Association between Apgar scores of 7 to 9 and neonatal mortality and morbidity: population based cohort study of term infants in Sweden

Neda Razaz,1 Sven Cnattingius,1 KS Joseph2

ABSTRACT

OBJECTIVE
To investigate associations between Apgar scores of 7, 8, and 9 (versus 10) at 1, 5, and 10 minutes, and neonatal mortality and morbidity.

DESIGN
Population based cohort study.

SETTING
Sweden.

PARTICIPANTS
1 551 436 non-malformed live singleton infants, born at term (>37 weeks’ gestation) between 1999 and 2016, with Apgar scores of ≥7 at 1, 5, and 10 minutes.

EXPOSURES
Infants with Apgar scores of 7, 8, and 9 at 1, 5, and 10 minutes were compared with those with an Apgar score of 10 at 1, 5, and 10 minutes, respectively.

MAIN OUTCOME MEASURES
Neonatal mortality and morbidity, including neonatal infections, asphyxia related complications, respiratory distress, and neonatal hypoglycaemia. Adjusted odds ratios (aOR), adjusted rate differences (aRD), and 95% confidence intervals were estimated.

RESULTS
Compared with infants with an Apgar score of 10, aORs for neonatal mortality, neonatal infections, asphyxia related complications, respiratory distress, and neonatal hypoglycaemia were higher among infants with lower Apgar scores, especially at 5 and 10 minutes. For example, the aORs for respiratory distress for an Apgar score of 9 versus 10 were 2.0 (95% confidence interval 1.9 to 2.1) at 1 minute, 5.2 (5.1 to 5.4) at 5 minutes, and 12.4 (12.0 to 12.9) at 10 minutes. Compared with an Apgar score of 10 at 10 minutes, the aRD for respiratory distress was 9.5% (95% confidence interval 9.2% to 9.9%) for an Apgar score of 9 at 10 minutes, and 41.9% (37.7% to 46.4%) for an Apgar score of 7 at 10 minutes. A reduction in Apgar score from 10 at 5 minutes to 9 at 10 minutes was also associated with higher odds of neonatal morbidity, compared with a stable Apgar score of 10 at 5 and 10 minutes.

CONCLUSIONS
In term non-malformed infants with Apgar scores within the normal range (7 to 10), risks of neonatal mortality and morbidity are higher among infants with lower Apgar score values, and also among those experiencing a reduction in score from 5 minutes to 10 minutes (compared with infants with stable Apgar scores of 10).

Introduction
The most routinely used measure of health status of newborns is the Apgar score, typically quantified at 1, 5, and 10 minutes after birth.1 Our recent population based studies have shown that non-malformed term infants born with lower Apgar scores within the normal range (7 to 9) at 1, 5, or 10 minutes are at higher risk of adverse long term outcomes, such as epilepsy, cerebral palsy, having additional needs, and adverse child developmental health (compared with non-malformed term infants with an Apgar score of 10).2-4 Both the timing and the score are important: compared with an Apgar score of 10 at 5 and 10 minutes, an Apgar score of 9 at 5 minutes and an Apgar score of 9 at 10 minutes are both associated with an increased risk of cerebral palsy, with an Apgar score of 9 at 10 minutes conferring higher risk of cerebral palsy than an Apgar score of 9 at 5 minutes.3

The findings of differential risks associated with Apgar scores within the normal range are unexpected as it is commonly assumed that Apgar scores of 9 versus 10 are assigned arbitrarily. This belief is supported by international comparisons of Apgar scores, which show that the frequency of Apgar scores of 10 at 5 minutes vary from 8.8% in some countries to 92.7% in others.5 It is widely recognised that a low Apgar score, commonly defined as a score less than 7, is associated with increased risks of neonatal mortality,6,7 morbidity,8-10 and long term outcomes11-16; however, no previous study has investigated whether Apgar scores of 7, 8, and 9 are similarly associated with higher risks of neonatal mortality and morbidity. Quantifying associations between Apgar scores in the normal range and neonatal morbidity, such as neonatal infections, neonatal respiratory distress, and hypoxic-ischaemic
encephalopathy is important because such conditions are known risk factors for later neurodevelopmental adversity in children. In this population based study of more than 1.5 million infants born in Sweden, we evaluated associations between Apgar scores of 7, 8, and 9 (versus 10) at 1, 5, or 10 minutes and risks of neonatal mortality and morbidity.

