Risk Factors for Suffocation and Unexplained Causes of Infant Deaths

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abstract

BACKGROUND: Observational studies have improved our understanding of the risk factors for sudden infant death syndrome, but separate examination of risk for sleep-related suffocation and unexplained infant deaths has been limited. We examined the association between unsafe infant sleep practices and sudden infant deaths (sleep-related suffocation and unexplained causes including sudden infant death syndrome).

METHODS: We conducted a population-based case-control study using 2016 to 2017 Centers for Disease Control and Prevention data. Controls were liveborn infants from the Pregnancy Risk Assessment Monitoring System; cases were from the Sudden Unexpected Infant Death Case Registry. We calculated risk factor prevalence among cases and controls and crude and adjusted odds ratios.

RESULTS: We included 112 sleep-related suffocation cases with 448 age-matched controls and 300 unexplained infant death cases with 1200 age-matched controls. Adjusted odds for sleep-related suffocation ranged from 18.7 (95% confidence interval [CI]: 6.8–51.3) among infants not sharing a room with their mother or caregiver to 1.9 (95% CI: 0.9–4.1) among infants with nonsupine sleep positioning. Adjusted odds for unexplained death ranged from 7.6 (95% CI: 4.7–12.2) among infants not sharing a room with their mother or caregiver to 1.6 (95% CI: 1.1–2.4) among nonsupine positioned infants.

COCLUSIONS: We confirmed previously identified risk factors for unexplained infant death and independently estimated risk factors for sleep-related suffocation. Significance of associations for suffocation followed similar patterns but was of larger magnitude. This information can be used to improve messaging about safe infant sleep.

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Dr Parks conceptualized and designed the study, drafted the initial manuscript, and reviewed the manuscript; Dr DeSisto conceptualized and designed the study, conducted all analyses, drafted the methods section, and reviewed the manuscript; Dr Kortsmit conceptualized and designed the study, assisted with analyses, and reviewed and the manuscript; Ms Bombard conceptualized and designed the study, and critically reviewed the manuscript; Dr Shapiro-Mendoza conceptualized and designed the study, and critically reviewed the manuscript; and all authors approved the final manuscript as submitted.

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WHAT'S KNOWN ON THIS SUBJECT: Few studies have examined risk factors for sudden unexpected infant deaths since 2000. Studies examining risk factors for sleep-related suffocation independently from unexplained infant deaths are also limited.

WHAT THIS STUDY ADDS: We confirmed unexplained death risk factors and estimated suffocation risk factors. Nonapproved sleep surface use was associated with 4-fold higher suffocation risk, but not associated with unexplained death. Soft bedding use was more strongly associated with suffocation than unexplained death.

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In 2019, approximately 3400 families in the United States experienced the devastating loss of an infant to sudden death, including deaths from accidental suffocation and strangulation in bed, sudden infant death syndrome (SIDS), and unknown causes.[1] Explaining why and how these deaths occur is challenging because they often occur during sleep and are unwitnessed events.[2] The Triple Risk Model theorizes that SIDS results when 3 factors converge: (1) a critical period of infant development, (2) environmental or exogenous triggers or "stressors" like prone or side sleep position, and (3) intrinsic physiologic vulnerability in the infant, such as immature cardiorespiratory or arousal systems.[3,4]

The Triple Risk Model has guided SIDS research since the 1990s. Observational studies aligned with this theory identified the peak age of SIDS vulnerability (2–3 months) and the most highly associated risk factors (eg, nonsupine position, exposure to tobacco smoke, soft or loose bedding use, surface sharing).[5–12] Furthermore, case-control studies of unsafe sleep environments are a basis for global SIDS reduction campaigns, including the Safe to Sleep (formerly Back to Sleep) Campaign[13] in the United States. Accidental suffocation in a sleep environment, which also occurs suddenly, is caused by an airway obstruction from bedding, an overlay, or entrapment between objects, but is difficult to differentiate from SIDS because neither have biological markers and cause-of-death determination depends heavily on scene investigation findings.[14,15] Understanding of sleep-related suffocation risk is limited by the lack of information about the sleep environment in some previous analyses of vital records data[16,17] and by limited use of comparison groups in other studies.[18–23] Further, very few case-control studies of SIDS have been published in the last 20 years.[7,9,18,24–29] To improve understanding and inform prevention strategies, we conducted a case-control study. We examined the association between unsafe infant sleep practices and sudden infant deaths (sleep-related suffocation and unexplained causes, including SIDS).

