Association of Supine Going-to-Sleep Position in Late Pregnancy With Reduced Birth Weight
A Secondary Analysis of an Individual Participant Data Meta-analysis

Ngaire H. Anderson, PhD; Adrienne Gordon, PhD; Minglan Li, PhD; Robin S. Cronin, MMid; John M. D. Thompson, PhD; Camille H. Raynes-Greenow, PhD; Alexander E. P. Heazell, PhD; Tomasina Stacey, PhD; Vicki M. Culling, PhD; Jessica Wilson, MSc; Lisa M. Askie, PhD; Edwin A. Mitchell, DSc; Lesley M. E. McCowan, MD

Abstract

IMPORTANCE Supine maternal position in the third trimester is associated with reduced uterine blood flow and increased risk of late stillbirth. As reduced uterine blood flow is also associated with fetal growth restriction, this study explored the association between the position in which pregnant women went to sleep and infant birth weight.

OBJECTIVE To examine the association between supine position when going to sleep in women after 28 weeks of pregnancy and lower birth weight and birth weight centiles.

DESIGN, SETTING, AND PARTICIPANTS Prespecified subgroup analysis using data from controls in an individual participant data meta-analysis of 4 case-control studies investigating sleep and stillbirth in New Zealand, Australia, and the United Kingdom. Participants were women with ongoing pregnancies at 28 weeks' gestation or more at interview.

MAIN OUTCOMES AND MEASURES The primary outcome was adjusted mean difference (aMD) in birth weight. Secondary outcomes were birth weight centiles (INTERGROWTH-21st and customized) and adjusted odds ratios (aORs) for birth weight less than 50th and less than 10th centile (small for gestational age) for supine vs nonsupine going-to-sleep position in the last 1 to 4 weeks, adjusted for variables known to be associated with birth size.

RESULTS Of 1760 women (mean [SD] age, 30.25 [5.46] years), 57 (3.2%) reported they usually went to sleep supine during the previous 1 to 4 weeks. Adjusted mean (SE) birth weight was 3410 (112) g among women who reported supine position and 3554 (98) g among women who reported nonsupine position (aMD, 144 g; 95% CI, −253 to −36 g; P = .009), representing an approximate 10-percentile reduction in adjusted mean INTERGROWTH-21st (48.5 vs 58.6; aMD, −10.1; 95% CI, −17.1 to −3.1) and customized (40.7 vs 49.7; aMD, −9.0; 95% CI, −16.6 to −1.4) centiles. There was a nonsignificant increase in birth weight at less than the 50th INTERGROWTH-21st centile (aOR, 1.90; 95% CI, 0.83-4.34) and a 2-fold increase in birth weight at less than the 50th customized centile (aOR, 2.12; 95% CI, 1.20-3.76). Going to sleep supine was associated with a 3-fold increase in small for gestational age birth weight by INTERGROWTH-21st standards (aOR, 3.23; 95% CI, 1.37-7.59) and a nonsignificant increase in small for gestational age birth weight customized standards (aOR, 1.63; 95% CI, 0.77-3.44).

CONCLUSIONS AND RELEVANCE This study found that going to sleep in a supine position in late pregnancy was independently associated with reduced birth weight and birth weight centile. This novel association is biologically plausible and likely modifiable. Public health campaigns that

(continued)
encourage women in the third trimester of pregnancy to settle to sleep on their side have potential
to optimize birth weight.

