Hypoxic ischemic encephalopathy in offspring of immigrant women in Sweden: A population-based cohort study

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Abstract
Introduction: One in four women giving birth in Sweden is foreign-born. Immigrant status has been suggested as a risk factor for adverse perinatal outcomes. It is not known if infants to foreign-born women have an increased risk of severe birth asphyxia, or which factors might mediate such association.

Material and methods: A population-based cohort study of 726,730 live births at 36 weeks of gestation or more in Sweden in 2009–2015. The exposure was maternal country of birth, grouped according to the World Bank country classification: low-, lower-middle, upper-middle, and high-income economies. The main outcome was neonatal hypoxic ischemic encephalopathy (HIE). The outcome was estimated by severity and classified as non-hypothermia-treated HIE, representing mainly mild cases, and hypothermia-treated HIE, representing moderate to severe cases. A secondary outcome was low Apgar score at 5 minutes, defined as <7 or <4. Odds ratios with 95% CI were calculated, using Swedish-born women as the reference. Structural equation modeling was used to investigate potential mediation of known antepartum risk factors.

Results: A total of 854 infants were diagnosed with HIE and 398 received therapeutic hypothermia. Offspring of mothers born in low-income countries had the highest incidences of HIE and low Apgar score, with an incidence of therapeutic hypothermia of 1.1 per 1000. Compared with offspring of Swedish-born mothers, these neonates had an almost two-fold increased risk of HIE, with or without hypothermia treatment (odds ratio 1.7; 95% CI 1.2–2.7 and odds ratio 1.7; 95% CI 1.2–2.6, respectively), and a 2- to 3-fold increased risk of low Apgar score. The structural equation model analysis indicated an exclusive direct effect of country of birth on HIE. Factors reflecting socio-economic status mediated a small proportion of the risk of Apgar score <7 at 5 minutes.

Conclusions: Offspring of women born in low-income countries had associations with severe birth asphyxia, with increased risk of both HIE and low Apgar score at
1 | INTRODUCTION

Sweden is one of several European countries that has received a large number of immigrants. In 2014, 26% of women giving birth in Sweden were foreign-born; 10% were from Asia, mainly Iran, Iraq, Syria, Lebanon, and Thailand, 8% from Europe outside the Nordic countries, and 5% from Africa. Immigrant status has been suggested as a factor associated with adverse perinatal outcomes. The immigrant population is diverse and, although some immigrant groups have been found to have better outcomes than the host population, asylum seekers and immigrants from low-income countries and some specific geographic areas have greater risks of adverse outcomes. Higher rates of low birthweight, low Apgar score at 5 minutes, and perinatal death have been reported. Socio-economics has been put forward as an important explanatory factor for these differences. However, few studies have focused on other antepartum factors that might contribute to the increased risk in the affected groups.

Severe birth asphyxia increases the risk of neurologic sequelae and death. Neonatal hypoxic ischemic encephalopathy (HIE) is caused by perinatal asphyxia in the term or near-term infant and is graded as mild, moderate or severe based on neurological symptoms at birth. Moderate to severe neonatal HIE predicts neurological disability and neonatal death. Recent studies have also found an association between mild HIE and long-term disabilities, justifying further consideration of these infants. Therapeutic hypothermia treatment within the first 6 hours after birth reduces death and disability in infants diagnosed with moderate to severe HIE. Infants with mild HIE do not qualify for hypothermia treatment because of a perceived good prognosis. To our knowledge, there are no previous studies on immigrant status and association with HIE.

The primary aim of this population-based study including more than 600,000 births was to investigate the association between being a foreign-born mother and the risk of giving birth to an infant with HIE. The secondary aim was to study the outcome low Apgar score at 5 minutes. Further, we explored the impact of antepartum factors on the outcomes.

2 | MATERIAL AND METHODS

This is a Swedish national population-based cohort study using data from the Swedish Medical Birth Register (MBR), the Swedish Neonatal Quality Register (SNQ), and the Total Population Register. Linking of registers was possible using the personal identification number allocated to each individual at birth or when becoming a legal resident of Sweden. The MBR, established in 1973, contains high-quality data on more than 98% of all births in Sweden and receives data from antenatal, obstetric, and neonatal caregivers through standardized forms. Antenatal care is standardized and free of charge in Sweden. At the first antenatal visit, maternal medical and reproductive history is obtained, together with information about height, weight, and socio-economic factors. Delivery and neonatal care are also free of charge in Sweden. After delivery, the standardized forms are forwarded to the MBR, and relevant diagnoses of mother and infant are included, using International Classification of Disease (ICD) codes.