METHODS

We conducted a population-based case-control study to examine risk factors for unexplained infant deaths and sleep-related suffocations. Cases and controls were infants 2–9 months of age. The 2 case groups were unexplained infant deaths and sleep-related suffocation deaths. Controls were liveborn infants.

DATA SOURCES

Cases

Cases were derived from the Centers for Disease Control and Prevention's (CDC) Sudden Unexpected Infant Death (SUID) Case Registry (Registry), a multijurisdictional, population-based surveillance system built upon Child Death Review (CDR) programs.[30,31] The Registry comprises states and large metropolitan jurisdictions that identify all resident sudden infant death cases in their jurisdictions through active surveillance, in concert with local medicolegal systems and vital statistics offices. CDR teams compile case information from multiple sources (eg, death certificates; autopsy, death, and law enforcement investigation reports; and child protective services and medical records). Compiled case information is entered into the National Fatality Review Case Reporting System.

Sudden infant deaths included infants with any of the following underlying causes on the death certificate: unknown, undetermined, SIDS, SUID, unintentional sleep-related asphyxia, suffocation or strangulation, unspecified suffocation, cardiac or respiratory arrest without other well-defined causes, or unspecified causes with potentially contributing unsafe sleep factors.[32] Trained Registry staff classified all cases using the Registry classification system and algorithm.[32]

Sudden infant deaths were grouped into 2 mutually exclusive classifications: unexplained infant deaths, including, but not limited to those caused by SIDS, and sleep-related suffocation deaths using the Registry classification system categories. Unexplained infant deaths were those with complete scene investigation and autopsy information that could not be explained, regardless of the sleep environment. Sleep-related suffocation deaths were those that had complete scene investigation and autopsy information with strong evidence of suffocation (ie, report of full obstruction of nose and mouth or external compression of the neck or chest) along with a reliable, nonconflicting witness account and no potentially fatal findings or other concerning medical conditions.[32]

Controls

The control population comprised live-born infants from CDC's Pregnancy Risk Assessment Monitoring System (PRAMS), a site-specific, population-based surveillance system. In PRAMS, a stratified random sample of women with a recent live birth is selected from state birth certificates from participating states. Sampling and data collection typically occur 2 to 6 months after delivery using a standardized protocol and questionnaire. The questionnaire collects data on self-reported maternal behaviors and experiences before, during, and shortly after pregnancy, including infant sleep practices. Demographic variables from the birth certificate (maternal race, age, and insurance at delivery) and prenatal or delivery (maternal

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smoking, infant gestational age, infant sex, plurality, and previous live births) were available in the PRAMS dataset. A detailed description of PRAMS data collection methodology has been previously published.[33] Site-specific PRAMS data are weighted for sampling design, nonresponse, and noncoverage to produce a dataset representative of each state's live birth population when performing weighted analyses.[33] Respondents from 7 PRAMS states also had a SUID Registry and were eligible for inclusion. States with <55% PRAMS weighted response rate threshold were excluded.

Selection of Cases and Controls

Cases and controls were restricted to infants born during 2016 and 2017 and who resided in Alaska, Delaware, Louisiana, Michigan, New Jersey, New Mexico, and Wisconsin, states participating in both the Registry and PRAMS. All states agreed to using their aggregated, deidentified data for this analysis. Although sudden infant deaths occur from birth through 11 months, we included only those occurring from 2 through 9 months to coincide with the timing of PRAMS survey completion.

We selected control infants from the same at-risk population from where the cases were derived (ie, live births occurring in the same states as cases). Using the PRAMS population, we first created a state-representative pseudo-population of controls to represent all registered live births in each of the included states.[34] To do this, we duplicated each PRAMS record (n = 14 938) by its corresponding PRAMS person-weight. From the pseudo-population of 668 157 live births, we randomly selected 4 living controls for each case. Controls were matched to cases on infant age in months, defined as age at death for cases and age at time of survey completion for controls.

Variables

The primary exposures of interest were infant sleep practices: (1) sleep position (on back versus not on back); (2) soft bedding use during sleep (none versus at least 1 form of soft bedding); (3) sleep surface type (crib, bassinet, or portable crib versus other sleep surface); (4) sleep surface sharing (sleeping on the same surface as an adult or child); and (5) room sharing (sleeping in room with mother or another caregiver) (Table 1). Soft bedding included soft objects like stuffed animals, loose bedding, bumper pads, or other objects that could increase the risk for suffocation.[12] Sleep practice data came from reported death scene investigation information (cases) and self-reports (controls).