JAMA Network Open. 2019;2(10):e1912614. doi:10.1001/jamanetworkopen.2019.12614

Introduction

Maternal supine position in late pregnancy is associated with significant hemodynamic changes that
can result in a reduction in blood flow to the fetus.\(^1\) Supine maternal going-to-sleep position has
recently been found to confer an independent 2.6-fold (adjusted odds ratio [aOR], 2.63; 95% CI, 1.72-
4.04) increased risk of late (≥28 weeks’ gestation) stillbirth.\(^2\) Maternal effects of a supine position
in late pregnancy include compression of the inferior vena cava\(^1\) and aorta\(^1\) leading to a reduction
in maternal cardiac output\(^1\),\(^7\),\(^9\) a reduction in uterine artery blood flow\(^1\),\(^9\) and consequently
decreased placental perfusion.\(^1\)\(^1\) Fetal effects associated with supine maternal position include a
redistribution of blood circulation with increased flow through the fetal middle cerebral artery\(^1\)\(^2\),\(^3\)\(^1\)\(^3\) and increased fetal quiescence,\(^1\)\(^4\) suggesting fetal adaptation to mild hypoxic stress. Given that
impaired uterus-placental flow is associated with fetal growth restriction,\(^1\)\(^5\) it is plausible that
repeated exposure to supine maternal position during sleep in late pregnancy may adversely affect
fetal growth.

The initial going-to-sleep position is the sleep position that women maintain for the longest
duration throughout the night\(^1\)\(^6\); therefore, going-to-sleep position is likely to have the greatest
impact on blood flow to the developing fetus.

In this prespecified subgroup analysis of the control participants included in an individual
participant data (IPD) meta-analysis of going-to-sleep position and risk of late pregnancy stillbirth,
we hypothesized that women in the third trimester who reported going to sleep in a supine position
during the previous 1 to 4 weeks would have babies with lower birth weight and birth weight centiles
compared with women who did not go to sleep in a supine position.

Methods

We selected women from the control group with ongoing pregnancies from the Collaborative
Individual Participant Data Meta-analysis of Sleep and Stillbirth (CRIBSS) study population.\(^2\)\(^-\)\(^6\) This
was a 1-stage meta-analysis stratified by study and site. The IPD search strategy, search results, and
PRISMA checklist have been published elsewhere\(^2\),\(^1\)\(^7\) and the CRIBSS study was registered with the
PROSPERO register of systematic reviews.\(^1\)\(^8\) Five international case-control studies that collected
data regarding maternal going-to-sleep position and late stillbirth were included in the CRIBSS
IPD.\(^3\)\(^-\)\(^6\),\(^1\)\(^9\) Ethical approval was obtained by each individual case-control study.\(^2\) Each participant in the
case-control studies provided written informed consent. Additional approval for the IPD meta-
analysis was obtained from the New Zealand Health and Disability Ethics Committee; this approval
applied to the study reported here. Reporting of this study followed the Preferred Reporting Items
for Systematic Reviews and Meta-analyses (PRISMA) reporting guideline.

Inclusion criteria for the current study were participation in the control group in the CRIBSS IPD
study (comprising control participants recruited in 4 case-control studies from 3 high-income
countries, New Zealand [2 studies],\(^5\)\(^,\)\(^6\) Australia,\(^3\) and the United Kingdom,\(^4\) between June 2006 and
March 2016), gestational age at birth collected in weeks and days (to allow accurate calculation of
the customized and INTERGROWTH-21st birth weight centiles), gestation at study interview of 28
weeks and 0 days or more, gestation at birth less than or equal to 42 weeks and 6 days, and data
available for usual going-to-sleep position up to 4 weeks before the study interview.\(^2\)\(^0\) A further case-
control study that was included in the CRIBSS IPD was excluded from the current analysis as this
online survey collected gestational age in completed weeks only. Individual participants were also excluded if they had missing variables required for calculation of birth weight centiles. There were no missing data for the variables included in the analyses and no imputation was therefore undertaken. In all studies, a detailed face-to-face interview was undertaken with participants during pregnancy. Maternal ethnicity was included in the analyses as ethnicity has been associated with birth weight and fetal growth. Ethnicity data were self-reported from the original studies and harmonized by criteria agreed on by the CRIBSS IPD collaboration: white (includes New Zealand and Australian European, British, Irish, and Romani, and other Europeans), black (includes British Black, African, and Caribbean), South Asian (includes Indian, Pakistani, Bangladeshi, Sri Lankan, Nepali, Bhutanese, Afghan and Maldivian), Southeast and East Asian (includes Chinese, Japanese, Korean, Vietnamese, Malaysian, and Indonesian), Maori, Pacific Islander, and other ethnicity. Birth weight data were collected after birth from hospital records.

