 3.15) | 28.81   |

#### Gastrointestinal disease

| Suboutcome                  | Migrant(N) | Control(N) | OR (95% CI) | %Weight |
|-----------------------------|------------|------------|-------------|---------|
| Kumar (2010) [44] Diarrhea  | 974/11327  | 182/2488   | 1.19 (1.01, 1.41) | 3.09    |
| Barin (2018) [75] Gastroenteritis | 462/2187 | 405/191345 | 1.74 (1.57, 1.94) | 3.14    |
| Li (2016) [74] Diarrhea      | 209/991    | 80/650     | 1.90 (1.42, 2.53) | 2.94    |
| Subtotal (I-squared = 67.3%, p = 0.044) |            |            | 1.56 (1.30, 2.07) | 1.87    |

#### Respiratory diseases

| Suboutcome                  | Migrant(N) | Control(N) | OR (95% CI) | %Weight |
|-----------------------------|------------|------------|-------------|---------|
| Charania (2019) [76] Pneumonia | 1683/12551 | 1799/567408 | 0.41 (0.30, 0.54) | 3.16    |
| Li (2019) [77] Pneumonia     | 567/5477   | 595/2213   | 0.52 (0.46, 0.60) | 3.12    |
| Migliore (2007) [78] Asthma  | 55/1032    | 276/28293  | 0.53 (0.46, 0.70) | 0.96    |
| Lindstrom (2014) [89] Asthma | 200/2423   | 932/7195   | 0.60 (0.51, 0.71) | 3.09    |
| Keet (2011) [79] Asthma      | ---        | ---        | 0.73 (0.44, 1.22) | 2.56    |
| Li (2019) [77] Asthma        | 263/3477   | 294/2123   | 0.77 (0.52, 1.13) | 2.78    |
| Barin (2018) [75] Pneumonia  | 202/2187   | 2059/191345 | 1.18 (1.01, 1.37) | 3.10    |
| Svenson (2009) [80] Asthma   | 399/2026   | 1008/4370  | 1.20 (1.04, 1.38) | 3.11    |
| Radhakrishnan (2018) [81]    | Asthma     | 888/1822305 | 19145/960265 | 1.21 (1.13, 1.25) | 3.17    |
| Marcon (2011) [36] Pneumonia | 23/641     | 74/980     | 1.46 (0.86, 2.58) | 2.56    |
| Barin (2018) [75] Asthma     | 54/2187    | 665/191345 | 1.53 (1.22, 2.06) | 2.92    |
| Migliore (2007) [78] Pneumonia | 69/1012    | 1028/28293 | 1.94 (1.48, 2.50) | 2.96    |
| Subtotal (I-squared = 70.1%, p = 0.001) |            |            | 0.90 (0.60, 1.38) | 25.52   |

#### Allergic disease

| Suboutcome                  | Migrant(N) | Control(N) | OR (95% CI) | %Weight |
|-----------------------------|------------|------------|-------------|---------|
| Marcon (2011) [36] Eczema   | ---        | ---        | 0.61 (0.43, 0.86) | 2.85    |
| Apfelbacher (2011) [82]     | Eczema     | ---        | 0.63 (0.49, 0.80) | 3.00    |
| Li (2019) [77] Eczema       | 527/3477   | 590/2213   | 0.82 (0.67, 1.01) | 3.05    |
| Keet (2011) [79] Eczema     | ---        | ---        | 0.91 (0.64, 1.31) | 2.84    |
| Svenson (2009) [80] Asthma  | ---        | Food allergy | 23/1055 | 499/2495 | 1.53 (1.05, 2.24) | 2.80    |
| Koplin (2014) [83] Food allergy | --- | --- | 2.60 (1.80, 3.80) | 2.81    |
| Subtotal (I-squared = 70.4%, p = 0.002) |            |            | 1.01 (0.68, 1.50) | 17.36   |

#### Congenital disease

| Suboutcome                  | Migrant(N) | Control(N) | OR (95% CI) | %Weight |
|-----------------------------|------------|------------|-------------|---------|
| Ramadhani (2009) [84] Heart defect | ---        | 13/76 | 0.89 (0.76, 1.06) | 3.09    |
| Kang (2013) [85] Heart defect  | 733/32594  | 423/214634 | 1.14 (1.03, 1.27) | 3.15    |
| Ramadhani (2009) [84] Neural tube defect | --- | --- | 1.30 (1.06, 1.60) | 2.96    |
| Velik (2008) [86] Neural tube defect | 174/265 | 213/484 | 2.40 (1.88, 3.02) | 2.92    |
| Subtotal (I-squared = 61.1%, p = 0.001) |            |            | 1.32 (0.91, 1.91) | 12.15   |