Methods
We based our study on singleton live births in Sweden between 1999 and 2016, with data obtained from the Medical Birth Register. This database contains information on antenatal, obstetrical, and neonatal care that is prospectively recorded on standardised forms for more than 98% of births in Sweden. The most recent extensive validation of the Medical Birth Register showed that coverage and validity of most variables were high. Using the person-unique national registration numbers of mothers and infants, we linked data from the Birth Register to several national registries. The nationwide National Patient Register includes diagnostic codes on hospital in-patient care since 1987 and hospital out-patient care from 2001. We coded diagnoses in the patient and birth registers using the Swedish versions of the International Classification of Diseases, 10th Revision (ICD-10) from 1997 onwards. We obtained information on neonatal deaths from the National Cause of Death Register, which includes information on all deaths in Sweden since 1961. Information on maternal education and country of origin was obtained from the Education Register and the Total Population Register, respectively.

Study population
We analysed data for 18 years (1999-2016), during which 1,834,641 singleton live births were recorded in the Birth Register. We excluded preterm infants (≤36 completed weeks’ gestation, n=94,545), infants with major congenital malformations (n=60,762), and records with missing data on maternal or infant identification numbers (n=25,658), leaving 1,653,676 term (≥37 completed weeks’ gestation) singleton, non-malformed infants. Complete information on Apgar scores at 1 and 5 minutes was available for 1,645,396 infants (99%), of whom 1,620,473 (98.5%) also had information on Apgar scores at 10 minutes. We restricted our study population to infants with Apgar scores of 7 to 10 at 1, 5, and 10 minutes (n=1,551,436).

We obtained data on neonatal mortality and morbidity from nationwide Swedish registries: the Medical Birth Register and the Swedish patient and cause of death registers. Neonatal mortality was defined as infant deaths within the first 0-27 days after birth. Neonatal morbidity, assessed in the first 0-27 days after birth, included neonatal infections, asphyxia related neonatal complications (hypoxic-ischaemic encephalopathy and related conditions, and neonatal convulsions/seizures), neonatal hypoglycaemia, and respiratory distress (see supplementary table A for specific ICD-10 codes).

In Sweden, all women are offered an ultrasound scan at 18 weeks’ gestation or earlier for dating and screening for congenital abnormalities. In our study, we estimated gestational age (in completed weeks) using the following hierarchy: date of early second trimester ultrasoundography (87.7%), date of last menstrual period (7.4%), or a postnatal assessment (4.9%).

Among maternal characteristics, we retrieved information on age at delivery, country of origin, highest attained level of education, cohabitation with a partner, parity, height, body mass index (BMI, kg/m²), and smoking during pregnancy. Maternal age at delivery was calculated as date of delivery minus the mother’s birth date, and parity was defined as the number of births to each mother (including the index birth). BMI was calculated using weight measured at registration to antenatal care (wearing light indoor clothing) and self reported height. BMI was categorised according to the World Health Organization groups as underweight (BMI <18.5), normal weight (18.5 to <25), overweight (25 to <30), obesity grade 1 (30 to <35), obesity grade 2 (35 to <40), or obesity grade 3 (≥40). We obtained information on cohabitation with a partner during the first antenatal visit. Mothers who reported daily smoking at the first antenatal visit and/or at 30 to 32 weeks’ gestation were classified as smokers, whereas mothers who stated that they were non-smokers were classified as such. Information on induction of labour and mode of delivery was noted on the obstetric record at onset of labour and after delivery, respectively.