We calculated the centiles for our study population according to INTERGROWTH-21st and customized centiles using published methods. INTERGROWTH-21st centiles are a birth weight standard derived from a low-risk birth cohort and are adjusted for gestation at birth and infant sex. Customized centiles are based on a fetal growth standard and are adjusted for gestation and infant sex as well as maternal height, weight, parity, and ethnicity. As adverse perinatal outcomes, including stillbirth, increase with decreasing birth weight and birth weight centiles, birth weight centiles were also categorized into less than the 10th centile (small for gestational age [SGA]) and less than the 50th centile. Specifically, birth weight less than the 50th centile was included as well as SGA as per our previous analyses of CRIBBS data. Furthermore, other publications have demonstrated an association with increased risk of stillbirth compared with infants with birth weight greater than the 50th centile. We also included data on large for gestational age (LGA), defined as birth weight greater than the 90th centile for each measure.

For this analysis, maternal going-to-sleep position was the usual position over the previous week, previous 2 weeks, or previous month (whichever was longest) and varied by study. Position was recorded as left side, right side, supine, and other (which included variable sides, prone, and propped). For the main analysis, supine was compared with nonsupine. Secondary analysis was performed using all 4 going-to-sleep positions.

Data were available on going-to-sleep position last night and last month for the same participant from 2 of the included studies. Changes in maternal going-to-sleep position over time were therefore investigated in sensitivity analysis using this subset of participants.

Statistical Analysis
Birth weight and birth weight centiles were compared by maternal going-to-sleep position and adjusted for infant gestational age at birth and at time of interview, infant sex, and maternal age, height, weight, parity, ethnicity, preexisting diabetes, preexisting hypertension, antepartum hemorrhage, gestational hypertensive disorder, gestational diabetes, cigarette smoking, and recreational drug use. To account for possible study differences, multivariable analyses were also adjusted for individual studies as a covariate. For continuous outcomes (birth weight and birth weight centiles), a generalized linear model was used with predicted adjusted means obtained using least-squares means. For binary outcomes (birth weight centile <10th, <50th, and >90th) logistic regression was used, stratified by study, and aORs and 95% confidence intervals were reported. The threshold for statistical significance was set at 2-tailed P < .05. Statistical analyses were performed using SAS statistical software version 9.4 (SAS Institute Inc).

Results
There were 1804 women who were controls in our CRIBBS database, of whom 1760 (97.6%; mean [SD] age, 30.25 [5.46] years) met the eligibility criteria (Figure). Of these women, 57 (3.2%) reported they usually went to sleep supine during the previous 1 to 4 weeks. Demographic characteristics by
maternal going-to-sleep position in control participants are reported in Table 1. There were no differences in maternal age, body mass index, ethnicity, and educational status for those who reported going to sleep in a supine position compared with those who went to sleep in a nonsupine position. Women who were not cohabiting were more likely to report going to sleep in a supine position, as were women who had a parity of 1. Gestation at interview was on average 1 week earlier for those who reported supine going-to-sleep position (mean [SD], 35.5 [3.9] vs 36.5 [3.5] weeks’ gestation; difference, −1.01 weeks; 95% CI, −1.94 to −0.08 weeks; P = .03), but mean (SD) gestation at birth was 40.0 (1.4) weeks for both groups (Table 1).

After adjustment for potential confounding factors, participants who reported they usually went to sleep in a supine position gave birth to infants with an adjusted mean (SE) weight of 3410 (112) g vs 3554 (98) g for participants who reported they usually went to sleep in a nonsupine position, an adjusted mean difference (aMD) of −144 g (95% CI, −253 to −36 g; P = .009) (Table 2). Supine going-to-sleep position was also associated with a mean (SE) INTERGROWTH-21st centile of 48.5 (71) vs 58.6 (6.2) for nonsupine position (aMD, −101; 95% CI, −171 to −31) and a mean (SE) customized centile of 40.7 (7.6) vs 49.7 (6.7) for nonsupine (aMD, −9.0; 95% CI, −16.6 to −1.4) (Table 2). Supine position was associated with twice the odds of birth weight less than the 50th customized centile (aOR, 2.12; 95% CI, 1.20-3.76). The increase in odds of birth weight less than the 50th INTERGROWTH-21st centile for supine position was not significant (aOR, 1.90; 95% CI, 0.83-4.34) (Table 2). Supine position was associated with a 3-fold increase in odds of SGA by INTERGROWTH-21st centiles (aOR, 3.23; 95% CI, 1.37-7.59), but there was no significant increase in odds of SGA by customized centiles (aOR, 1.63; 95% CI, 0.77-3.44) (Table 2). There was no significant difference in rates of LGA by either birth weight standard between women who went to sleep supine vs nonsupine in the last 1 to 4 weeks of pregnancy.