Variables considered as confounders were risk factors previously identified for SIDS and available in the data (Table 1). These included infant age at the time of survey or death,[35] infant sex,[5,36] plurality,[35] infant gestational age,[36,37] infant (Registry), and maternal (PRAMS) race and ethnicity,[38] season of survey or death,[39] infant ever breastfed,[40] maternal age, insurance (as a proxy for low socioeconomic status),[35] maternal smoking during pregnancy,[41] receipt of prenatal care,[42] and number of previous live births.[35]

Statistical Analysis

We conducted 2 case-control analyses, 1 for each outcome of interest (deaths classified as sleep-related suffocation and deaths classified as unexplained infant deaths). First, we examined differences in the distribution of demographic characteristics and risk factors among cases and controls by calculating prevalence and crude exposure odds ratios (ORs). Second, for each of the case-control studies, we calculated crude and adjusted exposure ORs and 95% confidence intervals (CIs) for each sleep environment variable in the model using unconditional logistic regression.[43] The recommended infant sleep practice[44] was used as the reference category for each variable. Odds ratios were adjusted for known confounders available in our data (each of the other sleep environment variables, gestational age at birth, infant sex, plurality, season of survey or death, race and ethnicity, ever breastfed, maternal age, insurance at delivery, number of live births, maternal smoking, use of prenatal care) and infant age in months (the matching variable). All analyses were performed using SAS version 9.4 (Cary, NC).

RESULTS

Descriptive Characteristics of SUID Cases Compared With the Controls

More than half of all cases and controls were 2 to 3 months old at the time of death or survey completion (Table 2). The case groups had more males than the control groups. The racial and ethnic composition for both case groups were similar, with non-Hispanic Black infants comprising the largest proportion of cases, followed by non-Hispanic white and Hispanic infants. This differed from the composition of the control groups, for which most infants were non-Hispanic white and approximately equal proportions non-Hispanic Black and Hispanic.

The maternal age distributions for both case groups were more skewed to younger age groups than for the control groups. Most mothers of sudden infant death cases were aged 20 to 29 years, whereas most control mothers were aged 25 to 34 years. Sudden infant death cases also had higher proportions of Medicaid coverage, maternal smoking during pregnancy, no prenatal care, nonsingleton births, and preterm births than controls. The

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TABLE 1 Variable Definitions by Data Source, Sudden Unexpected Infant Death Case Registry and Pregnancy Risk Assessment Monitoring System (PRAMS), 2016 to 2017

Analytic Variable	PRAMS Variable[a]	Sudden Unexpected Infant Death Case Registry Variable[b]
State	State (PRAMS)	State (CDR)
Age (months) at time of survey or death,	Age at time of survey (PRAMS)	Age at time of death (DC)
season of survey or death: winter - December, January, February; spring - March, April, May; summer - June, July, August; fall - September, October, November	Calendar month of survey (PRAMS)	Calendar month of death (DC)
Race and ethnicity	Maternal race (BC)	Race of infant (DC)
Maternal age, y	Maternal age (BC)	Maternal age at time of infant's death (multiple)
Insurance	Method of payment for delivery (BC)	Type of health insurance infant had at time of death (multiple)
Maternal smoking	Maternal smoking at any time during pregnancy (BC)	Maternal smoking at any time during pregnancy (BC or multiple)
Prenatal care	Trimester that prenatal care began (converted to a dichotomous variable) (PRAMS)	Prenatal care provided (BC or medical record)
Gestational age	Gestational age at delivery (BC)	Gestational age at delivery (BC or medical record)
Infant sex	Infant sex (BC)	Infant sex (DC)
Plurality	Plurality (BC)	Plurality (BC or medical record)
Number of live births	Number of previous live births (summed with plurality to create total number of live births, including index infant) (BC)	Total number of live births (BC or medical record)
Infant ever breastfed	Infant ever breastfed (PRAMS)	Infant ever breastfed (BC or multiple)
Sleep position	Infant sleep position: back versus side, stomach, side or back, side or stomach, back or stomach, all 3 positions (PRAMS)	Infant placed to sleep at incident: back versus stomach, side (multiple)
Soft bedding use	Infant did not sleep with blanket, toys, cushions, pillows, or bumper pads versus slept with at least 1 of the above (PRAMS)	The following objects were not in the infant's sleeping area: comforter, quilt, thin blanket or flat sheet, pillow, cushion, U-shaped pillow, sleep positioner, bumper pads, toys versus at least 1 of the above objects was present in the infant's sleeping area at the incident (multiple)
Sleep surface	Infant slept in crib, bassinet, or play yard versus infant slept on mattress or bed, couch, futon, or chair, or car seat or swing (PRAMS)	Incident sleep place was a crib or bassinet versus an adult bed, waterbed, playpen, or other play structure but not portable crib, chair, floor, car seat, stroller, or futon (multiple)
Room sharing	Infant slept in room with mom versus did not sleep in room with mom (PRAMS)	Infant sleeping in the same room as caregiver or supervisor at time of death versus not sleeping in the same room as caregiver or supervisor at time of death (multiple)
Surface sharing	Infant always slept alone vs infant often or almost always, sometimes, rarely, or never slept alone (PRAMS)	Infant was not sleeping on same surface with person or animal at the incident versus infant was sleeping on same surface with person or animal (Multiple)