The SNQ includes detailed information and diagnoses for all infants who are referred to a neonatal care unit within the first 27 days after birth. The SNQ was established in 2001 and all neonatal care units in Sweden are now affiliated with the register. The Total Population Register is held by Statistics Sweden and includes country of birth for all residents of Sweden.

Figure 1 describes the study population. The cohort included 726,730 neonates live-born in Sweden at 36 gestational weeks or more, without chromosomal abnormalities or congenital malformations, between 1 January 2009 and 31 December 2015. A gestational age of 36 weeks or more at birth was chosen to meet the criteria for therapeutic hypothermia. A total of 34,302 births from the southernmost health-care region in Sweden were excluded for the years 2009–2010 because the region did not register data in the SNQ until 1 January 2011. Further, 57,848 pre-labor cesarean sections and 9598 multiple births were excluded. The final population included 621,397 live-born neonates.

The exposure variable was maternal country of birth, collected from the Total Population Register. Paternal country of birth was not taken into consideration. In total, 178 countries were represented and divided into four subgroups representing low-, lower-middle-,
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upper-middle- and high-income economies, based on the World Bank country classification from 2015 (Table S1). The classification is based on countries’ gross national income, which is considered a determinant of health. At arrival in Sweden, immigrants and refugees receive temporary personal identification numbers, not linkable to other registers, resulting in unknown/missing country of birth. In total, 3585 births (0.05%) were excluded for this reason.

The primary outcome was neonatal HIE registered in the SNQ. The outcome was sub-grouped by severity, based on receiving hypothermia treatment or not. This was identified through a checkbox in the SNQ. Consequently, infants with HIE were sub-grouped as those who did not receive therapeutic hypothermia, mainly mild HIE, and those who received therapeutic hypothermia, mainly moderate to severe HIE. Hypothermia treatment was introduced in Sweden in 2007 and was established virtually nationwide in 2008. The outcome Apgar score was obtained from the MBR. A low Apgar score was defined as <4 or <7 at 5 minutes.

Covariates were collected from the MBR. Maternal age, parity, previous cesarean section, height, and weight were collected at the first antenatal visit and early pregnancy body mass index (BMI) was calculated (kg/m²). BMI was grouped based on the World Health Organization classification: underweight (BMI <18.5 kg/m²), normal weight (BMI 18.5–24.9 kg/m²), overweight (BMI 25.0–29.9 kg/m²), and obesity (BMI ≥30.0 kg/m²). Information on socio-economic factors: daily smoking habits, cohabitation, and employment in early pregnancy, was also registered at one of the first antenatal visits and categorized as yes or no. Employment included both full-time and part-time employment. Pre-gestational and gestational disorders of hypertension and diabetes were identified using ICD 10th revision codes and stratified into: chronic hypertension (O10), gestational hypertension (O13, O16), preeclampsia (O11, O14), eclampsia (O15), pre-gestational diabetes mellitus (O240–O243), and gestational diabetes mellitus (O244). Gestational age in weeks at delivery was mainly based on an early-second-trimester dating ultrasound.

2.1 | Statistical analyses

IBM SPSS Statistics version 26 was used for descriptive statistics and logistic regression analysis. Descriptive statistics were used to present numbers, missing data, percentages, and rate/1000 for study population characteristics and outcomes. Logistic regression analysis was conducted to calculate odds ratios (ORs) with 95% CIs for the outcomes. All subgroups of maternal country of birth were included in the analyses, with infants to Swedish-born mothers used as the reference. A theoretical framework and a causal diagram were created for investigating potential confounders based on known antenatal risk factors for HIE (http://dagitty.net/m9UOb91). We did not identify any true confounders in the relations between country of birth and our outcomes.