Analysis of all 4 going-to-sleep positions (left side, right side, other, and supine) are shown in Table 3. Birth weight, birth weight centiles, and SGA rates were similar for left, right, and other going-to-sleep positions.

Within the subset of women who had going-to-sleep position data for both last night and last month (1019 participants), 999 (98.0%) did not change going-to-sleep position between the 2 points. Of the 20 (2.0%) who did change their position, a similar proportion changed from supine to nonsupine (11 women [1.1%]) and from nonsupine to supine (9 women [0.9%]).

Discussion
In this analysis of women in their third trimester of pregnancy who participated in the control group of CRIBSS, maternal supine going-to-sleep position over the last 1 to 4 weeks was associated with a
significant reduction in mean birth weight of 144 g and a 10-percentile reduction in mean INTERGROWTH-21st and customized birth weight centiles. A 3-fold increase in the adjusted odds of SGA by INTERGROWTH-21st centiles was also observed among those who reported they usually went to sleep supine. These reductions in birth weight were independent of variables known to be associated with birth size.

Our finding of similar birth weight and birth weight centiles in all 3 nonsupine going-to-sleep positions (left side, right side, other) is consistent with our previous findings suggesting no difference in stillbirth risk between left side and other nonsupine going-to-sleep positions.2

Supine maternal position is associated with a reduction in maternal cardiac output and subsequent fetal blood supply,1,10 so it is biologically plausible that supine maternal going-to-sleep position could contribute to reduced birth size. Our finding of an independent mean reduction in birth weight associated with supine going-to-sleep position is clinically relevant. Rates of LGA did not differ between supine and nonsupine groups, but our study may be underpowered to detect a difference. However, rates of LGA in the nonsupine group (22.6% by INTERGROWTH-21st and 9.3% by customized centile) were similar to those reported in general populations.28

This is the first study, to our knowledge, to describe the association between supine maternal going-to-sleep position and reduced birth weight in a general obstetric population of women with

| Characteristic                        | Maternal Going-to-Sleep Position | P Value |
|--------------------------------------|----------------------------------|---------|
|                                      | Nonsupine | Supine |         |
| No. (%)                             | 1703 (96.8) | 57 (3.2) |         |
| Individual study                     |          |        |         |
| Auckland                             | 288 (96.3) | 11 (3.7) | .38    |
| Sydney                               | 182 (98.4) | 3 (1.6)  |         |
| New Zealand                          | 541 (95.6) | 15 (4.4) |         |
| England                              | 692 (96.1) | 28 (3.9) |         |
| Age, mean (SD), y                    | 30.3 (5.5) | 29.6 (5.5) | .38    |
| Earliest pregnancy BMI, median (IQR) | 24.6 (22.0-29.0) | 24.0 (21.0-28.7) | .95    |
| Ethnicity, No. (%)                   |          |        |         |
| White                                | 1074 (97.2) | 31 (2.8) |         |
| Black                                | 35 (97.2) | 1 (2.8) |         |
| South Asian                          | 202 (95.7) | 9 (4.3) | .28    |
| Southeast or East Asian              | 104 (95.4) | 5 (4.6) |         |
| Maori                                | 104 (98.1) | 2 (1.9) |         |
| Pacific Islander                     | 143 (94.1) | 9 (5.9) |         |
| Other ethnicities                    | 41 (100) | 0 |         |
| Parity, No. (%)                      |          |        | .006    |
| 0                                    | 749 (97.5) | 19 (2.5) |         |
| 1                                    | 604 (95.0) | 32 (5.0) |         |
| ≥2                                   | 350 (98.3) | 6 (1.7) |         |
| Education, No. (%)                   |          |        | .12     |
| Primary and/or secondary school      | 554 (95.5) | 26 (4.5) |         |
| Trade school                         | 220 (97.3) | 6 (2.7) |         |
| Tertiary—university and postgraduate | 929 (97.4) | 25 (2.6) |         |
| Marital status, No. (%)              |          |        | .002    |
| Single                               | 118 (92.2) | 10 (7.8) |         |
| Married or cohabiting                | 1585 (97.1) | 47 (2.9) |         |
| Preexisting hypertension or diabetes, No. (%) | 20 (95.2) | 1 (4.8) | .50    |
| Maternal smoking beyond the first trimester, No. (%) | 178 (97.8) | 4 (2.2) | .52    |
| Recreational drug use during pregnancy, No. (%) | 33 (100) | 0 | .33    |
| Gestation at interview, mean (SD), wk | 36.5 (3.5) | 35.5 (3.9) | .03    |
| Gestation at birth, mean (SD), wk    | 40.0 (1.4) | 40.0 (1.4) | .87    |