#### Overall (I-squared = 76.5%, p = 0.042)

|                | 2 | 5 | 1 | 2 |
|----------------|---|---|---|---|
| Better outcome |   |   |   |   |
| Worse outcome  |   |   |   |   |

1.34 (1.11, 1.65) 100.00

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|                  | Migrant(v/N) | Control(v/N) | OR (95% CI) | %Weight |
|------------------|--------------|--------------|-------------|---------|
| Depression       |              |              |             |         |
| Kim (2018) [87]  | ---          | ---          | 1.17 (0.89, 1.27) | 7.33    |
| Lin (2011) [46]  | 32/157       | 89/519       | 1.23 (0.76, 1.97) | 5.35    |
| Fuhrmann (2014) [86] | 8/118       | 29/335       | 1.26 (0.48, 2.94) | 3.09    |
| Estevez-Gonzalo (2014) [50] | 14/335   | 30/1742       | 2.48 (1.20, 4.90) | 4.02    |
| Subtotal (I-squared = 31.5%, p = 0.223) | 1.29 (1.00, 1.65) | 19.79        |
| ADHD             |              |              |             |         |
| Adriamse (2014) [39] | 68/576     | 191/702       | 0.33 (0.24, 0.46) | 6.28    |
| Lehti (2016) [33] | 507/730      | 9902/47803    | 1.58 (1.42, 1.76) | 7.26    |
| Wong (2017) [81] | 58/731       | 17/451        | 2.20 (1.24, 4.08) | 4.62    |
| Subtotal (I-squared = 87.6%, p = 0.000) | 1.03 (0.63, 1.20) | 18.16        |
| ASD              |              |              |             |         |
| Van der (2013) [91] | 98/36597    | 420/6354      | 0.70 (0.55, 0.87) | 6.80    |
| Wandell (2009) [92] | 12965/1149504 | 39451/2837445 | 0.81 (0.60, 0.84) | 7.39    |
| Magnusson (2012) [35] | 796/9965    | 3122/34567    | 0.93 (0.65, 1.10) | 7.31    |
| Lehti (2013) [22] | 97/347       | 1025/5300     | 1.59 (1.23, 2.05) | 6.66    |
| Subtotal (I-squared = 71.8%, p = 0.001) | 0.93 (0.78, 1.12) | 28.16        |
| Schizophrenia    |              |              |             |         |
| Weiser (2008) [44] | 204/104638  | 46/557154     | 1.50 (1.25, 1.80) | 7.01    |
| Hjem (2004) [95] | 635/87988    | 4049/1056225  | 1.88 (1.73, 2.05) | 7.31    |
| Pedersen (2012) [96] | 129/202     | 739/1659      | 2.15 (1.57, 2.95) | 6.33    |
| Subtotal (I-squared = 66.4%, p = 0.051) | 1.79 (1.50, 2.14) | 20.65        |
| Suicide attempt  |              |              |             |         |
| Lu (2018) [97]   | 189/1805     | 193/2284      | 1.26 (1.02, 1.57) | 6.86    |
| Vassonji (2017) [58] | 54/741      | 344/6546      | 1.41 (1.03, 1.91) | 6.37    |
| Subtotal (I-squared = 0.0%, p = 0.558) | 1.31 (1.10, 1.56) | 13.23        |
| Overall (I-squared = 77.7%, p = 0.000) | 1.24 (1.00, 1.52) | 100.00       |

**FIGURE 2** | Continued
|                  | Migrant(n/N) | Control(n/N) | OR (95% CI) | %Weight |
|------------------|-------------|--------------|-------------|---------|
| **Fetal death**  |             |              |             |         |
| Ratnasiri (2003) | 2037/446724 | 2720/611253  | 1.02 (0.96, 1.08) | 4.18    |
| Mika (2003)      | 124/34357   | 363/110008   | 1.09 (0.88, 1.34) | 3.47    |
| Choi (2019)      | ---         | ---          | 1.14 (1.02, 1.27) | 4.01    |
| Vik (2019)       | 1108/198520 | 5585/1156444 | 1.15 (1.08, 1.23) | 4.16    |
| Bastola (2020)   | 63/1454     | 496/350548   | 1.41 (1.07, 1.84) | 3.10    |
| Villadsen (2010) | ---         | ---          | 1.42 (1.31, 1.54) | 4.11    |
| Fuster (2014)    | 1647/412906 | 469/1874913  | 1.59 (1.50, 1.68) | 4.18    |
| **Subtotal**     |             |              | 1.24 (1.07, 1.45) | 27.21   |