[a] CDC - PRAMS Questionnaires - Pregnancy Risk Assessment Monitoring System - Reproductive Health.

[b] National Fatality Review Case Reporting System Data Dictionary (ncfrp.org).

PRAMS: as self-reported in the PRAMS survey; CDR: auto-populated in the National Center for Fatality Review and Prevention Case Reporting system; state: reflects the state of the Child Death Review team reviewing the case; multiple: may have been noted on any of the following: birth certificate, hospital records, pediatric medical records, Special Supplemental Nutrition Program for Women, Infants and Children, Child Protective Services, or other social service agency files, or autopsy or death scene investigation reports; BC: birth certificate; DC: death certificate.

proportion of sudden infant death cases born to mothers with 3 or more live births was higher than for controls. Fewer case infants were ever breastfed than control infants.

Unsafe Sleep Practices

Compared with the recommended infant sleep practice (used as the reference category for each variable), unsafe infant sleep practices were associated with increased odds of sleep-related suffocation and unexplained infant death in both crude and adjusted logistic regression models (Table 3). Infants who were not placed to sleep supine had nearly 2 times the

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TABLE 2 Distribution of Infant and Maternal Characteristics Among Sudden Unexpected Infant Death Case Registry Cases and Pregnancy Risk Assessment Monitoring System (PRAMS) Controls, by Cause of Death, 2016 to 2017