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); IQR, interquartile range.
ongoing pregnancies from a high-income setting. A small observational study from Ghana reported an increased odds of low-birth weight infants (<2500 g) among maternal supine sleepers but did not report birth weight or birth weight centiles. The study speculated that the association between stillbirth and supine sleep may be mediated by fetal growth restriction.

There is currently no international consensus on the most appropriate way to define normal birth weight; therefore, we elected to investigate 2 commonly used birth weight centiles. For the same infant, customized centiles tend to be lower than INTERGROWTH-21st centiles. This phenomenon has previously been noted and relates to conceptual differences between the birth weight references: INTERGROWTH-21st is a birth weight standard derived from low-risk pregnancies, while customization is a fetal growth standard adjusted for maternal characteristics that influence birth weight. In this study, this is demonstrated by lower mean customized centile and greater numbers of infants with birth weight less than the 10th centile using customized compared with INTERGROWTH-21st centiles. Among nonsupine sleepers, 4.5% of infants were SGA and 22.6% were LGA by the INTERGROWTH-21st standard, compared with 11.0% and 9.3%, respectively, by

| Measure | Maternal Going-to-Sleep Position | Nonsupine | Supine |
|---------|---------------------------------|-----------|--------|
| Total study population, No. (%) | 1703 (96.8) | 57 (3.2) |
| Birth weight, g^a | 3554 (98) | 3410 (112) |
| aMD (95% CI) | −144 (−253 to −36) |
| INTERGROWTH-21st centile^b | 58.6 (6.2) | 48.5 (7.1) |
| aMD (95% CI) | −10.1 (−17.1 to −3.1) |
| INTERGROWTH-21st centile <10th^b | 76 (4.5) | 8 (14.0) |
| OR | 1 [Reference] | 3.50 (1.60 to 7.64) |
| aOR | 1 [Reference] | 3.23 (1.37 to 7.59) |
| INTERGROWTH-21st centile <50th^b | 528 (31.0) | 26 (45.6) |
| OR | 1 [Reference] | 1.87 (1.10 to 3.18) |
| aOR | 1 [Reference] | 1.90 (0.83 to 4.34) |
| INTERGROWTH-21st centile >90th^b | 384 (22.6) | 10 (17.5) |
| OR | 1 [Reference] | 0.73 (0.37 to 1.46) |
| aOR | 1 [Reference] | 0.67 (0.32 to 1.41) |
| Customized centile^c | 49.7 (6.7) | 40.7 (7.6) |
| aMD (95% CI) | −9.0 (−16.6 to −1.4) |
| Customized centile <10th^c | 179 (11.0) | 9 (15.8) |
| OR | 1 [Reference] | 1.60 (0.77 to 3.31) |
| aOR | 1 [Reference] | 1.63 (0.77 to 3.44) |
| Customized centile <50th^c | 865 (50.8) | 39 (68.4) |
| OR | 1 [Reference] | 2.10 (1.19 to 3.70) |
| aOR | 1 [Reference] | 2.12 (1.20 to 3.76) |
| Customized centile >90th^c | 158 (9.3) | 3 (5.3) |
| OR | 1 [Reference] | 0.54 (0.17 to 1.76) |
| aOR | 1 [Reference] | 0.53 (0.16 to 1.70) |

Abbreviations: aMD, adjusted mean difference; aOR, adjusted odds ratio; OR, odds ratio.