Statistical analyses
The frequency of each Apgar score value was calculated within categories of maternal and infant characteristics. Logistic regression was used to examine associations between Apgar scores of 7, 8, or 9 (versus 10) at 1, 5, or 10 minutes and neonatal mortality and each neonatal morbidity. Results were expressed as odds ratios with 95% confidence intervals. In the multivariable analyses, estimates were adjusted for maternal factors (age at childbirth, parity, country of birth, education, smoking, cohabitation with a partner, height and early pregnancy BMI) and birth characteristics of the infant (sex, gestational age in weeks, and year of birth). Lastly, the magnitude of absolute effects was quantified by calculating adjusted rate differences. The adjusted rate difference represents the number of excess cases of neonatal mortality and morbidity per 100 births among infants receiving an Apgar score of 7, 8, or 9 at 1, 5, and 10 minutes compared with infants receiving an Apgar score of 10. Two sided P values of less than 0.05 were considered to indicate statistical significance.

Supplementary analyses
Pregnancy and delivery complications are associated with increased risks of a low Apgar score (0 to 6) and neonatal morbidity. We therefore also quantified the association between risk factors, such as gestational diabetes, pre-eclampsia, choioamnionitis, placental abruption, premature rupture of membranes,
induction of labour, mode of delivery, and meconium aspiration (see supplementary table A for specific ICD-10 codes) and Apgar scores of 7, 8, and 9 (versus 10) at 1, 5, or 10 minutes. Logistic regression with the Apgar score of interest (eg, 5 minute Apgar score of 9 versus 10) as the dependent variable was used to obtain odds ratios and 95% confidence intervals for each risk factor.

**Patient and public involvement**

This study was based on analysis of information from linked databases and no patients were involved in designing the research question or the outcome measures, nor were they involved in developing plans for implementation of the study. No patients were asked to advise on interpretation or writing up of results.

**Results**

Only 11% (163800/1551436) of infants had an Apgar score of 10 at 1 minute, whereas 89% (1373314/1551436) and 97% (1501605/1551436) had a score of 10 at 5 and 10 minutes, respectively. Apgar scores of 10 at 5 minutes were less common in offspring of mothers who were primiparous, born in Sweden, shorter (<159 cm), or very obese (BMI ≥35 kg/m²), and less common in those who delivered at 37 weeks’ and ≥42 weeks’ gestation. The frequency of an Apgar score of 10 at 5 minutes was also lower in boys compared with girls (table 1).

**Neonatal mortality and morbidity**

Apgar scores of 7, 8, and 9 at 1, 5, and 10 minutes were strongly associated with neonatal mortality and morbidity, compared with an Apgar score of 10 at 1, 5, and 10 minutes (fig 1, supplementary table B). Compared with an Apgar score of 10 at 10 minutes, adjusted odds ratios for neonatal mortality increased from 4.8 for an Apgar score of 9 at 10 minutes to 29.8 for an Apgar score of 7 at 10 minutes (fig 1; supplementary table B). Furthermore, adjusted odds ratios between lower Apgar score values and neonatal mortality and each neonatal morbidity were higher with increasing time after birth. For example, compared with an Apgar score of 10 at 1 minute, an Apgar score of 9 at 1 minute was associated with 1.5-fold higher adjusted odds of neonatal infections, whereas the association was larger at 5 and 10 minutes (adjusted odds ratios 2.1 and 3.3, respectively). Asphyxia related complications, neonatal hypoglycaemia, and respiratory distress were also strongly associated with Apgar scores of 7, 8, and 9, and adjusted odds ratios increased with time since birth. The adjusted rate difference for respiratory distress was 9.5% (95% confidence interval 9.2% to 9.9%) for an Apgar score of 9 at 10 minutes and increased to 41.9% (37.7% to 46.4%) for an Apgar score of 7 at 10 minutes, compared with an Apgar score of 10 at 10 minutes (table 2). Lastly, the association between Apgar score and neonatal morbidity remained strong regardless of mode of delivery, and the highest odds ratios were observed for infants born following a non-instrumental vaginal delivery (supplementary table C).