	Sleep-Related Suffocation[a]			Unexplained Infant Death[b]		
	Controls, (N = 448) %	Cases, (N = 112) %	Exposure Odds Ratio, (95% CI)	Controls, (N = 1200) %	Cases, (N = 300) %	Exposure Odds Ratio, (95% CI)
Infant characteristics						
Infant age at time of survey or death						
2 mo (60–89 d)	33.0	33.0	NA	27.3	27.3	NA
3 mo (90–119 d)	22.3	22.3	NA	26.0	26.0	NA
4 mo (120–149 d)	14.3	14.3	NA	17.3	17.3	NA
5 mo (150–179 d)	11.6	11.6	NA	11.3	11.3	NA
6 mo (180–209 d)	8.9	8.9	NA	4.3	4.3	NA
7 mo (210–239 d)	7.1	7.1	NA	4.7	4.7	NA
8 mo (240–269 d)	0.9	0.9	NA	5.7	5.7	NA
9 mo (270–299 d)	1.8	1.8	NA	3.3	3.3	NA
Infant sex						
Male	45.5	60.7	1.9 (1.3–3.0)	52.0	63.0	1.6 (1.2–2.1)
Female	54.5	37.5	Reference	48.0	36.7	Reference
Missing	0.0	1.8	NA	0.0	0.3	NA
Plurality						
Singleton	99.1	91.1	Reference	98.7	90.3	Reference
Multiple	0.9	8.9	10.9 (3.4–35.4)	1.3	8.0	6.6 (3.4–12.5)
Missing	0.0	0.0	NA	0.0	1.7	NA
Gestational age						
Early preterm (<34 wk)	3.1	5.4	1.8 (0.7–4.8)	1.8	10.0	6.8 (3.9–12.1)
Late preterm (34–36 wk)	6.5	8.0	1.3 (0.6–2.9)	6.3	14.0	2.8 (1.9–4.2)
Term (≥37 wk)	90.4	85.7	Reference	91.8	73.3	Reference
Missing	0.0	0.9	NA	0.2	2.7	NA
Race and Hispanic origin						
Hispanic	16.1	14.3	1.7 (0.9–3.3)	14.1	13.7	1.7 (1.1–2.5)
Non-Hispanic white	56.3	29.5	Reference	60.2	35.0	Reference
Non-Hispanic Black	17.0	45.5	5.1 (3.1–8.5)	14.1	41.7	5.1 (3.7–6.9)
Non-Hispanic American Indian or Alaska Native	0.7	1.8	5.1 (0.8–31.6)	1.1	3.3	5.3 (2.3–12.4)
Non-Hispanic Asian, Native Hawaiian, or Pacific Islander	4.5	5.4	2.3 (0.9–6.1)	6.3	1.3	0.4 (0.1–1.0)
Non-Hispanic Multiracial	3.6	3.6	1.9 (0.6–6.1)	2.3	4.7	3.4 (1.8–6.7)
Missing	2.0	0.0	NA	2.0	0.3	NA
Season of survey or death						
Winter (December, January, February)	28.6	18.8	0.7 (0.4–1.2)	24.6	26.0	1.3 (0.9–1.8)
Spring (March, April, May)	19.0	24.1	1.3 (0.7–2.3)	21.5	21.0	1.2 (0.8–1.7)
Summer (June, July, August)	26.6	26.8	Reference	30.4	25.7	Reference
Fall (September, October, November)	24.3	30.4	1.2 (0.7–2.2)	22.4	27.3	1.5 (1.0–2.1)
Missing	1.6	0.0	NA	1.1	0.0	NA
Infant ever breastfed						
Yes, ever breastfed	85.0	55.4	0.2 (0.1–0.4)	84.3	56.3	0.2 (0.2–0.3)
No, never breastfed	13.2	38.4	Reference	13.1	39.0	Reference
Missing	1.8	6.3	NA	2.6	4.7	NA
Maternal characteristics						
Maternal age (years)						
< 20	3.4	13.4	3.9 (1.8–8.9)	4.3	10.3	2.6 (1.6–4.3)
20–24	22.5	32.1	1.4 (0.8–2.4)	18.8	27.0	1.5 (1.1–2.2)
25–29	29.9	30.4	Reference	31.9	30.0	Reference
30–34	26.1	13.4	0.5 (0.3–1.0)	28.8	18.3	0.7 (0.5–1.0)
35[b]	18.1	9.8	0.5 (0.3–1.1)	16.3	10.7	0.7 (0.5–1.1)
Missing	0.0	0.9	NA	0.0	3.7	NA
Insurance						

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TABLE 2 Continued

	Sleep-Related Suffocation[a]			Unexplained Infant Death[b]		
	Controls, (N = 448) %	Cases, (N = 112) %	Exposure Odds Ratio, (95% CI)	Controls, (N = 1200) %	Cases, (N = 300) %	Exposure Odds Ratio, (95% CI)
Medicaid	44.4	73.2	4.7 (2.8–7.9)	43.9	75.0	6.0 (4.3–8.5)
Private	50.9	17.9	Reference	51.7	14.7	Reference
Other (Indian Health Service, Champus or Tricare, other government insurance, other)	1.1	4.5	11.4 (3.0–42.7)	1.2	5.7	17.1 (7.9–37.0)
None	3.6	0.9	0.7 (0.1–5.7)	3.0	2.0	2.4 (0.9–5.9)
Missing	0.0	3.6	NA	0.3	2.7	NA
Maternal smoking						
Smoked during pregnancy	5.6	39.3	12.0 (6.8–20.9)	10.8	31.0	4.3 (3.2–5.9)
Did not smoke during pregnancy	94.0	55.4	Reference	88.8	58.7	Reference
Missing	0.5	5.4	NA	0.4	10.3	NA
Prenatal care						
Did not receive prenatal care	0.5	3.6	8.3 (1.5–45.6)	0.8	3.0	4.2 (1.7–10.7)
Received prenatal care	97.5	94.6	Reference	96.8	92.3	Reference
Missing	2.0	1.8	NA	2.5	4.7	NA
Number of live births						
1	39.5	20.5	Reference	39.4	21.7	Reference
2	33.3	30.4	1.8 (1.0–3.1)	30.8	30.0	1.8 (1.3–2.5)
3 or more	27.2	46.4	3.3 (1.9–5.6)	29.8	44.0	2.7 (1.9–3.7)
Missing	0.0	2.7	NA	0.0	4.3	NA

Definitions for infant characteristics included in Table 1. NA, not applicable.

