A comparison of neonatal outcomes between adolescent and adult mothers in developed countries: A systematic review and meta-analysis

MARVIN-DOWLE, K and SOLTANI, Hora <http://orcid.org/0000-0001-9611-6777>

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A comparison of neonatal outcomes between adolescent and adult mothers in developed countries: A systematic review and meta-analysis

Katie Marvin-Dowle, Hora Soltani*

Sheffield Hallam University, Faculty of Health and Wellbeing, 34 Collegiate Crescent, Sheffield, S10 2BP, UK

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A B S T R A C T
Evidence suggests that adolescent pregnancies are at increased risk of adverse neonatal outcomes compared to adult pregnancies; however, there are significant inconsistencies in the literature, particularly in studies conducted in developed countries.

The objective of this study therefore is to systematically review the current literature with regard to the relationship between adolescent pregnancy and neonatal outcomes.

A literature search was conducted in eight electronic databases (AMED, ASSIA, Child Development and Adolescent Studies, CINAHL, Cochrane Library, Health Source: Nursing, Maternity and Infant Care, MEDLINE and Scopus. The reference lists of included studies were also hand-searched.

Studies were included if: they were conducted in countries with very high human development according to the United Nations Human Development Index; reported at least one comparison between adolescents (19 years or under) and adult mothers (20–34 years); and were published between January 1998 and March 2018.

Studies were screened for inclusion and data extracted by one reviewer. A second reviewer independently reviewed a sub-set of studies. Disagreements were resolved by consensus. Meta-analysis was performed using RevMan 5.3 using crude counts reported in the included studies. Sub-group analyses of adolescents aged 17 and under and 18–19 were conducted. Pooled analysis of adjusted odds ratios was also undertaken in order to consider the effect of confounding factors. Meta-analysis effect estimates are reported as risk ratios (RR) and pooled association as adjusted odds ratios (aORs). Point estimates and 95% confidence intervals are presented.

After removal of duplicates a total of 1791 articles were identified, of which 20 met the inclusion criteria.

The results of the meta-analysis showed adolescents to have increased risk of all primary adverse outcomes investigated. Sub-group analysis suggests an increased risk of perinatal death and low birthweight for children born to adolescent mothers; 17 and under (perinatal death: RR 1.50, CI 1.32–1.71; low birthweight RR 1.43, CI 1.20–1.70); 18–19 (perinatal death RR 1.21, CI 1.06–1.37; low birthweight RR 1.10, CI 1.08–1.57). Mothers aged 17 and under were also at increased risk of preterm delivery (RR 1.64, CI 1.54–1.75). Analysis adjusted for confounders showed increased risk of preterm delivery (aOR 1.23, CI 1.09–1.38), very preterm delivery (aOR 1.22, CI 1.03–1.44) and neonatal death (aOR 1.31, CI 1.14–1.52).

Findings show that young maternal age is a significant risk factor for adverse neonatal outcomes in developed countries. Adolescent maternal age therefore should be considered as a potential cause for concern in relation to neonatal health and it is recommended that health care professionals respond accordingly with increased support and monitoring.

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* Corresponding author.
E-mail address: h.soltani@shu.ac.uk (H. Soltani).

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Introduction

Adolescent pregnancies are defined as pregnancies occurring in women aged 19 years or under at the time of conception. Adolescent pregnancy is a global issue with approximately 2 million girls under the age of 16, and 16 million between the ages of 15 and 19 becoming pregnant annually. Adolescent pregnancies are associated with socio-economic deprivation, on both a global and local level [1]. Young women who are living in poverty, with low levels of education and in marginalised communities are most likely to become pregnant at an early age and continue to experience high levels of deprivation.

Globally rates of adolescent pregnancy have reduced from 56.3 conceptions per 1,000 females aged 15–19 in 2000 to 42.5 per 1,000 in 2017. Rates in high income countries are reducing faster from 23.4–12.5 in the same time period. This said, even amongst countries with the highest levels of human development according to the UN human development index there is significant variation in the adolescent fertility rate from 2.7 per 1,000 in Hong Kong to 19.9 per 1,000 in the United States, suggesting that social and cultural factors play an important part in the prevalence of adolescent childbearing [2].