**Combinations**

Table 3 shows adjusted odds ratios for neonatal mortality and morbidity in relation to changes in Apgar score values from 5 to 10 minutes. A reduction of Apgar score from 10 at 5 minutes to 9 at 10 minutes was associated with higher adjusted odds ratios for neonatal infections, neonatal hypoglycaemia, and respiratory distress (compared with an Apgar score of 10 at both 5 and 10 minutes). For instance, compared with Apgar scores of 10 at both time points, a reduction in Apgar score from 10 at 5 minutes to 9 at 10 minutes was associated with a 4.1-fold higher odds of neonatal infections. Compared with Apgar scores of 10 at both time points, infants whose Apgar scores increased from 9 at 5 minutes to 10 at 10 minutes also had higher relative odds for all outcomes including neonatal mortality. For example, compared with Apgar scores of 10 at both time points, an improvement from an Apgar score of 9 at 5 minutes to 10 at 10 minutes was associated with a 1.8-fold higher odds of neonatal infections (adjusted odds ratio 1.8, 95% confidence interval 1.7 to 1.9).

**Supplementary analyses**

Pregnancy and delivery factors, including gestational diabetes, pre-eclampsia, chorioamnionitis, placental abruption, induced onset of labour, vaginal instrumental or caesarean delivery, and meconium aspiration were associated with Apgar scores of 7, 8, and 9 (versus 10) at 5 and 10 minutes (see supplementary table D). The strength of association differed markedly, and the highest relative odds were obtained for pre-eclampsia, chorioamnionitis, placental abruption, vaginal instrumental delivery, emergency caesarean delivery, and meconium aspiration. Premature rupture of the membranes was not associated with increased odds for Apgar scores of 7, 8, or 9 at 5 or 10 minutes. Pregnancy and delivery factors were not or were only modestly associated with Apgar scores of 7, 8, or 9 versus 10 at 1 minute, except for vaginal instrumental delivery and meconium aspiration, which were associated with markedly higher odds of an Apgar score of 7, 8, or 9 at 1 minute (eg, the adjusted odds ratio for an Apgar score of 9 versus 10 at 1 minute for meconium aspiration was 3.7 (95% confidence interval 1.9 to 7.2)).

**Discussion**

In this nationwide Swedish cohort study, we found that a lower Apgar score within the normal range at 1, 5, and 10 minutes is strongly associated with increased risks of neonatal mortality and morbidity. Furthermore, we found progressively higher relative odds of neonatal mortality, infections, asphyxia related complications, neonatal hypoglycaemia, and respiratory distress with lower Apgar scores (7 to 9) at 1, 5, and 10 minutes. The relative odds of neonatal mortality and morbidity associated with lower Apgar scores (in the normal range) increased with increasing time from birth. A small change in Apgar score from 5 minutes to 10 minutes (eg, from
10 to 9) was also associated with an increased risk of neonatal morbidity. Pregnancy and delivery related factors, such as pre-eclampsia, chorioamnionitis, placental abruption, induced onset of labour, vaginal instrumental delivery, and meconium aspiration were associated with Apgar scores of 7 to 9 (versus 10), suggesting that low Apgar scores in the normal range represent early prognostic indicators highlighting the effects of pregnancy and delivery complications on neonatal morbidity.
Table 2 | Adjusted rate differences (per 100 births) for neonatal mortality and morbidity outcomes for Apgar scores of 7, 8, and 9 at 1, 5, and 10 minutes compared with a score of 10, in Sweden, 1999–2016