* Adjusted for study site, gestation, infant sex, and maternal age, height, weight, parity, ethnicity, preexisting diabetes, preexisting hypertension, antepartum hemorrhage, gestational hypertensive disorder, gestational diabetes, cigarette smoking, and recreational drug use.

* Adjusted for study site and maternal age, height, weight, parity, ethnicity, preexisting diabetes, preexisting hypertension, antepartum hemorrhage, gestational hypertensive disorder, gestational diabetes, cigarette smoking, and recreational drug use.

* Adjusted for study site and maternal age, preexisting diabetes, preexisting hypertension, antepartum hemorrhage, gestational hypertensive disorder, gestational diabetes, cigarette smoking, and recreational drug use.

* Adjusted for study site and maternal age, preexisting diabetes, preexisting hypertension, antepartum hemorrhage, gestational hypertensive disorder, gestational diabetes, cigarette smoking, and recreational drug use.
customized centiles. Despite low numbers of SGA infants in this study, there was a 3-fold increase in odds of SGA by INTERGROWTH-21st centiles in women who reported they usually went to sleep supine (<10th centile: aOR, 3.23; 95% CI, 1.37-7.59) and a nonsignificant increase in SGA by customized centiles. We postulate that the differences in aORs between INTERGROWTH-21st and customized centiles relate to the different location of the distribution of birth weight by each criteria.

Strengths of this study include that it was a prespecified analysis with objective and standardized sleep data and birth weight measurements. In the original case-control studies, sleep position data were collected blinded to the hypothesis, so any bias would be nondifferential. To our knowledge, this is the largest data set assembled with robust data on maternal going-to-sleep position and birth weight.

### Table 3. Birth weight, INTERGROWTH-21st Centile, and Customized Centile by Original Maternal Going-to-Sleep Position

| Measure                                      | Original Maternal Going-to-Sleep Position | P Value<sup>a</sup> |
|----------------------------------------------|------------------------------------------|---------------------|
|                                              | Left (45.4)                             | 452 (25.7)          |
|                                              | Right (25.7)                            | 452 (25.7)          |
|                                              | Supine (3.2)                            | 57 (3.2)            |
| Birth weight, g<sup>b</sup>                  | Adjusted mean (SE)                      | 3552 (99)           |
|                                              | aMD (95% CI)                            | −8 (−56 to 40)      |
| INTERGROWTH-21st centile<sup>c</sup>         | Adjusted mean (SE)                      | 58.2 (6.3)          |
|                                              | aMD (95% CI)                            | 0.5 (−2.6 to 3.5)   |
| INTERGROWTH-21st <10th centile              | No. (%)                                 | 22 (9.4)            |
|                                              | 1 [Reference]                           | 1.27 (0.73 to 2.22) |
|                                              | aOR<sup>d</sup>                         | 1.05 (0.58 to 1.90) |
| INTERGROWTH-21st <50th centile              | No. (%)                                 | 23 (5.1)            |
|                                              | 1 [Reference]                           | 1.33 (0.77 to 2.31) |
|                                              | aOR<sup>d</sup>                         | 1.14 (0.62 to 2.09) |
| INTERGROWTH-21st >90th centile              | No. (%)                                 | 8 (14.0)            |
|                                              | 1 [Reference]                           | 4.05 (1.77 to 9.27) |
|                                              | aOR<sup>d</sup>                         | 3.39 (1.38 to 8.33) |
| Customized centile<sup>d</sup>               | Adjusted mean (SE)                      | 49.5 (6.7)          |
|                                              | aMD (95% CI)                            | 0.3 (−1.1 to 1.6)   |
| Customized centile <10th                     | No. (%)                                 | 50 (11.1)           |
|                                              | 1 [Reference]                           | 1.01 (0.70 to 1.45) |
|                                              | aOR<sup>d</sup>                         | 0.99 (0.68 to 1.44) |
| Customized centile <50th                     | No. (%)                                 | 41 (9.1)            |
|                                              | 1 [Reference]                           | 1.52 (0.72 to 3.19) |
|                                              | aOR<sup>d</sup>                         | 1.55 (0.72 to 3.35) |
| Customized centile >90th                     | No. (%)                                 | 225 (49.8)          |
|                                              | 1 [Reference]                           | 2.06 (1.16 to 3.65) |
|                                              | aOR<sup>d</sup>                         | 2.08 (1.16 to 3.72) |