Adolescent age may be an independent risk factor for adverse pregnancy outcomes. One robust systematic review of studies of young adolescents conducted in low and middle income countries found that maternal age <15 years or less than 2 years after menarche had a negative effect on maternal and foetal growth, and infant survival, and a moderate relationship between young maternal age and anaemia, premature birth and neonatal mortality. [3].

There are suggestions that because some adolescents will still be growing during pregnancy they may compete with the developing embryo to satisfy their own growth needs. A prospective cohort study examining the relationship between maternal growth and outcomes found that continued maternal growth in adolescents affected nutrient partitioning between mother and child, and that this impacted negatively upon foetal growth and prematurity [4]. This is however contested by a UK based study [5] which found that the average birthweight of babies born to adolescent women who were still growing was in fact higher than those of young women who had finished growing. Average infant birthweight in the non-growing adolescent group was however significantly lower than adult controls.

There exists a reasonable amount of evidence to indicate that outcomes for adolescent mothers compare less favourably with adults. However, there is considerable inconsistency in these findings particularly between those studies conducted in developed countries. For example, one Canadian study found that while adolescent women were at increased risk of very preterm birth there was no difference in risk of foetal death between adolescent and adult mothers [6]; however a further Australian study identified adolescent maternal age as a risk factor for stillbirth and neonatal death [7]. There has been no recent systematic review creating an overall picture of differences in birth outcomes for adolescent women compared to an adult control group, particularly focused on high income countries. This study therefore aims to review the evidence to address the question

"Is there a higher risk of adverse perinatal outcomes among babies born to adolescent mothers (age 19 years or younger) compared to those born to older mothers in developed countries?"

Materials and methods

A protocol for this systematic review is registered with Prospero (number CRD42018092182). The study was exempt from ethics approval because the research was not conducted with humans or animals and used publicly available data. There was no patient or public (PPI) involvement in the study.

Search strategy

The following electronic databases were searched: AMED, ASSIA, Child Development and Adolescent Studies, CINAHL, Cochrane Library, Health Source: Nursing, Maternity and Infant Care, MEDLINE and Scopus from 1 Jan 1998 to 1 March 2018. Primary studies using any design were included where they reported data for at least one of the outcomes of interest for an adolescent group (≤19 years) alongside an adult control group (20–34 years) or groups within these age brackets. A detailed report of the search strategy employed is available in Appendix 1. Bibliographies of papers selected for inclusion in the review were also hand searched to identify any further relevant references. Identified citations were entered into a ReWorks database and duplicates removed. One researcher screened papers; initially by title and abstract followed by a full text review of papers whose abstracts appeared to fulfil the inclusion criteria, papers selected after full text review were then screened by a second reviewer. Where uncertainties regarding inclusion arose the article was reviewed by a third researcher and a consensus decision made.

Study selection

Primary studies were included if: they were conducted in countries with very high human development according to the United Nations Human Development Index; reported a comparison of at least one of the prespecified outcomes of interest between
adolescent (19 years and under) and adult mothers (20–34 years); and were published between January 1998 and March 2018. Inclusion criteria were not limited with respect to study design [8]. All types of non-peer reviewed literature including editorials, letters and newspaper articles were excluded. The AXIS tool [9] for the critical appraisal of the quality of cross-sectional studies was used. Where there were serious concerns such as inadequate or inconsistent reporting the paper was excluded following unsuccessful attempts to contact the authors.

Outcomes

The prespecified outcomes of interest in this study as outlined in the published protocol were: low birthweight (<2500 g); preterm delivery (<37 completed weeks gestation); small for gestational age (<5th percentile); APGAR score at 1 min and 5 min <7; stillbirth (death of the foetus before or during birth); perinatal death (death of the foetus or neonate between 22 completed weeks of gestation and 7 days after birth); and neonatal death (deaths up to 28 days following birth). The APGAR score is a value from 0 to 10 which is derived from the sum of scores out of 2 for each of the five components (Appearance, Pulse, Grimace, Activity, Respiration). Assessments are usually made at 1 and 5 min following birth and scores below 7 indicate cause for concern [10]. Where stratified data are reported in the included papers (e.g. very low birthweight, very preterm delivery) these strata were also considered as secondary outcomes in the analysis. No core outcome set was used as none were available concerning maternal age. Core outcome sets for pre-term delivery, stillbirth and Intrauterine Growth Restriction (IUGR) were reviewed and the present study is considered to contribute to the wider understanding of these outcomes.