| **Perinatal death** | | | | |
| Racape (2010) | ---         | ---          | 0.97 (0.74, 1.26) | 3.13    |
| Mika (2003)    | 203/34357   | 627/110008   | 1.03 (0.88, 1.21) | 3.77    |
| Fann (2013)    | 187/23518   | 1064/1773102 | 1.33 (1.13, 1.56) | 3.76    |
| Essen (2000)   | 53/5211     | 65/10784     | 1.50 (1.10, 2.00) | 2.64    |
| Barona-Wilar (2012) | 399/40834 | 1053/162043  | 1.31 (1.34, 1.69) | 3.98    |
| **Subtotal**    |             |              | 1.25 (1.04, 1.50) | 17.27   |

| **Neonatal death** | | | | |
| Choi (2019)        | ---         | ---          | 0.98 (0.87, 1.11) | 3.95    |
| Mika (2003)        | 82/54357    | 264/110008   | 0.99 (0.76, 1.27) | 3.19    |
| Madan (2006)      | 3333/2418501| 5127/4005671 | 1.07 (1.03, 1.12) | 4.21    |
| Vang (2016)       | ---         | ---          | 1.07 (0.86, 1.33) | 3.43    |
| Villadsen (2010)  | ---         | ---          | 1.17 (1.03, 1.32) | 3.94    |
| Gillet (2014)     | 210/16400   | 566/261556   | 1.28 (1.07, 1.53) | 3.66    |
| Bastola (2020)    | 38/1454     | 282/350548   | 1.50 (1.04, 2.11) | 2.60    |
| **Subtotal**      |             |              | 1.10 (1.02, 1.19) | 24.98   |

| **Post-neonatal death** | | | | |
| Ratnasiri (2003) | 711/446724  | 1434/611253  | 0.67 (0.61, 0.74) | 4.06    |
| Gillet (2014)    | 107/6400    | 310/261556   | 0.97 (0.76, 1.24) | 3.26    |
| Madan (2006)     | 4036/2415801| 6669/4005671 | 0.99 (0.96, 1.03) | 4.22    |
| Vang (2016)      | ---         | ---          | 1.02 (0.85, 1.22) | 3.65    |
| Bastola (2020)   | 16/5454     | 151/350548   | 1.18 (0.65, 1.98) | 1.65    |
| **Subtotal**     |             |              | 0.92 (0.74, 1.14) | 16.84   |

| **Infant death**  | | | | |
| Rosenberg (2002)  | 1109/72293  | 2938/130681  | 0.67 (0.63, 0.72) | 4.16    |
| Landale (2006)    | 973/4342    | 154/715      | 1.05 (0.86, 1.28) | 3.54    |
| Troe (2006)       | 178/30331   | 263/3838     | 0.86 (0.57, 1.36) | 2.17    |
| Gillet (2014)     | 317/6400    | 876/261556   | 1.17 (1.01, 1.35) | 3.84    |
| **Subtotal**      |             |              | 0.92 (0.65, 1.30) | 13.71   |

| **Overall**       | | | | |
| ---               |             |              | 1.11 (1.01, 1.21) | 100.00  |

FIGURE 2 | Continued
perinatal death [OR 1.25 (95% CI 1.04–1.50)], and neonatal death [OR 1.20 (95% CI 1.06–1.35)] indicated a higher risk for migrant children in European countries than for non-migrant children, but not in the non-European countries, with the exception of neonatal death. The insufficient number of studies did not allow for analyses of the risk of death among internal migrant children. Sensitivity analyses did not change the above results (Appendix).