Structural equation modeling (SEM) was used to examine the direct effect of maternal country of birth as well as the mediating effects of known antepartum risk factors for the four outcomes separately: non-hypothermia-treated HIE, hypothermia-treated HIE, Apgar score <7 at 5 minutes and Apgar score <4 at 5 minutes (Figure S1). In the models, maternal age, height, weight, parity, and gestational age were included as continuous variables, and previous cesarean section, socio-economic factors, and maternal disease were included, categorized as yes or no. For this analysis, Sweden was classified as a high-income economy and not analyzed separately. The mediated effect was calculated by multiplying the individual coefficients belonging to the same path and adding the products. The total effect was defined as the sum of the direct and mediated effects and the proportion of the effect due to mediation was defined as 1 – direct effect/total effect. R version 4.0.3 was used to fit the SEM.

2.2 | Ethical approval

The study was approved by the Research and Ethics Committee in Uppsala (No. 2015/156) on May 6, 2015.

3 | RESULTS

Among the 621 397 live births at gestational age 36 weeks or more, 854 infants were diagnosed with HIE, giving an incidence of
was mediated (of hypothermia treatment or not, or Apgar score at birth. No sign of significant mediation was found for HIE, regardless of maternal country of analysis and indicates independent increased risks of HIE and low Apgar scores at 5 minutes. This result is in line with the logistic regression analysis and the occurrence of adverse perinatal outcomes. The majority of previous studies use a geographic classification of immigrants, with the recurring result that offspring of women from specific areas of Africa and Asia are at the highest risk. In our study, these areas fell mainly in lower-middle-income and low-income countries (Tables S1 and S2).

Table 1 displays maternal characteristics by country of birth group: 75.5% of the mothers were born in Sweden, 5.6% in other high-income countries, 10.9% in upper-middle-income countries, 4.5% in lower-middle-income countries, and 3.5% in low-income countries. Compared with those born in other countries, women from low-income countries were less often primiparous, more often overweight or obese, and less often cohabiting and employed. The incidence of gestational diabetes mellitus varied between 0.7% and 2.8%, with the highest incidence in women from lower-middle- and low-income countries. The prevalence of pre-gestational diabetes varied less. For hypertensive disorders, the highest prevalence was found in the high-income countries.

Women from low-income countries had pregnancies extend into post-term (>42 weeks) twice or almost twice as often as the other groups.

Table 2 shows the incidence and risk of HIE. The incidence of non-hypothermia-treated HIE varied between 0.7 and 1.2 per 1000 live-born infants, and the incidence of hypothermia-treated HIE was 0.5 to 1.1 per 1000. Compared with infants of Swedish-born mothers, infants born to mothers from low-income countries had a 70% increased risk of both non-hypothermia-treated HIE and hypothermia-treated HIE (OR 1.7, 95% CI 1.2–2.6 and OR 1.7, 95% CI 1.2–2.7, respectively). An association with non-hypothermia-treated HIE was also seen in infants born to mothers from lower-middle-income countries.

Table 3 displays the risk of a low Apgar score by maternal country of birth group. The incidence of Apgar scores <7 and <4 at 5 minutes varied between 7.3 and 18.9 per 1000 live infants and 1.1 to 3.9 per 1000 live infants, respectively. The low-income countries groups had the highest incidence in both Apgar categories. Compared with offspring of Swedish-born women, offspring of women from low-income countries had more than twice the risk of an Apgar score <7 at 5 minutes (OR 2.3, 95% CI 2.1–2.6) and an almost tripled risk of Apgar score <4 at 5 minutes (OR 2.9, 95% CI 2.3–3.7). An association with Apgar score <7 at 5 minutes was also seen in offspring of women from lower-middle-income countries (OR 1.2, 95% CI 1.1–1.4), whereas offspring of women from upper-middle-income countries had a 20% reduced risk.

The SEM (Figure S1) displayed negative coefficients for the direct effect of country of birth group on both HIE and low Apgar scores at 5 minutes. This result is in line with the logistic regression analysis and indicates independent increased risks of HIE and low Apgar scores with lower economic status of maternal country of birth. No sign of significant mediation was found for HIE, regardless of hypothermia treatment or not, or Apgar score <4 at 5 minutes. For the outcome Apgar score <7 at 5 minutes, 13% of the total effect was mediated (P < 0.01). The majority of this mediation (9%) was through cohabitation, the remaining 4% was distributed between the remaining antepartum risk factors.