Data synthesis

Data from the included studies were extracted and collated using RevMan 5.3 by one researcher and checked by a second. Where data are expressed as percentages or rates, crude counts were imputed to enable inclusion in the analysis. Following a sensitivity analysis of the included studies, no sub-groups based on characteristics of included studies were considered to be appropriate, therefore heterogeneity of included studies was assessed statistically. Meta-analytical estimates were reported using a fixed effects model if $I^2$ statistic was less than 50% (indicating low-moderate heterogeneity between study results), otherwise a random effects model was assumed. Estimation for dichotomous outcomes were expressed as risk ratios (RR) with 95% confidence intervals (CI).

Sub-group analyses consisting of adolescents aged 17 and under versus those aged 18–19 (both compared with an adult group) was undertaken where data allowed.

In order to account for potential confounders inverse-variance weighting was used to obtain meta-analytical estimates of adjusted odds ratios (aORs) on the natural logarithmic scale; random effects were assumed. There were insufficient data to perform a sub-group analysis of adjusted odds ratios.

Results

Participants

Following a comprehensive search of relevant databases a total of 1,791 unique studies were identified after removal of duplicates. Following screening of the papers and application of the inclusion and exclusion criteria 20 papers remained for inclusion in the review. A PRISMA flowchart of study selection is shown in Fig. 1. Characteristics of included studies are given in Table 1. The twenty studies included [6,7,11–28] in the review reported data on 191,091 adolescent mothers aged under 20, 25,655 adolescent mothers aged 17 and under and 69,761 adolescent mothers aged 18–19 years as well as 1,745,955 adult women. Sample sizes ranged from 35 to 60,680 in the adolescent groups and from 35 to 523,721 in the adult groups. Women included in the adult group were all aged 20–34 years in order to control for the effect of advanced maternal age; however there was some variation between studies within this bracket. With the exception