Abbreviations: aMD, adjusted mean difference; aOR, adjusted odds ratio; OR, odds ratio.

<sup>a</sup> P values reflect the comparison between the 4 groups.

<sup>b</sup> Adjusted for study-site, gestation at interview and delivery, infant sex, and maternal age, height, weight, parity, ethnicity, preexisting diabetes, preexisting hypertension, antepartum hemorrhage, gestational hypertensive disorder, gestational diabetes, cigarette smoking, and recreational drug use.

<sup>c</sup> Adjusted for study site and maternal age, height, weight, parity, ethnicity, preexisting diabetes, preexisting hypertension, antepartum hemorrhage, gestational hypertensive disorder, gestational diabetes, cigarette smoking, and recreational drug use.

<sup>d</sup> Adjusted for study site and maternal age, preexisting diabetes, preexisting hypertension, antepartum hemorrhage, gestational hypertensive disorder, gestational diabetes, cigarette smoking, and recreational drug use.
Limitations
We acknowledge some limitations with the study. Only a small number of women reported supine sleeping position in late pregnancy, thus limiting power to investigate outcomes in smaller groups such as SGA and LGA. The going-to-sleep position was self-reported; however, it has been demonstrated that there is good correlation between maternal short-term recall of going-to-sleep position and going-to-sleep position recorded by video technology. Although sleep position changes several times during the night, women spend the longest duration in the position in which they first go to sleep. Therefore, going-to-sleep position is likely to have the greatest association with fetal blood flow and subsequent associations with birth weight.

The subgroup analysis of women who had going-to-sleep data at 2 points (last night and last month) suggests that the majority of women (97.8%) maintained the same going-to-sleep position over the 2 periods, signifying consistency in their exposure. It is also biologically plausible that the association of decreased maternal blood flow on birth size with supine maternal position is cumulative over time. Consequently, increased duration of supine sleeping may lead to greater reduction in birth size. We were not able to investigate this question.

Changing from a supine to a side-lying going-to-sleep position in late pregnancy is a simple intervention that can be easily adopted without known harm and is applicable to all pregnant women. Public health campaigns such as those recently launched in both the United Kingdom and New Zealand to encourage women in the third trimester to settle to sleep on their side have potential to optimize birth weight. As the public health message to go to sleep on the side in the third trimester of pregnancy is adopted, further research into the effect of supine maternal going-to-sleep position and birth size is likely to be more difficult to undertake.

Conclusions
This study found that supine maternal going-to-sleep position is associated with reduced birth size in late pregnancy. Women who reported going to sleep on their back had a clinically relevant and independent reduction in mean birth weight of 144 g, or an adjusted mean reduction of 10% in birth weight centile (customized or INTERGROWTH-21st). Public health campaigns to encourage women to go to sleep lying on their side have potential to increase birth size.