| Variables                  | 1 min Apgar score | 5 min Apgar score | 10 min Apgar score |
|----------------------------|-------------------|-------------------|--------------------|
| Neopatal mortality         |                   |                   |                    |
| Apgar scores:             |                   |                   |                    |
| 7                         | 16 (0.03)         | 0.02 (0.004 to 0.1)| 4 (0.1)            |
| 8                         | 42 (0.03)         | 0.02 (0.005 to 0.04)| 22 (0.1)            |
| 9                         | 207 (0.02)        | 0.004 (−0.002 to 0.01)| 67 (0.04)         |
| 10                        | 17 (0.01)         | Reference          | 189 (0.01)         |
| Neonatal infections        |                   |                   |                    |
| Apgar scores:             |                   |                   |                    |
| 7                         | 1252 (2.4)        | 1.5 (1.3 to 1.7)  | 210 (6.3)          |
| 8                         | 2051 (1.7)        | 0.8 (0.7 to 1)    | 856 (4.1)          |
| 9                         | 9834 (0.8)        | 0.3 (0.2 to 0.3)  | 2595 (1.7)         |
| 10                        | 823 (0.5)         | Reference          | 10299 (0.7)        |
| Asphyxia related complications |                 |                   |                    |
| Apgar scores:             |                   |                   |                    |
| 7                         | 178 (0.1)         | 0.2 (0.2 to 0.3)  | 25 (0.7)           |
| 8                         | 218 (0.2)         | 0.1 (0.1 to 0.1)  | 105 (0.5)          |
| 9                         | 834 (0.1)         | 0.02 (0.01 to 0.03)| 259 (0.2)         |
| 10                        | 69 (0.04)         | Reference          | 910 (0.1)          |
| Neonatal hypoglycaemia     |                   |                   |                    |
| Apgar scores:             |                   |                   |                    |
| 7                         | 1799 (3.5)        | 2.4 (2.2 to 2.8)  | 228 (6.8)          |
| 8                         | 5539 (2.9)        | 1.9 (1.7 to 2.1)  | 1038 (5.0)         |
| 9                         | 18815 (1.6)       | 0.7 (0.6 to 0.8)  | 4496 (2.9)         |
| 10                        | 1460 (0.9)        | Reference          | 19851 (1.4)        |
| Respiratory distress       |                   |                   |                    |
| Apgar scores:             |                   |                   |                    |
| 7                         | 3736 (7.3)        | 6.0 (5.6 to 6.6)  | 1127 (33.8)        |
| 8                         | 4920 (4.0)        | 3.1 (2.9 to 3.4)  | 3628 (16.3)        |
| 9                         | 12712 (1.0)       | 0.5 (0.4 to 0.6)  | 6446 (4.2)         |
| 10                        | 896 (0.5)         | Reference          | 11083 (0.8)        |

*Adjusted for maternal factors (age at childbirth, parity, country of birth, education, smoking, cohabitation with a partner, height, early pregnancy BMI) and birth characteristics of the infant (sex, gestational age in weeks, year of birth).
**RESEARCH**

**Table 3 | Combinations of Apgar scores at 5 and 10 minutes and adjusted odds ratios for neonatal mortality and morbidity among term singleton live births in Sweden, 1999–2016**