![Figure 1. PRISMA Flow chart.](image-url)
| Study | Country | Design | Time period of data collection | Participants | Outcomes | Quality |
|-------|---------|--------|-----------------------------|-------------|----------|---------|
| Bai 1999 | Australia | Retrospective cohort | March 1996–June 1998 | Number in adolescent group (s): 128, Number in adult group: 313 | Singletons born at Liverpool Hospital, New South Wales, during the study period | Less than 20 weeks gestation or birth weight less than 500 grams | +/− |
| Buschman 2001 | UK | Retrospective cohort | NR | Number in adolescent group (s): 104, Number in adult group: 150 | Files with incomplete data | Preterm delivery (<37 weeks) +/− Stillbirth Low birth weight (<2500 g) Average birth weight Mean gestation at delivery Mean birth weight Low birth weight (<2500 g) | + |
| El-Gilany 2012 | Saudi Arabia | Retrospective cohort | Jan 2010 – Dec 2010 | Number in adolescent group (s): 404, Number in adult group: 3691 | Women accessing maternity care across 40 primary health care centres in the Northern region of Saudi Arabia | Preterm delivery (<37 weeks) +/− Stillbirth Low birth weight (<2500 g) | + |
| Fayed 2018 | Saudi Arabia | Retrospective cohort | Nov 2013 - Mar 2015 | Number in adolescent group (s): 296, Number in adult group: 6994 | Women recruited for the RAHMA multi-centre cohort study | Preterm delivery (<37 weeks) +/− Stillbirth Low birth weight (<2500 g) | + |
| Fleming 2013 | Canada | Retrospective cohort | Jan 2006 – Dec 2010 | Number in adolescent group (s): 23,810, Number in adult group: 523,721 | Women registered on the Better Outcomes Registry and Network Ontario database | Age over 35 years, stillborn, multiple births | Mean gestation at delivery Mean birth weight Small for gestational age Low birth weight (<2500 g) Preterm delivery (<37 weeks) Preterm delivery (<32 weeks) Preterm delivery (<29–32 weeks) Preterm delivery (<24–28 weeks) Low birth weight (<2500 g) | + |
| Gupta 2008 | UK | Retrospective cohort | Jan 1990 – Dec 1999 | Number in adolescent group (s): 587, Number in adult group: 17,615 | Primiparous women recruited for the Cardiff Births Survey | Age over 34 years | Mean gestation at delivery Mean birth weight Small for gestational age Low birth weight (<2500 g) Preterm delivery (<37 weeks) Preterm delivery (<32 weeks) Preterm delivery (<29–32 weeks) Preterm delivery (<24–28 weeks) Low birth weight (<2500 g) | + |
| Haldre 2007 | Estonia | Retrospective cohort | Jan 1992 – Dec 2002 | Number in adolescent group (s): 4,248, Number in adult group: 35,266 | Primiparous women recorded on the Estonian Medical Birth Registry | Age over 24 years | Preterm delivery (<37 weeks) +/− Stillbirth Low birth weight (<2500 g) Stillbirth Neonatal death Perinatal death Small for gestational age Preterm delivery (<37 weeks) Preterm delivery (<32 weeks) Stillbirth APGAR <7 Neonatal death Perinatal death | + |
| Jolly 2000 | UK | Retrospective cohort | Jan 1988 – Dec 1997 | Number in adolescent group (s): 5,245, Number in adult group: 336,462 | Singleton births recorded in the St Mary’s Maternity Information System Database | Age over 34 years | Preterm delivery (<37 weeks) +/− Stillbirth Neonatal death Perinatal death Small for gestational age Preterm delivery (<37 weeks) Preterm delivery (<32 weeks) Stillbirth APGAR <7 Neonatal death Perinatal death | + |
| Kawakita 2016 | USA | Retrospective cohort | Jan 2002 – Dec 2008 | Number in adolescent group (s): 1,189, Number in adult group: 27,645 | Primiparous women with singleton pregnancies recorded in the Consortium of Safe Labor | Women aged over 24 | Preterm delivery (<37 weeks) +/− Stillbirth Preterm delivery (<34 weeks) Preterm delivery (<28 weeks) Low birth weight (<2500 g) Very low birth weight (<1500 g) APGAR <7 | Perinatal death |
| Study | Location | Study Design | Study Period | N | Description |
|-------|----------|--------------|--------------|---|-------------|
| Korencan 2017 | Slovenia | Retrospective cohort | Jan 2008 – Dec 2012 | 318 | Primiparous women recorded on the National Perinatal Information System in Slovenia | 
| | | | | 1,413 | Women aged over 24 |
| Lao 2012 | Hong Kong | Retrospective cohort | Jan 1998 – June 2008 | 1,505 | Primiparous women with singleton pregnancies delivering at Prince of Wales Hospital, Shatin during the study period | 
| | | | | 20–24 | Women aged over 24 |
| Leppalahti 2013 | Finland | Retrospective cohort | Jan 2006 – Dec 2011 | 84 | Primiparous women with singleton pregnancies recorded on the Finish national Medical Birth Register | 
| | | | | 1,234 | Cases of major congenital abnormalities, women aged 20–24 or over 29 years |
| | | | | 5,987 | Preterm delivery (<32 weeks) + Preterm delivery (32–36 weeks) + Small for gestational age + Low birth weight (<2500 g) + Very low birth weight (<1500 g) + APGAR <7 | 
| Marvin-Dowle 2018 | UK | Retrospective cohort | Mar 2007 – Dec 2010 | 68 | Primiparous women with singleton pregnancies in the Born in Bradford cohort study | 
| | | | | 3,951 | Women aged over 34 years |
| | | | | 640 | Small for gestational age + Preterm delivery (<37 weeks) + Preterm delivery (<32 weeks) + Preterm delivery (<28 weeks) + Stillbirth/neonatal death + Small for gestational age + APGAR <7 | 
| Mohsin 2006 | Australia | Retrospective cohort | Jan 1998 – Dec 2002 | 19,648 | Births recorded in the NSW Midwives data Collection | 
| | | | | | Births at less than 20 weeks gestation or with a birthweight of less than 400g | 
| | | | | | Stillbirth + Preterm delivery (<28 weeks) + Neonatal death + Mean gestation at delivery |
| O'Leary 2007 | Australia | Retrospective cohort | Jan 1994 – Dec 2003 | 14,725 | Births recorded in the MCHRDB database | 
| | | | | | Births at less than 20 weeks gestation or with a birthweight of less than 400g | 
| | | | | | Stillbirth + Neonatal death + Mean gestation at delivery |
| Otterblad Olausson 1999 | Sweden | Retrospective cohort | Jan 1973 – Dec 1989 | 831 | Primiparous women with singleton pregnancies recorded on the Swedish Medical Birth Register | 
| | | | | | Women aged over 24 years |
| | | | | | Neonatal death + Post-neonatal death + Preterm delivery (33–36 weeks) + Preterm delivery (23–32 weeks) | 