4 | DISCUSSION

This large population-based study shows that offspring of mothers born in low-income countries have an association with neonatal HIE and Apgar score <7 and <4 at 5 minutes. Increased risks of non-hypothermia-treated HIE and Apgar score <7 at 5 minutes were also seen in offspring of women from lower-middle-income countries but, infants of women from upper-middle-income countries had a slightly decreased risk of Apgar score <7 at 5 minutes. The association between country of birth group and HIE could not be explained by mediation of antepartum risk factors. A small proportion of mediation was found in the association with Apgar score <7 at 5 minutes.

An important strength of our population-based study was the size of the cohort, which enabled us to study a rare outcome like neonatal HIE. Maternal care is standardized and free of charge in Sweden, disparities in maternal care were not an issue. The prospectively collected data on exposure from the Total Population Register and covariates from healthcare registers minimized the risk of selection bias and information bias. Both the MBR and the SNQ are validated registers covering 98% of births and infants admitted to neonatal care in Sweden, respectively.7,23

The use of SEM for multivariate analyses is another strength of our study, which allowed us to assess a large number of possible mediating factors. SEM enabled a complex analysis of covariates that could not only affect the outcome, but could also be interdependent.

SEM has strengths, but also limitations. In order to disentangle the mediating effects, we had to fit a linear SEM to a binary outcome. This is clearly suboptimal and can yield predicted values outside the (0, 1) range. However, the prevalence of the outcomes studied was so low that estimates from a linear model agreed with probability estimates from a logistic model.

Asylum seekers and refugees have globally been considered to be at especially high risk of adverse perinatal outcomes.4 Our data were limited to those with a personal identification number; asylum seekers and some refugees were therefore not included. This can entail a risk of underestimation. Further, the heterogeneity among immigrants is recognized, but we did not have data on reason for immigration, length of stay in Sweden before childbirth, knowledge of the Swedish language, or educational level. Nor did we have data on number of antenatal visits attended. There might also be other unknown factors of importance.

Our results are in line with previous studies indicating that immigrants from low-income countries are at greatest risk of adverse perinatal outcomes.2,3 The majority of previous studies use a geographic classification of immigrants, with the recurring result that offspring of women from specific areas of Africa and Asia are at the highest risk. In our study, these areas fell mainly in lower-middle-income and low-income countries (Tables S1 and S2).

To the best of our knowledge, no former studies have assessed the risk of HIE in infants born to immigrant women and there are few reports on the risk of Apgar score <4 at 5 minutes. These outcomes are strongly associated with short- and long-term morbidity and mortality, making risk factors important to explore. We found...
### TABLE 1  Characteristics of study population by maternal country of birth according to the World Bank country classification