### Substance Use

No significant differences were found in the risk of substance use [OR 0.83 (95% CI 0.54–1.27)], including alcohol, tobacco, and cannabis use among migrant children compared with non-migrant children (Figure 2F). The above results did not change after sensitivity analyses (Appendix). Given the studies included in substance use were all conducted in the European countries, subgroup analyses by region did not performed. Also, the effect of migration type...
TABLE 2 | The subgroup analyses by study region.

| Health outcomes | European country | Non-European country |
|-----------------|------------------|----------------------|
|                 | Pooled OR (95%CI) | Heterogeneity (I²)   | Pooled OR (95%CI) | Heterogeneity (I²)   |
| Birth outcome   | 0.95 (0.90, 1.02) | 68.5%                | 0.84 (0.75, 0.94) | 76.7%                |
| LBW             | 0.89 (0.84, 0.94) | 73.2%                | 0.83 (0.65, 1.05) | 79.8%                |
| HBW             | 1.11 (0.85, 1.45) | 69.3%                | —                   | —                   |
| Preterm birth   | 0.96 (0.88, 1.04) | 75.0%                | 0.81 (0.71, 0.92) | 80.4%                |
| Nutrition       | 1.51 (1.29, 1.78) | 71.1%                | 0.98 (0.81, 1.17) | 81.7%                |
| Overweight/obesity | 1.62 (1.39, 1.90) | 68.8%                | 0.86 (0.68, 1.09) | 80.3%                |
| Underweight     | 0.76 (0.57, 1.01) | 0%                   | —                   | —                   |
| Anemia          | —                 | 137 (1.01, 1.87)     | 73.6%                |
| Physical health | 1.48 (1.02, 2.14) | 79.1%                | 1.20 (1.03, 1.41) | 74.1%                |
| Oral disease    | 2.59 (2.10, 3.20) | 62.1%                | —                   | —                   |
| Gastrointestinal disease | — | — | — | — |
| Respiratory disease | 0.93 (0.57, 1.54) | 78.2%                | 1.48 (0.94, 2.34) | 86.5%                |
| Allergic disease | 0.62 (0.51, 0.76) | 0%                   | 0.85 (0.57, 1.27) | 77.4%                |
| Congenital disease | — | — | 1.30 (0.77, 2.19) | 80.7%                |
| Mental health   | 1.17 (0.88, 1.57) | 68.4%                | 1.32 (1.14, 1.52) | 49.5%                |
| Depression      | —                 | —                   | 1.17 (1.09, 1.26) | 0%                   |
| ADHD            | 0.73 (0.16, 3.38) | 78.8%                | —                   | —                   |
| ASD             | 0.93 (0.78, 1.12) | 71.8%                | —                   | —                   |
| Schizophrenia   | 1.90 (1.75, 2.06) | 0%                   | —                   | —                   |
| Suicide attempt | —                 | —                   | —                   | —                   |
| Death           | 1.23 (1.13, 1.34) | 70.2%                | 0.97 (0.87, 1.09) | 75.9%                |
| Fetal death     | 1.33 (1.12, 1.54) | 67.3%                | 1.07 (0.96, 1.19) | 67.45                |
| Perinatal death | 1.25 (1.04, 1.50) | 60.0%                | —                   | —                   |
| Neonatal death  | 1.20 (1.06, 1.35) | 30.7%                | 1.06 (1.02, 1.10) | 0%                   |
| Post-neonatal death | 1.00 (0.80, 1.25) | 0%                   | 0.88 (0.66, 1.16) | 66.4%                |
| Infant death    | 1.08 (0.82, 1.41) | 42.3%                | 0.83 (0.53, 1.29) | 74.3%                |
| Substance use   | 0.83 (0.54, 1.27) | 78.5%                | —                   | —                   |

**LBW**, low birth weight; **HBW**, high birth weight; **ADHD**, attention deficit hyperactivity disorder; **ASD**, autistic spectrum disorder. “—” indicate the studies included in the specific outcome no more than one. The pooled OR with 95%CI for the risk of health outcomes among subgroup using random-effects model.

on substance use did not conducted due to the limited available studies.

The Begg’s and Egger’s tests indicated no significant publication bias among the included studies in six health outcomes (all $P_{\text{Begg's Test}}>0.05$ and $P_{\text{Egger's Test}}>0.05$).

Meta-regression analyses showed that the sample size, study design, publish year, and study region had effects on physical health outcome ($\beta = 0.557$, $SE = 0.254$, $P = 0.043$; $\beta = 0.821$, $SE = 0.281$, $P = 0.010$; $\beta = 0.430$, $SE = 0.159$, $P = 0.015$; $\beta = 0.498$, $SE = 0.157$, $P = 0.096$; respectively), while had no effects on birth outcome and physical health outcome (all $P > 0.05$). Additionally, the effect of study region on nutrition outcome ($\beta = 0.597$, $SE = 0.209$, $P = 0.008$) and publish year on mental health outcome ($\beta = -0.557$, $SE = 0.228$, $P = 0.027$) were also observed.