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| Study     | Country | Design               | Time period of data collection | Study information                                                                 | Participants | Outcomes | Quality |
|-----------|---------|----------------------|-------------------------------|-----------------------------------------------------------------------------------|--------------|----------|---------|
| Papamichael 2009 | UK      | Retrospective case-control | Jan 2004 – Dec 2007          | The index group (all women aged <16) was drawn from the North Middlesex University Hospital database and the consecutive birth to a women in the other two age groups, matched by parity and ethnicity, selected for the two control groups. | 35 <16 35 16–19 20–30 | Not reported | Small for gestational age Stillbirth | *+-- |
| Smith 2001 | UK      | Retrospective cohort   | Jan 1992 – Dec 1998          | Primiparous women recorded on the Scottish morbidity record 2                      | 9699 15–19 59,315 20–29 | Not reported | Preterm delivery (33–36 weeks) Preterm delivery (24–32 weeks) Small for gestational age Stillbirth Neonatal death Mean gestation at delivery Mean birth weight | *+-- |
| Socolov 2017 | Romania | Retrospective cohort   | Jan 2007–Dec 2014            | Women delivering a singleton at Cuza Voda Hospital, Iasi, during the study period | 1,276 12–17 9,479 20–24 | Women aged over 24 years, delivery at less than 24 weeks gestation | Preterm delivery (24–28 weeks) Preterm delivery (24–34 weeks) Low birth weight (<2500 g) Very low birth weight (<1500 g) APGAR <7 | * |
| Suzuki 2018 | Japan   | Retrospective cohort   | Jan 2002 – Dec 2016          | Women delivering a singleton at Katsushika Maternity Hospital during the study period | 325 <18 2,029 28–30 | Delivery at less than 22 weeks gestation | Preterm delivery (<37 weeks) Low birth weight (<2500 g) Perinatal death | *+-- |
of one retrospective case-control study [25], all included studies used a retrospective cohort design.

Sensitivity analysis was undertaken to examine potential reasons for high levels of heterogeneity observed for some outcomes however no clear sub-groups based on study quality or design or inconsistencies in populations were evident. Four of the included studies were assessed as having a moderate risk of bias with the remaining 16 considered to have low risk of bias. There were sufficient data to perform meta-analysis for nine outcomes in all adolescents vs. control. Sub-group analyses of adolescents aged 17 and under and 18–19 were completed for four outcomes.

Meta-analysis results suggest adolescents to be at increased risk of adverse neonatal outcomes compared to the adult groups. Sub-group analyses showed increased risk of perinatal death, low birthweight and preterm delivery in women aged 17 and under and increased risk of perinatal death and low birthweight in those ages 18–19. Results of the meta-analyses are shown in Table 2. Forest plots showing sub-group analyses are provided in Figs. 2–5.

**Further analysis of adjusted outcomes**

Meta-analysis of adjusted odds ratios was carried out for all outcomes where the authors of the included studies had reported an adjusted odds ratio calculated using a multiple logistic regression model. Odds ratios were included where any confounding variables had been included in the model. All studies either only included primiparas and singleton or adjusted for parity and multiple births. Other variables commonly controlled for included measures of socioeconomic status, education, marital status, smoking and maternal body mass index. Full details of the specific variables included in regression models by each study are given in Table 3. Where studies reported more than one adjusted
odds ratio for a given outcome (for example one adjusted odds ratio for mothers aged 17 and under and another for mothers aged 18–19) all of these data points were included in the analysis. Care was taken to ensure that no participants were double counted so as to avoid unit of analysis errors.

As shown in Table 4, results of the meta-analysis of adjusted odds ratios indicates an increased risk of preterm delivery, very preterm delivery and neonatal death in adolescents compared to adults. Odds ratios for low birthweight, stillbirth and APGAR score <7 at 5 min were not statistically significant. Forest plots showing the results of the meta-analysis of adjusted odds ratios are shown in Figs. 6–10.