[a] Cases categorized as sleep-related suffocation per the Sudden Unexpected Infant Death Case Registry classification system: complete scene investigation and autopsy information with strong evidence of suffocation (eg, report of full obstruction of nose and mouth or external compression of the neck or chest) together with a reliable, nonconflicting witness account and no potentially fatal findings or other concerning medical conditions.

[b] Cases categorized into 1 of 3 unexplained infant death groups per the Sudden Unexpected Infant Death Case Registry classification system: (1) no unsafe sleep factors (sudden deaths with complete scene investigation and autopsy information with no unsafe factors documented in the sleep environment); (2) unsafe sleep factors (sudden deaths with complete scene investigation and autopsy information that could not be explained with documentation of unsafe factors in the sleep environment); or (3) possible suffocation with unsafe sleep factors (sudden deaths with complete scene investigation and autopsy information with documented unsafe factors in the sleep environment and evidence of airway obstruction, but lacking all criteria for strong evidence of suffocation).

odds of sleep-related suffocation (adjusted odds ratio [aOR] = 1.9, 95% CI: 0.9–4.1) and increased odds of unexplained infant death (aOR = 1.6, 95% CI: 1.1–2.4). The use of soft bedding was associated with a 16-fold increase in odds of explained suffocation (aOR = 16.3, 95% CI: 5.0–53.3) and 5-fold increase in unexplained infant death, compared with no soft bedding use (aOR = 5.0, 95% CI: 3.2–8.0). Infants who were not placed to sleep in a crib, bassinet, or portable crib had 4 times the odds of explained suffocation death compared with infants who slept on an approved sleep surface (aOR = 3.9, 95% CI: 1.4–10.4). For unexplained infant death, no association with sleep surface was found (aOR = 1.0, 95% CI: 0.7–1.6).

The largest odds ratios for both sleep-related suffocation and unexplained infant death were among infants who did not share a room with their mother or caregiver; these infants were 19 times more likely to die of sleep-related suffocation (aOR = 18.7, 95% CI: 6.8–51.3) and almost 8 times more likely to die of unexplained infant death (aOR = 7.6, 95% CI: 4.7–12.2), compared with infants who shared a room. Infants who shared a sleep surface with another person or animal were also at increased odds for both sleep-related suffocation or unexplained infant death (aORs = 2.5, 95% CI: 1.1–6.0 and 2.1, 95% CI: 1.4–3.2, respectively).

DISCUSSION

Our analysis confirms previously identified risk factors[12] for unexplained causes of sudden death in infancy, including SIDS. In addition, we independently estimated risk factors for explained sleep-related suffocation deaths using the standardized CDC SUID Case Registry classification system definition. The classification system used to define suffocation in this study aligns with recent expert group guidelines by the National Association of Medical Examiners Panel on Sudden Unexpected Death in Pediatrics[45] and the Radcliffe group definitions[46] for

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TABLE 3 Associations Between Sleep Environment Characteristics and Sudden Unexpected Infant Death Outcomes; Sudden Unexpected Infant Death Case Registry and Pregnancy Risk Assessment Monitoring System (PRAMS), 2016 to 2017

	Sleep-Related Suffocation[b]				Unexplained Infant Death[c]			
	Controls, ($N = 448$) (%)	Cases, ($N = 112$) (%)	Crude Exposure Odds Ratio, (95% CI)	Adjusted Exposure Odds Ratio[a], (95% CI)	Controls, ($N = 1200$) (%)	Cases, ($N = 300$) (%)	Crude Exposure Odds Ratio, (95% CI)	Adjusted Exposure Odds Ratio[a], (95% CI)
Sleep position								
On back	76.1	51.8	Reference	Reference	77.5	63.7	Reference	Reference
Not on back	21.0	45.5	3.2 (2.1–4.9)	1.9 (0.9–4.1)	18.1	32.7	2.2 (1.7–2.9)	1.6 (1.1–2.4)
Soft bedding use								
No	45.8	9.8	Reference	Reference	42.9	14.0	Reference	Reference
Yes	50.0	89.3	8.3 (4.3–15.9)	16.3 (5.0–53.3)	51.3	83.7	5.0 (3.5–7.1)	5.0 (3.2–8.0)
Sleep surface								
Crib, bassinet, or portable crib	33.3	15.2	Reference	Reference	32.8	27.3	Reference	Reference
Not in a crib, bassinet, or portable crib	62.3	84.8	3.0 (1.7–5.2)	3.9 (1.4–10.4)	62.1	72.0	1.4 (1.1–1.8)	1.0 (0.7–1.6)
Room sharing with a caregiver								
Yes	79.9	65.2	Reference	Reference	75.8	65.7	Reference	Reference
No	16.1	33.9	2.6 (1.6–4.1)	18.7 (6.8–51.3)	19.4	31.3	1.9 (1.4–2.5)	7.6 (4.7–12.2)
Surface sharing[d]								
No	59.8	43.8	Reference	Reference	59.5	44.7	Reference	Reference
Yes	37.5	55.4	2.0 (1.3–3.1)	2.5 (1.1–6.0)	36.5	54.0	2.0 (1.5–2.6)	2.1 (1.4–3.2)