**DISCUSSION**

Our findings demonstrated that migrant children tend to have overall worse health outcomes than non-migrant children. Compared with the controls, migrant children had an increased risk of malnutrition (e.g., overweight/obesity and anemia), poor physical health (oral diseases and gastrointestinal diseases), mental disorder (e.g., depression, schizophrenia, and suicide attempt), and death (fetal death, perinatal death, and neonatal death). The beneficial health effects were observed in birth outcomes such as lower risk of LBW and preterm birth.

The Healthy Migration Effect Does Not Necessarily Exist in Migrant Children

Although Superior Birth Outcome Was Observed

“The immigrant paradox” has been reported in studies targeting the adult migration population. Despite the average lower socio-economic status of migrants and their inferior access to healthcare, adult migrants in advanced societies are generally healthier than the natives in the host country (17). The healthy immigrant effect was also reported in some health outcomes in children upon their birth or arrival. A review on international migrants in Spain suggested that children with migrant mothers have superior birth outcomes, such as a lower incidence of LBW.
and preterm birth than the natives (108), which is consistent with the finding of our meta-analysis. Specific factors such as mother’s healthier migrant lifestyles and the cultural heritages of the migrant countries (e.g., lower rates of smoking and alcohol consumption) may partially explain the phenomenon (109). Another explanation is the selective migration hypothesis that healthier and/or wealthier women may choose to migrate to richer countries where they can have better birth outcomes (31). However, the notion that the health effect does not apply to all migrants is a subject of debate. Due to the limited generalizability, the immigrant paradox may be better conceptualized as outcome-specific with consideration of such relevant factors as immigrants’ ethnicity, length of residence (10), nativity, and age at arrival (110). This meta-analysis suggests that the immigrant paradox does not necessarily exist among children in multiple outcomes. Migrant children have an overall poorer health status, especially in overweight/obesity, mental disorder, poorly physical health, and mortality.

Migrant Children Have Higher Risk of Developing Malnutrition, Especially Being Overweight/Obesity

As reported, migrant children adhered poorly to health diet recommendations for vegetable consumption and more likely to consume sweet and soft drinks than did the native residents, which is a driver factor for obesity (111). Our meta-analysis indicated an increased risk of overweight/obesity in migrant children, especially in those who migrated to European countries with high incomes, which were consistent with the concept that migration to developed countries may develop to be overweight and obesity (112). The increased risk of obesity among migrant children can be caused by alterations in dietary intake and adopting “unhealthier” practices of the host nations (113), including increased saturated fat and carbohydrate consumption. Eating disorder among migrants may be associated with stress during acculturation compounded by pressure to adapt to new cultural body shape norms (114). Additionally, children within lower income migrant families may easily exposed to more processed and energy-dense foods because they are cheaper and quicker to prepare (111). Moreover, alterations in physical activity, a more sedentary way of life, and lower sleep duration among migrant children (115), are also important drivers for overweight and obesity (116). Our study also suggested that international migrant children had a higher risk of overweight/obesity, but the opposite result was observed among children migrating within the country. As we known, international migrants from low-middle income countries to high income countries were more likely to adopt the above-mentioned westernized lifestyle and unhealthy dietary habits (e.g., high energy, sugar, and fat intake) which were the key risk of overweight/obesity. While the rural-to-urban migrant children in India and China usually live in lower socioeconomic families and may less likely to access to more other foods compared to urban children. Yet, the prevalence of overweight/obesity of rural-to-urban migrant children is increasing gradually in recent year, which need to be of concern.

Psychological Wellbeing Is Also One of Concerns in the Broader Population of Migrant Children

Our study found that migrant children have poorer mental health than their indigenous peers, including higher risk of depression, suicide attempt, and schizophrenia. In general, stress, anxiety and depression in migrant children are strongly influenced by psychological adaption within the host country (117). Acculturation stress which refers to the potential challenges migrants face when they negotiate differences between their home and host cultures (118) increases the risks of various mental health problems among immigrant adolescents, including withdrawn, somatic, and anxious/depressed symptoms (119). Such stress arises from multiple aspects of the acculturation process, including learning new and sometimes confusing cultural rules and expectations, dealing with prejudice and discrimination, and managing the overarching conflict between maintaining elements of the old culture while incorporating those of the new (120). By the way, the publication year of the included studies had effect on migrant children’s mental health in our meta-regression analysis, this may be connected with the phenomenon that increasing number of researches focused on mental health were appeared in a decade year with the progress of globalization.