|                  | Total  | Sweden | High-income economies | Upper-middle-income economies | Lower-middle-income economies | Low-income economies |
|------------------|--------|--------|-----------------------|-------------------------------|-------------------------------|---------------------|
|                  | n = 621 397 | n = 469 084 | n = 34 545 | n = 67 904 | n = 28 124 | n = 21 740 |
| **Maternal age (years)** | | | | | | |
| ≤20              | 16 911 (2.7) | 11 618 (2.5) | 697 (2.0) | 2525 (3.7) | 904 (3.2) | 1167 (5.4) |
| 21–34            | 476 749 (76.7) | 361 574 (77.1) | 24 309 (70.4) | 52 193 (76.9) | 21 970 (78.1) | 16 703 (76.8) |
| ≥35              | 127 736 (20.6) | 95 892 (20.4) | 9538 (27.6) | 13 186 (19.4) | 5250 (18.7) | 3870 (17.8) |
| **Missing**      | 1 | 0 | 1 | 0 | 0 | 0 |
| **Parity**       | | | | | | |
| Nulliparous      | 277 155 (44.6) | 214 982 (45.8) | 15 495 (44.9) | 28 051 (41.3) | 12 163 (43.2) | 6464 (29.7) |
| Parous without previous cesarean | 302 582 (48.7) | 223 666 (47.7) | 24 309 (70.4) | 35 305 (52.0) | 13 759 (48.9) | 13 109 (60.3) |
| Parous with previous cesarean   | 41 660 (6.7) | 30 436 (6.5) | 2307 (6.7) | 4548 (6.7) | 2202 (7.8) | 2167 (10.0) |
| **Missing**      | 22 885 (3.7) | 17 644 (3.8) | 1290 (3.7) | 2144 (3.2) | 1008 (3.6) | 799 (3.7) |
| **Maternal height (cm)** | | | | | | |
| ≤155             | 28 349 (4.6) | 9290 (2.1) | 1674 (5.0) | 9024 (13.7) | 5925 (21.9) | 2436 (11.6) |
| 156–160          | 89 088 (14.3) | 50 563 (11.5) | 5701 (17.1) | 18 225 (27.7) | 7768 (28.6) | 5331 (25.5) |
| 161–172          | 379 482 (61.1) | 300 267 (66.5) | 20 546 (61.8) | 34 433 (52.4) | 12 338 (45.5) | 11 898 (56.8) |
| >172             | 101 593 (16.3) | 89 820 (19.9) | 5334 (16.0) | 4078 (6.2) | 1085 (4.0) | 1276 (6.1) |
| **Missing**      | 22 885 (3.7) | 17 644 (3.8) | 1290 (3.7) | 2144 (3.2) | 1008 (3.6) | 799 (3.7) |
| **BMIa (kg/m²)** | | | | | | |
| <18.5            | 14 966 (2.4) | 9811 (2.2) | 980 (3.0) | 2063 (3.2) | 1162 (4.4) | 950 (4.6) |
| 18.5–24.9        | 352 078 (56.7) | 271 701 (61.6) | 20 518 (63.2) | 36 235 (56.2) | 14 945 (56.3) | 8679 (42.3) |
| 25–29.9          | 146 035 (23.5) | 106 564 (24.2) | 7393 (22.8) | 18 234 (28.3) | 7325 (27.6) | 6519 (31.8) |
| ≥30              | 71 911 (11.6) | 52 871 (12.0) | 3561 (11.0) | 7966 (12.4) | 3130 (11.8) | 4383 (21.3) |
| **Missing**      | 36 407 (5.9) | 28 137 (6.0) | 2093 (6.1) | 3406 (5.0) | 1562 (5.6) | 1209 (5.6) |
| **Smokingb**     | | | | | | |
| Yes              | 34 992 (5.6) | 27 251 (5.8) | 2290 (6.6) | 4189 (6.2) | 923 (3.3) | 339 (1.6) |
| No               | 565 212 (91.0) | 424 650 (90.5) | 31 089 (90.0) | 62 043 (91.4) | 26 492 (94.2) | 20 938 (96.3) |
| **Missing**      | 21 193 (3.4) | 17 183 (3.7) | 1166 (3.4) | 1672 (2.5) | 709 (2.5) | 463 (2.1) |
| **Cohabitng**   | | | | | | |
| Yes              | 558 206 (89.8) | 425 650 (90.7) | 31 405 (90.9) | 61 420 (90.5) | 25 182 (89.5) | 14 549 (66.9) |
| No               | 38 523 (6.2) | 23 812 (5.1) | 1763 (5.1) | 4423 (6.5) | 1981 (7.0) | 6544 (30.1) |
| **Missing**      | 24 668 (4.0) | 19 622 (4.2) | 1377 (4.0) | 2061 (3.0) | 961 (3.4) | 647 (3.0) |