Mortality

The main meta-analysis of crude counts showed a higher risk of stillbirth for adolescent vs. adult mothers; however this was not
Table 3

| Study ID     | Number of data points | Restricted to primiparas | Restricted to singletons | Variables adjusted for in regression model                                                                 |
|--------------|-----------------------|--------------------------|--------------------------|-------------------------------------------------------------------------------------------------------------|
| Fayad 2018   | 1                     | Yes                      | Yes                      | BMI, parity, gestational age, smoke exposure, hypertension, diabetes                                           |
| Haldre 2007  | 2                     | Yes                      | Yes                      | Ethnicity, marital status, place of residence, calendar year, adequacy of prenatal care, smoking                |
| Jolly 2000   | 1                     | No                       | Yes                      | Ethnicity, parity, BMI, hypertension, diabetes, preclampsia, smoking                                         |
| Kawakita 2016| 2                     | Yes                      | Yes                      | Ethnicity, marital status, insurance type, substance abuse, BMI, hospital type, gestational age, diabetes, hypertension |
| Leppalahi 2013| 3                     | Yes                      | Yes                      | Cohabitation status, type of residence, smoking, adequacy of prenatal care, alcohol or drug misuse, BMI, diabetes, hypertension, placental abruption, chorioamnionitis, pre-eclampsia, eclampsia, anaemia, history of spontaneous abortions |
| Marvin-Dowle 2018| 1                   | Yes                      | Yes                      | Index of multiple deprivation score, ethnicity                                                                |
| Mohsin 2006  | 2                     | No                       | No                       | Infant sex, maternal age, country of birth, smoking behaviour during pregnancy, parity, maternal hypertension, birth weight, gestational age |
| Model 1      | 1                     | No                       | No                       | Infant sex, maternal age, country of birth, smoking behaviour during pregnancy, parity, maternal hypertension, birth weight |
|Model 2       | 1                     | No                       | No                       | Birth year, parity, marital status, race, multiple birth, socio-economic disadvantage, region, education, birth year |
| O’Leary 2007 | 2                     | No                       | No                       | Birth year, parity, marital status, race, multiple birth, socio-economic disadvantage, region, education, birth year |
| Otterblad-Olausson 1999 | 3              | Yes                      | Yes                      | Maternal height category, deprivation, previous spontaneous and therapeutic abortions, year                   |

Table 4

|                                     | Number of Studies | Number of Data Points | Odds Ratio [95% CI] | I2 (%) |
|-------------------------------------|-------------------|-----------------------|---------------------|--------|
| Preterm delivery <37 weeks [14,16–18] [21,29] | 6                 | 10                    | 1.23 [1.09–1.38]    | 82     |
| Very preterm delivery <32 weeks [17,29,30] | 3                 | 3                     | 1.22 [1.03–1.44]    | 53     |
| Low birthweight <2500 g [14,16,18,29] | 4                 | 6                     | 1.13 [0.98–1.30]    | 75     |
| Stillbirth [7,14,16,17,24,29–31] | 8                 | 13                    | 1.02 [0.96–1.09]    | 0      |
| Neonatal death [7,16,24,30,31] | 5                 | 10                    | 1.31 [1.14–1.52]    | 61     |
| APGAR score <7 at 5 min [14,18,29] | 3                 | 4                     | 0.97 [0.83–1.14]    | 0      |

* Details of variables included in the adjusted analysis by each study are shown in Table S2.

The results of the meta-analysis showed that adolescent women had higher risk of both pre-term birth and very pre-term birth (less than 32 completed weeks of gestation) in the adolescent group.
Fig. 6. Summary odds ratio - Preterm delivery.

Fig. 7. Summary odds ratio - Low birthweight.

Fig. 8. Summary odds ratio – Stillbirth.

Fig. 9. Summary odds ratio - Neonatal death.
The outcomes explored in this review were designed to reflect the main indicators which may affect health and wellbeing both neonatally and in the longer term.

Foetal growth and development has a significant influence on the health and wellbeing of individuals, affecting neonatal outcomes and infant survival as well as the health of the individual throughout their life course. The first 1,000 days of life, from conception to age 2 have been identified as a crucial time period for development and for laying the foundations for a healthy life. Nutrition [32], social support, relationships and environments [33] have been identified as the key components which shape future outcomes.