Poorly Experience of Health Is Not Uncommon Among Migrant Children

As reported that migrant children have high levels of ill health and unmet healthcare needs (121). In our study, migrant children have increased risk of mortality such as fetal death, perinatal death, and neonatal death, as well as worse physical health such as oral diseases and gastrointestinal diseases including diarrhea. The limited access to health service and insurance are the most challenging barriers for this situations (122). Experiences of health services are often unsatisfactory for migrant children, such as difficulties and delay in registering with the General medical Practitioners, difficulties securing medical appointments and missed follow-up appointments (121). Studies suggests that migrant children are four times as likely to be uninsured as native children (7). Moreover, access to health care may also be limited by their parents’ knowledge and healthcare awareness, and language and cultural barriers (123–125). Additionally, the effects of poverty on access to health insurance and healthcare appear to be the strongest (7). Children from a migrant household are more likely to live in poverty than children from a non-migrant household. For US migrant families, children in poorer families were nearly twice as likely to have not visited a dentist and to lack a usual source of sick care, and 50% were more likely not to have visited a doctor in the previous year (7).

Actions Are Required to Address the Health Inequity Among These Populations

To date, monitoring migrant health is among the key priorities of the International Organization for Migration, and a set of actions have been taken to monitor migrants’ health-seeking behaviors, access to and utilization of health services, and
to increase the collection of data related to health status and outcomes of migrants (1). However, strategies specially designed to improve the birth and health status of migrant children remain insufficient. Through the United Nations 2030 Agenda for Sustainable Development, countries worldwide have pledged to take actions to achieve the Sustainable Development Goals, including Goal 3 of good health and wellbeing and Goal 10 of reduced inequalities. Yet, the health inequalities are still prevalent. Poor health outcomes are secondary to system (e.g., long wait times between making appointments and seeing health professionals, and the long wait times at health facilities), financial, and language and cultural barriers (126). Addressing those barriers should be prioritized if the health status of migrants is to be improved. First, developing migrant-sensitive health systems and ensuring that health services are delivered to migrant children in a culturally and linguistically appropriate way, and enforce laws and regulations that prohibit discrimination. Second, adopting measures to improve the ability of health systems to deliver migrant inclusive services and programmes in a comprehensive, coordinated and financially sustainable way. Third, identifying good practices in monitoring migrant children’s health and mapping policy models that facilitate equitable access to health care (1).

**Strength and Limitations**

The comprehensive scope of this meta-analysis is a strength since evidence across multiple health outcomes and with low publication bias. However, our study has several limitations. First, our original systematic search included literature published up to January 30, 2021, and thus newer studies may draw different conclusions. Second, statistical heterogeneity was moderate high in this meta-analysis, which did not significantly decrease after subgroup-analyses. Yet, meta-regression indicated that the sample size, study design, publish year, or study region had effects on multiple health outcomes, which may partly explain the source of high heterogeneity. Similarly, high heterogeneity was identified in a systematic review and meta-analyses of the health impacts of parental migration on left-behind children (127). Third, most of the included studies in our meta-analysis were from European countries, focused on international migration and were cross-sectional, which means temporal causal inference is limited and might not generalized. Fourth, the studies with forced migrant and unaccompanied children were excluded, which might have underestimated the health status of the migrant children. Fifth, we only included studies published in English language, the non-English studies with internal migrant children especially in Chinese publications might have been excluded. Last but not the least, we were unable to explore the effect of socioeconomic status, origin country, migrant generation (e.g., the first-generation and second-generation migration) and length of residence in the host country on the health outcomes of migrant children due to the unavailability of this information, which might contribute to the migration paradox.

**CONCLUSION**

Children migrating with parents have higher risk of poor health outcomes such as malnutrition, physical diseases, mental disorder, and death than the host populations. The healthy migrant paradox does not necessary exist among children in multiple outcomes. Interventions that support migrants are urgently needed to prevent long-term negative effects on their health and development.

**DATA AVAILABILITY STATEMENT**

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

**AUTHOR CONTRIBUTIONS**

RC developed the study and oversaw its implementation, analyzed the data, and wrote the manuscript. RC, CL, HQ, and YZ did review activities, consisting of searches, study selection, data extraction, and quality assessment. JZ conceptualized and designed the study, coordinated, supervised data collection, and critically reviewed the manuscript for important intellectual content. All authors reviewed the study findings, read, and approved the final version before submission.

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**SUPPLEMENTARY MATERIAL**

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2022.810150/full#supplementary-material

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