(Continues)
| Employment | Total n = 621 397 | Sweden n = 469 084 | High-income economies n = 34 545 | Upper-middle-income economies n = 67 904 | Lower-middle-income economies n = 28 124 | Low-income economies n = 21 740 |
|------------|------------------|-------------------|-----------------------------|---------------------------------|---------------------------------|---------------------------------|
| n (%)      | n (%)            | n (%)             | n (%)                       | n (%)                           | n (%)                           | n (%)                           |
| Yes        | 430 597 (69.3)   | 362 504 (77.3)    | 22 478 (65.1)               | 29 820 (43.9)                   | 10 692 (38.0)                   | 5103 (23.5)                     |
| No         | 145 432 (23.4)   | 73 577 (15.7)     | 9458 (27.4)                 | 32 672 (48.1)                   | 14 963 (53.2)                   | 14 762 (67.9)                   |
| Missing    | 45 368 (7.3)     | 33 003 (7.0)      | 2609 (7.6)                  | 5412 (8.0)                      | 2469 (8.8)                      | 1875 (8.6)                      |
| Chronic hypertension | 2080 (0.3) | 1674 (0.4) | 156 (0.5) | 143 (0.2) | 75 (0.3) | 32 (0.1) |
| Pre-gestational diabetes| 2632 (0.4) | 2145 (0.5) | 81 (0.2) | 166 (0.2) | 100 (0.4) | 140 (0.6) |
| Pregnancy-induced hypertensive disorders| 22 562 (3.6) | 18 814 (4.0) | 1105 (3.2) | 1372 (2.0) | 682 (2.4) | 589 (2.7) |
| Gestational diabetes | 6359 (1.0) | 3249 (0.7) | 349 (1.0) | 1413 (2.1) | 777 (2.8) | 571 (2.6) |
| Gestational age at birth (weeks) |          |              |                            |                                |                                |                                |
| 36         | 11 122 (1.8)     | 8458 (1.8)       | 551 (1.6)                   | 1328 (2.0)                      | 556 (2.0)                      | 229 (1.1)                      |
| 37-40      | 437 307 (70.4)   | 327 468 (69.8)   | 24 583 (71.2)               | 50 752 (74.7)                   | 21 325 (75.8)                   | 13 179 (60.6)                   |
| 41 (late term) | 126 142 (20.3) | 97 562 (20.8)    | 6929 (20.1)                 | 11 864 (17.5)                   | 4577 (16.3)                     | 5210 (24.0)                     |
| ≥42 (post-term) | 46 826 (7.5) | 35 596 (7.6) | 2482 (7.2) | 3960 (5.8) | 1666 (5.9) | 3122 (14.4) |

Abbreviation: n, numbers.

a Body mass index; calculated from self-reported height and measured weight at first antenatal visit (gestational week 8–10).
b At first antenatal visit.
c Full- or part-time employment.
d Diabetes mellitus type 1 and 2.
e Gestational hypertension, pre-eclampsia, eclampsia.
that immigrant status per se was a risk factor for HIE, as there was no evidence of mediation in the multivariate analysis, despite known risk factors for HIE, such as maternal habitus, nulliparity, previous cesarean section, and gestational age at birth, being included.

In line with previous studies, we reported an increased risk of Apgar score <7 at 5 minutes in specific immigrant groups. Associations that have been suggested are prematurity, post-term pregnancies, and suboptimal care during pregnancy and in labor. Our material did not include premature births; but post-term pregnancies were more common among women born in low-income countries. Higher frequencies of post-term pregnancies are found in some ethnic groups. The reason is not well understood or investigated but it has been suggested that there might be a genetic predisposition. Only 13% of the total effect on Apgar score <7 at 5 minutes was mediated by variables addressed in our study, and 9% of the mediated path was through cohabitation. Therefore, we cannot confirm the role of gestational age, but the important role of socio-economic factors in pregnancy outcomes is highlighted. The low proportion of mediation indicates that there are unknown factors, not identified in our material, that pose a risk for women from low-income countries.

Suboptimal care in immigrants has been related to inadequate management of intrauterine growth restriction, inadequate interpretation of fetal heart rate surveillance, incorrect assessment of labor progress, and delayed management of obstetric emergencies. Suboptimal care could not be assessed in our material, but observational studies have reported suboptimal care in up to 30%-50% of HIE cases. Studies have shown that optimal communication is important for medical outcomes. Inadequate communication, often in combination with non-use of interpreters, has been found in studies on adverse perinatal outcomes and immigrant women. Unfortunately, information on language skills and use of interpreter was not available in our study. It is reasonable to assume that suboptimal care and failure in communication could be important, non-measurable factors contributing to our results.