ARTICLE INFORMATION
Accepted for Publication: August 14, 2019.
Published: October 2, 2019. doi:10.1001/jamanetworkopen.2019.12614
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Corresponding Author: Lesley M. E. McCowan, MD, Department of Obstetrics and Gynaecology, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand (lmccowan@auckland.ac.nz).
Author Affiliations: Department of Obstetrics and Gynaecology, Faculty of Medical and Health Sciences, University of Auckland, Auckland, New Zealand (Anderson, Li, Cronin, Thompson, Wilson, Mitchell); Department of Paediatrics: Child and Youth Health, Faculty of Medical and Health Sciences, University of Auckland, Auckland, New Zealand (Anderson, Li, Cronin, Thompson, Wilson, Mitchell); Discipline of Obstetrics, Gynaecology and Neonatology, University of Sydney, Sydney, Australia (Gordon, Raynes-Greenow); Maternal and Fetal Health Research Centre, School of Medical Sciences, Division of Developmental Biology & Medicine, University of Manchester, Manchester, England, United Kingdom (Heazell); Department of Nursing and Midwifery, School of Human and Health Sciences, University of Huddersfield, Huddersfield, West Yorkshire, England, United Kingdom (Stacey); Vicki Culling Associates, Wellington, New Zealand (Culling); National Health and Medical Research Council Clinical Trials Centre, University of Sydney, Sydney, Australia (Askie); Department Obstetrics and Gynaecology, University of Auckland, Auckland, New Zealand (McCowan).
Author Contributions: Dr McCowan had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Anderson, Gordon, Cronin, Thompson, Raynes-Greenow, Heazell, Stacey, Culling, McCowan.

Acquisition, analysis, or interpretation of data: Anderson, Gordon, Li, Cronin, Thompson, Heazell, Stacey, Wilson, Askie, Mitchell, McCowan.

Drafting of the manuscript: Anderson, Raynes-Greenow, Culling, Mitchell, McCowan.

Critical revision of the manuscript for important intellectual content: Gordon, Li, Cronin, Thompson, Raynes-Greenow, Heazell, Stacey, Wilson, Askie, Mitchell, McCowan.

Statistical analysis: Anderson, Cronin, Thompson, Raynes-Greenow, Wilson, Askie, Mitchell.

Obtained funding: Li, Heazell, Askie, Mitchell, McCowan.

Administrative, technical, or material support: Anderson, Gordon, Li, Cronin, Raynes-Greenow, McCowan.

Supervision: Gordon, Thompson, Raynes-Greenow, McCowan.

Conflict of Interest Disclosures: Dr Gordon reported receiving grants from Stillbirth Foundation Australia during the conduct of the study; and support from a National Health and Medical Research Council Early Career Fellowship outside the submitted work. Dr Li reported receiving grants from Health Research Council of New Zealand, Cure Kids, Merica Barnes Trust, Nurture Foundation, and University of Auckland Faculty Research Development Fund during the conduct of the study. Mrs Cronin reported receiving grants from Health Research Council of New Zealand, Cure Kids, Merica Barnes Trust, Nurture Foundation, University of Auckland Faculty Research Development Fund, and the Sir John Logan Campbell Medical Trust during the conduct of the study. Dr Stacey reported receiving grants from Cure Kids, Nurture Foundation, Auckland District Health Board Charitable Trust, Health Research Council of New Zealand, Merica Barnes Trust, Nurture Foundation, and University of Auckland Faculty Research Development Fund during the conduct of the study. Dr Raynes-Greenow reported receiving grants from Stillbirth Foundation Australia during the conduct of the study; and support from a National Health and Medical Research Council Career Development Fellowship outside the submitted work. Dr Heazell reported receiving grants from Action Medical Research during the conduct of the study; and grants from Tommy's and the National Institute for Health Research outside the submitted work. Dr Stacey reported receiving grants from Cure Kids, Nurture Foundation, Auckland District Health Board Charitable Trust, Health Research Council of New Zealand, Merica Barnes Trust, and University of Auckland Faculty Research Development Fund during the conduct of the study. Dr McCowan reported receiving grants from Cure Kids, Nurture Foundation, Auckland District Health Board Charitable Trust, Health Research Council of New Zealand, Merica Barnes Trust, and University of Auckland Faculty Research Development Fund during the conduct of the study. No other disclosures were reported.

Funding/Support: Funding for this research was provided by a Trans-Tasman Research Funding Grant by Cure Kids and Red Nose Australia in 2016 (grant 6601).

Role of the Funder/Sponsor: The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Additional Information: All applications for data sharing will be considered by the Collaborative Individual Participant Data Meta-analysis of Sleep and Stillbirth (CRIIBSS) collaboration. We will endeavor to establish research collaborations with those interested in using the data.

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