Missing proportions were <5% for all predictors.

[a] Adjusted for all other listed sleep practices, infant age at the time of survey or death, gestational age at birth, infant sex, plurality, season of survey or death, race or ethnicity, ever breastfed, maternal age, insurance, number of live births, maternal smoking, use of prenatal care.

[b] Cases categorized as sleep-related suffocation per the Sudden Unexpected Infant Death Case Registry classification system: complete scene investigation and autopsy information with strong evidence of suffocation (eg, report of full obstruction of nose and mouth or external compression of the neck or chest) together with a reliable, nonconflicting witness account and no potentially fatal findings or other concerning medical conditions.

[c] Cases categorized into 1 of 3 unexplained infant death groups per the Sudden Unexpected Infant Death Case Registry classification system: (1) no unsafe sleep factors (sudden deaths with complete scene investigation and autopsy information with no unsafe factors documented in the sleep environment); (2) unsafe sleep factors (sudden deaths with complete scene investigation and autopsy information that could not be explained with documentation of unsafe factors in the sleep environment); or (3) possible suffocation with unsafe sleep factors (sudden deaths with complete scene investigation and autopsy information with documented unsafe factors in the sleep environment and evidence of airway obstruction, but lacking all criteria for strong evidence of suffocation).

[d] Among those sharing a sleep surface, only 3 were sharing with an animal, and the rest were sharing with another person.

distinguishing SIDS from suffocation. Although we confirmed some previous findings, several new findings emerged.

Like previous studies, risk factors for unexplained infant death (ie, SIDS) included male infant sex, non-Hispanic Black or American Indian or Alaska Native race, and maternal age <25 years.[35,38] Significance and magnitudes of association for sleep-related suffocation followed similar patterns as those for unexplained infant death for each of these factors. We also confirmed increased odds of unexplained infant death associated with nonsupine sleep, soft bedding use, not room sharing, and surface sharing.[7–10,24–28,47–51] Interestingly, nonsupine sleep position had the smallest aOR for unexplained infant death, although we could not rule out a small positive or null association. This smaller magnitude of association for nonsupine sleep compared with earlier studies is likely caused by an increased prevalence of supine position, from 17% before the Back to Sleep campaign,[52] which began in 1994, to 80% in 2019.[53] Unlike in prior SIDS and unexplained infant death studies,[7,9,24] use of a nonapproved sleep surface (eg, not a crib, bassinette, or portable crib) was not significantly associated with unexplained infant death after adjustment for other variables. Conversely, use of a nonapproved sleep surface was strongly associated with explained suffocation. This may reflect differences between the case classification in earlier studies, which did not examine explained suffocations independently of other explained sudden infant deaths,[27,54] a major strength of this study.

Another unique finding was the increased risk for unexplained infant death among Hispanic infants. There was no significant increase in risk for explained suffocation. This finding suggests that analyses that combine explained and unexplained infant deaths may obscure a small to moderate increase in risk of unexplained deaths among Hispanic infants. Additional exploration of this finding is warranted, including consideration of potential impacts of acculturation on the relation

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between Hispanic ethnicity and risk for unexplained death. Because each analysis controlled for all other sleep practices included in the study, we were able to examine not room sharing and surface sharing as separate risk factors for unexplained infant deaths and sleep-related suffocation deaths. After adjustment for other infant and maternal factors, room sharing, independent of surface sharing, was protective against both explained and unexplained infant deaths. This important distinction among risk factors is one that has not been made in recent studies. Surface sharing was also a risk factor for both sleep-related suffocation and unexplained infant death, but the magnitudes of association were smaller than for not room sharing.