An interesting finding of our study was the lower proportion of nulliparous women in the low-income countries group compared with the other groups. Nulliparity is generally a predictor of difficulties related to labor, which implies that the risk estimates may have been underestimated. On the other hand, a recent Norwegian study by Vik et al. showed that infants born to immigrant women with a first delivery outside Norway were at higher risk of adverse

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**TABLE 2** Risk of hypoxic ischemic encephalopathy by maternal country of birth according to the World Bank country classification, subgrouped into hypothermia treatment or not

| Maternal country of birth | Hypoxic ischemic encephalopathy | |  |
|---------------------------|---------------------------------|---|---|
|                           | No hypothermia treatment        | <1000 OR (95% CI) | P |
|                           | n = 456 | 1/1000 | OR | P |
| Sweden                    | 326     | 0.7    | 1.0 |  |
| High-income economies     | 28      | 0.8    | 1.2 (0.8-1.7) | 0.39 |
| Upper-middle-income economies | 47    | 0.7    | 1.0 (0.7-1.3) | 0.94 |
| Lower-middle-income economies | 29    | 1.0    | 1.5 (1.0-2.2) | 0.04 |
| Low-income economies      | 26      | 1.2    | 1.7 (1.2-2.6) | 0.01 |

| Hypothermia treatment | n = 398 | OR (95% CI) | P |
|-----------------------|---------|-------------|---|
| n = 456               | 295     | 0.6        | 1.0 |
| 20                    | 0.6     | 0.9 (0.6-1.5) | 0.77 |
| 37                    | 0.5     | 0.9 (0.6-1.2) | 0.39 |
| 22                    | 0.8     | 1.2 (0.8-1.9) | 0.32 |
| 24                    | 1.1     | 1.7 (1.2-2.7) | 0.01 |

**TABLE 3** Risk of low Apgar score at 5 minutes by maternal country of birth according to the World Bank country classification

| Maternal country of birth | Apgar score at 5 minutes | <7 | n = 5266 |
|---------------------------|--------------------------|---|---------|
|                           | n = 1000 | OR (95% CI) | P |
| Sweden                    | 3854     | 8.2        | 1.0 |
| High-income economies     | 253      | 7.3        | 0.9 (0.8-1.0) | 0.12 |
| Upper-middle-income economies | 466    | 6.9        | 0.8 (0.8-0.9) | <0.01 |
| Lower-middle-income economies | 282    | 10.0       | 1.2 (1.1-1.4) | <0.01 |
| Low-income economies      | 411      | 18.9       | 2.3 (2.1-2.6) | <0.01 |

| <4 | n = 878 |
|---|---------|
| n = 1000 | OR (95% CI) | P |
| Sweden   | 622     | 1.3        | 1.0 |
| 47       | 1.4     | 1.0 (0.8-1.4) | 0.79 |
| 78       | 1.1     | 0.9 (0.7-1.1) | 0.21 |
| 47       | 1.7     | 1.3 (0.9-1.7) | 0.12 |
| 84       | 3.9     | 2.9 (2.3-3.7) | <0.01 |

Abbreviations: CI, confidence interval; n, numbers; OR, odds ratio.
outcomes (preterm birth, post-term birth, Apgar score <7 at 5 minutes, and stillbirth) than infants born to immigrant women with a first delivery in Norway. Suggested explanations were the stress of migration, difficulties for the midwife to obtain a complete obstetric history, and the lesser attention paid to parous women compared with nulliparous women during pregnancy. In Sweden, parous women with an uncomplicated first pregnancy and delivery also receive less attention in subsequent pregnancies. It can be discussed if this approach needs to be adjusted for specific groups of foreign-born pregnant women.

Our results were consistent with previous evidence concerning increased risk of adverse perinatal outcome in specific immigrant groups, but also support the findings that some immigrant groups seem to have a better outcome. These results might be due to the healthy migrant effect; a theory suggesting that immigrants have better health outcomes, compared with both the population remaining in the home country and that in the host country.

5 | CONCLUSION

Neonatal HIE and low Apgar scores at 5 minutes are issues in the subgroup of immigrants from low-income countries. Maternal country of birth group had a direct effect on HIE whereas socio-economic mediators affected Apgar score to a small extent. Our model implied that the associations were complex. A clinical implication is that maternal origin from low-income countries should be considered a risk at admission to the labor ward. Future studies are needed to further understand the associations and to enable prevention.

CONFLICT OF INTEREST
None.

AUTHOR CONTRIBUTIONS
MJ, AET, and AKW designed the study. The data collection was performed by MJ. All authors contributed to the statistical analysis and interpretation of the results. AET drafted the article. Critical revision and final approval of the version to be published was made by MJ, AKW, and EL.

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SUPPORTING INFORMATION
Additional supporting information may be found online in the Supporting Information section.

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