Babies born with extremely low birthweight and those who are extremely preterm are at significantly higher risk of dying within the first few months of life [34]. Mortality rates of babies born prematurely in the UK decrease rapidly with each additional week of gestation [35] therefore understanding the causes of extremely preterm delivery is a significant factor in reducing perinatal deaths. Longer term, outcomes for children born very preterm and/or with very low birthweight have been shown to include difficulties at school with both behaviour and achievement [36] and low birthweight has been linked to a number of chronic conditions in adulthood such as ischaemic heart disease, hypertension and central adiposity [37]. The results of this review and meta-analysis suggest that young maternal age is associated with perinatal mortality, low birthweight and preterm delivery. This may be an important modifiable factor for reducing the burden of disease in the population.

Analysis of neonatal and perinatal death showed a significant increased risk in adolescents. There is some evidence to suggest that mortality may be higher among babies born to adolescent women due in part to the relationship between these types of...
death and pre-term, low birthweight babies, which it has already been established are more common in this population. Chen et al. [38] found that the odds of neonatal death were higher in all adolescent age groups studied (10–15 years, 16–17 years and 18–19 years) but that maternal age was no longer predictive of neonatal death once gestational age and birthweight were included in the regression model. Due to the limited availability of reported data it was not possible to consider the influence of birthweight or gestational age on mortality in this review, suggesting that this may be an avenue for further work.

The APGAR score is the most commonly used method of assessing the condition of a new-born at birth. Evidence of low APGAR scores in babies born to adolescent mothers reported to date is mixed; while one large study reports greater relative risk of scores under 7 and under 4 in babies born to young women aged under 17 [38], a number of other similar studies failed to detect a significant difference between groups for this variable [11,31,39]. Using meta-analysis therefore to examine APGAR score in this population is helpful in drawing conclusions regarding the wellbeing of babies at birth. The results reported here show a higher risk of low APGAR score in babies born to adolescent women; however there were insufficient data to include this variable in the sub-group or adjusted analyses.

In addition to the evidence presented here of the impact of young maternal age, there is significant evidence in the literature of the impact of other factors on adverse outcomes. Factors such as socio-economic status [40], cigarette smoking [41] and lower gestational weight gain [42] have all been shown to increase the likelihood of adverse outcomes; particularly preterm delivery and low birthweight. These factors have also been independently associated with adolescent pregnancy [43,44], suggesting that not only are babies born to adolescents potentially affected by the mother’s biological immaturity [4,45], they may also be at higher risk of exposure to other detrimental environmental factors. These factors were addressed to some extent in the analysis of adjusted odds ratios, a strategy which was also employed by a previous review [3] which excluded studies which did not control for parity and SES. The previous review only assessed outcomes in women aged under 16 years and did not restrict inclusion by study country of origin. The sub-group analysis conducted in the current review showed a significantly higher risk of preterm birth in those aged under 17 which was not present in the analysis of 18–19 year olds. This suggests that younger age is associated with higher risk of preterm birth even within the adolescent cohort. The results of the two reviews overall are however largely consistent suggesting that higher risk of adverse outcomes is still relevant to older adolescents and those living in countries with high levels of human development.

Although in recent years significant reductions in adolescent pregnancies have been achieved, both globally [46] and locally [47], well-designed studies are required to understand the aetiology of such observed poor outcomes and what appropriate maternity care pathways should be put in place for those adolescent mothers who are pregnant to enhance the health and survival of the new-borns in these vulnerable groups.

**Conclusion**

Young maternal age is a significant risk factor for adverse neonatal outcomes in developed countries. Adolescent maternal age therefore should be considered as a potential cause for concern in relation to neonatal health and it is recommended that health care professionals respond accordingly with increased support and monitoring.

Further research into the mechanisms underlying differences due to maternal age would be advantageous.

**Contribution to authorship**

The concept and design of the review was developed jointly by KMD and HS. Acquisition, analysis and interpretation of data was conducted by KMD with HS carrying out checks for quality and accuracy at each stage. The article was drafted by KMD and revised critically by HS, with both authors approving the final version for publication. Both authors agree to be accountable for all aspects of the work.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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**Appendix A. Supplementary data**

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.eurox.2020.100109.

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