Use of the SUID Case Registry classification system category, which does not rely on official cause of death from death certificates, thus reducing investigation or certification bias, allowed for a unique discernment of risk factors for sleep-related suffocation independent of unexplained infant death. This distinction revealed unique differences and similarities; for example, the 4-fold increase in odds of sleep-related suffocation associated with use of a nonapproved sleep surface, but no association for unexplained infant death. In contrast, not room sharing, surface sharing, and use of soft bedding were significantly associated with both sleep-related suffocation and unexplained infant death. Soft bedding use was associated with higher odds of sleep-related suffocation than of unexplained infant death. We also demonstrated differences in the degree to which confounding affects the relation between risk factors and suffocation and unexplained death. Adjusting for confounding revealed markedly stronger relations between soft bedding use and not room sharing for suffocation and between not room sharing and unexplained deaths.

Our study had 4 limitations. First, PRAMS data are self-reported; thus, like previous SIDS case-control studies, the data for controls are subject to social desirability bias in how mothers or caregivers respond to sleep environment questions (eg, over-reporting use of safe sleep practices). If case caregivers disproportionately over-reported safe practices as compared with control caregivers, the resulting risk estimates may be artificially high. Second, PRAMS data are also subject to potential nonresponse bias, particularly among populations that may be at higher risk for sudden infant death, those from racial and ethnic minority groups, those with lower educational attainment, and women whose infants died.[55,56] The weighting of PRAMS data to achieve population representativeness and account for nonresponse bias reduces these potential biases. In addition, because PRAMS sampling begins at 2 months of age, our study sample did not include a portion of the infants at highest risk for SIDS, those who were 1 month old. Exclusion of these high-risk infants may have resulted in attenuation in the strength of observed associations.

Fourth, because sudden infant deaths are almost always unwitnessed, caregiver accounts of circumstances immediately before and after the death obtained during death investigation are the primary source of information for cases in this study. Although detailed information about the infant sleep environment and circumstances surrounding an infant death is available for more than 85% of all Registry cases,[57] approaches to investigations are not uniform.[58,59] This can lead to wide discrepancies in the amount and quality of data captured. However, standardization of infant deaths investigation and documentation has improved with introduction of the CDC Sudden Unexplained Infant Death Investigation Reporting Form and related guidance in 1996.[58]

Despite these limitations, our study addressed several key limitations of prior SIDS and SUID risk factor studies. Our cases were obtained from a large, multistate registry and used standardized case definitions differentiating unexplained infant deaths and sleep-related suffocation deaths.[60] We also used control groups that represented the population from which cases arose, minimizing bias and improving accuracy of our risk estimates. Our approach to generating a pseudo-population from which to draw population-based controls was also novel among infant mortality studies with rare outcomes and may serve as an example for other rare infant and maternal health outcomes.

This study examined risk factors for unexplained infant deaths and sleep-related infant suffocation deaths. Although risk factors for unexplained infant deaths are well established from studies in the 1990s and 2000s, recent US data have not been examined; an examination of this data are especially important because the prevalence of unsafe sleep factors (nonsupine sleep) has shifted.[53,61] Also, risk factors for sleep-related suffocation have not been fully characterized separate from unexplained infant death. Early studies on suffocation were limited to data in vital records[16,17] or lacked an appropriate comparison group[18–20,22,29] and thus could not fully characterize the role of hazards in the sleep environment.

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It may be easier for parents to understand that risk factors may lead to death from suffocation than to understand that risk factors may lead to deaths without a known cause.[62] For instance, informing parents that soft bedding use, surface sharing, and not room sharing are risk factors for sleep-related suffocation may make it easier for them to visualize what to do and to comprehend the risk than informing them that these are risk factors for death from an unknown cause. Discussions of risk factors for SIDS, for which the causes are unknown, may not resonate with parents. The results of this study can be used to better communicate about safe sleep and hazards in the sleep environment for SIDS, other unexplained infant deaths, and sleep-related suffocation deaths.

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ABBREVIATIONS

aOR: adjusted odds ratio
CDC: Centers for Disease Control and Prevention
CDR: child death review
PRAMS: Pregnancy Risk Assessment Monitoring System
SUID: sudden unexpected infant death
SIDS: sudden infant death syndrome

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