| Morbidity                      | Score | 5 min | 10 min | No (%) | Adjusted odds ratio (95% CI)* |
|--------------------------------|-------|-------|--------|--------|-------------------------------|
| **Neonatal mortality**         |       |       |        |        |                               |
| 10                             | 10    | 188   | 0.01   | Reference |                               |
| 9                              | 9     | 1     | 0.1    | -      |                               |
| <9                             | 9     | 39    | 0.03   | 2.8 (2.0 to 4.0) |                               |
| <9                             | 9     | 27    | 0.1    | 5.5 (3.5 to 8.7) |                               |
| <9                             | <9    | 1     | 0.2    | -      |                               |
| **Neonatal infections**        |       |       |        |        |                               |
| 10                             | 10    | 10266 | 0.7    | Reference |                               |
| 9                              | 10    | 27    | 3.7    | 4.1 (2.7 to 6.6) |                               |
| 9                              | 9     | 1716  | 1.4    | 1.8 (1.7 to 1.9) |                               |
| <9                             | 9     | 848   | 2.5    | 3.0 (2.8 to 3.3) |                               |
| <9                             | <9    | 31    | 6.0    | 6.9 (4.6 to 10.4) |                               |
| **Asphyxia related complications** |       |       |        |        |                               |
| 10                             | 10    | 907   | 0.1    | Reference |                               |
| 9                              | 9     | 2     | 0.3    | -      |                               |
| <9                             | 9     | 194   | 0.2    | 2.4 (2.0 to 2.8) |                               |
| <9                             | 9     | 67    | 0.2    | 2.6 (2.0 to 3.5) |                               |
| <9                             | <9    | 2     | 0.6    | -      |                               |
| **Neonatal hypoglycaemia**     |       |       |        |        |                               |
| 10                             | 10    | 19841 | 1.4    | Reference |                               |
| 9                              | 10    | 31    | 4.3    | 2.5 (1.7 to 3.7) |                               |
| 9                              | 9     | 3225  | 2.7    | 1.8 (1.7 to 1.8) |                               |
| 9                              | 9     | 1399  | 3.6    | 2.3 (2.2 to 2.6) |                               |
| <9                             | 9     | 32    | 6.2    | 3.8 (2.6 to 5.6) |                               |
| <9                             | <9    | -     | -      | -      |                               |
| **Respiratory distress**       |       |       |        |        |                               |
| 10                             | 10    | 10883 | 0.8    | Reference |                               |
| 9                              | 10    | 156   | 21.6   | 29.0 (23.9 to 35.3) |                               |
| 9                              | 9     | 3138  | 2.6    | 3.3 (3.2 to 3.6) |                               |
| 9                              | 9     | 5088  | 9.0    | 11.7 (11.1 to 12.2) |                               |
| <9                             | 9     | 220   | 42.6   | 77.1 (63.8 to 93.3) |                               |
| <9                             | <9    | -     | -      | -      |                               |

*Adjusted for maternal factors (age at childbirth, parity, country of birth, education, smoking, cohabitation with a partner, height and early pregnancy BMI) and birth characteristics of the infant (sex, gestational age in weeks, and year of birth).

**Strengths and weaknesses of this study**

Our study included more than 1.5 million births. We included all eligible births in Sweden over an 18 year period, thereby avoiding selection bias. Furthermore, we were able to adjust for several important confounders in multivariable analyses. In Sweden, all citizens have free access to uniform publicly funded healthcare, which contributes to high internal validity. However, the Apgar score is not subject to quality control measures and is prone to interobserver variability, and there are known international differences in the frequency of scores within the normal range. Nevertheless, the Apgar score has been shown to have good internal validity and could provide useful information about national trends in newborn health. Lastly, we lacked information about neonatal interventions and umbilical cord blood gas analysis, which could influence Apgar scores and neonatal morbidity and mortality. Future studies should examine the relation between acidosis and Apgar score within the normal ranges and its impact on neonatal morbidity.

**Comparison with other studies**

Previous studies have shown that an Apgar score of less than 7 is associated with neonatal morbidity, including meconium aspiration, neonatal respiratory distress, hypoxic-ischaemic encephalopathy, and infant mortality. The relation between Apgar score of less than 7 and neonatal and infant mortality is mainly attributed to anoxia or infections. Our study expands on these findings by showing that even “normal” Apgar scores (7 to 9) are strongly associated with higher risks of neonatal mortality and neonatal morbidity, and neonatal morbidity is associated with risks of long term neurological disorders. These findings are consistent with evidence suggesting that some infants with reassuring Apgar scores (7 to 9) with acidaemia have higher rates of adverse outcomes. Furthermore, risks associated with a low Apgar score (in the normal range) at 10 minutes were generally higher than those associated with the same score at 1 or 5 minutes. The strong relations between Apgar scores of 7, 8, and 9 and neonatal morbidity, and the associations between pregnancy complications and lower Apgar scores in the normal range observed in our study, provide insight into previous findings of increased risks of cerebral palsy, epilepsy, autism, and adverse developmental outcomes in children with Apgar scores of 7, 8, and even 9, compared with an Apgar score of 10.

In our study only 11% of infants had an Apgar score of 10 at 1 minute, which is typically attributable to a reduction in score for skin colour. This finding warrants attention as our results show that an Apgar score of 9 at 1 minute was associated with higher risk of neonatal morbidity. Although a reduction in the 5 minute Apgar score due to colour is independently associated with an increased risk of infant mortality, current guidelines consider Apgar scores of 7 or more at 1 and 5 minutes to be reassuring. Our findings of an incremental increase in the risks of neonatal mortality and morbidity among infants with Apgar scores of 7, 8, and 9 at 1, 5, and 10 minutes, along with previous results of a linear relation between decreasing Apgar scores and increasing risk of adverse neurodevelopmental outcomes, suggest that efforts should be made to reduce the rate of low Apgar scores within the normal range and to strive for an Apgar score of 10 immediately after birth.

Seizures, intracranial haemorrhage, and birth asphyxia have been shown to be associated with Apgar scores of less than 7 at 5 and 10 minutes. Our study is, to our knowledge, the first to show an association between a reduction in Apgar score (from 10 at 5 minutes to <9 at 10 minutes) and increased risks of neonatal mortality and morbidity, including infections, asphyxia related conditions, and respiratory distress. A low Apgar score at 5 minutes and 10 minutes might indicate the lack of an optimal response to resuscitation and could imply an adverse long term prognosis. A reduction in Apgar score from 5 minutes to 10 minutes is also associated with higher risks of later developing cerebral palsy, epilepsy, or other developmental adversity. Although Apgar scores at 10 minutes are often not recorded in the medical charts if scores are within the normal range (7 to 10) at 5 minutes, our findings suggest that all newborns should be assigned an Apgar score at 10 minutes, regardless of their score at 1 minute and 5 minutes. This will enable at-risk neonates to be identified and monitored to minimise the risk of adverse outcomes.

**Apgar score**

The Apgar score is a standardized assessment of the newborn's condition immediately after birth. It is a composite score ranging from 0 to 10, with 10 being the highest score, indicating optimal health. The score is calculated based on the newborn's heart rate, respiratory effort, muscle tone, reflex irritability, and skin colour at 1 minute and 5 minutes after birth. Higher Apgar scores are associated with better neonatal outcomes, including lower risks of neonatal mortality and morbidity. However, a low Apgar score at 5 minutes and 10 minutes might be an indicator of potential neonatal problems, and further follow-up is recommended.
Conclusions
Our study shows that low Apgar scores within the normal range (7 to 10) are strongly associated with neonatal mortality and morbidity and that these associations are substantially stronger with increasing time after birth. Additionally, a decrease in Apgar score from 10 at 5 minutes to 9 or less at 10 minutes is associated with a higher risk of neonatal morbidity. Our findings provide strong evidence to support the proposition that the optimal Apgar score is 10 at each time point, and all newborns should be assigned an Apgar score at 10 minutes, regardless of their score at 1 minute and 5 minutes.

Contributors: NR and SC had full access to all the data in the study and take full responsibility for the integrity of the data and the accuracy of the data analysis. They are the guarantors. NR, SC, and KSJ conceived and designed the study. All authors interpreted the data and critically revised the manuscript for important intellectual content. NR drafted the manuscript and carried out the statistical analysis. SC obtained funding and provided administrative, technical, or material support.

Funding: This study was funded by the Swedish Research Council for Health, Working Life and Welfare (grant No 2017-00134), and by an unrestricted grant from Karolinska Institutet (No 2368/10-221). Distinguished Professor Award to SC. NR is supported by a postdoctoral fellowship award from the Canadian Institutes of Health Research. KSJ is supported by the BC Children’s Hospital Research Institute. Funders were not involved in the design and conduct of the study; collection, management, analysis, or interpretation of the data; and preparation, review, or approval of the manuscript.

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or financial disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no additional data available.

Data sharing: This study was approved by the regional ethic committee. No additional data available.

Supplementary materials: Supplementary tables A-D