Sudden Unexpected Infant Deaths: Sleep Environment and Circumstances

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Objectives. We sought to describe the characteristics and sleep circumstances of infants who die suddenly and unexpectedly and to examine similarities and differences in risk factors among infants whose deaths are classified as resulting from sudden infant death syndrome (SIDS), suffocation, or undetermined causes.

Methods. We used 2005 to 2008 data from 9 US states to assess 3136 sleep-related sudden unexpected infant deaths (SUIDs).

Results. Only 25% of infants were sleeping in a crib or on their back when found; 70% were on a surface not intended for infant sleep (e.g., adult bed). Importantly, 64% of infants were sharing a sleep surface, and almost half of these infants were sleeping with an adult. Infants whose deaths were classified as suffocation or undetermined cause were significantly more likely than were infants whose deaths were classified as SIDS to be found on a surface not intended for infant sleep and to be sharing that sleep surface.

Conclusions. We identified modifiable sleep environment risk factors in a large proportion of the SUIDs assessed in this study. Our results make an important contribution to the mounting evidence that sleep environment hazards contribute to SUIDs. (*Am J Public Health.* 2012;102:1204–1212. doi:10.2105/AJPH.2011.300613)

Each year in the United States, more than 4000 infants without prior known illness or injury die suddenly and unexpectedly.[1] Sudden unexpected infant deaths (SUIDs) may result from a variety of causes, some of which are discovered during autopsies or death investigations (e.g., previously undiagnosed metabolic disorders, homicides). One unifying factor is that, in many cases, the cause of death is not determined.

Consequently, more than half of SUIDs are ultimately classified as resulting from sudden infant death syndrome (SIDS).[2] SIDS is defined as the sudden death of an infant that remains unexplained after thorough investigation, including autopsy, death scene investigation, and a review of the infant's clinical history.[3] Approximately 14% of SUIDs are categorized as accidental suffocation, probably as a result of information obtained during death scene investigations. In the case of nearly 30% of SUIDs, the cause remains undetermined and is listed as such on the death certificate.[2] This may occur when the requirements for a SIDS classification are not met (e.g., no death scene investigation or autopsy is conducted).

Although SIDS remains a leading cause of infant mortality, SIDS mortality rates in the United States declined from 120.3 per 100 000 live births in 1992 to 54.6 per 100 000 in 2004[4]; much of this decline has been attributed to national campaigns introduced in 1992 that promoted supine sleep positions for infants.[5] During this same period, infant mortality rates resulting from suffocation and undetermined causes increased from 3.1 and 19.7 per 100 000 live births to 12.5 and 25.3 per 100 000, respectively.[2]

It has been noted that this decrease in SIDS and coinciding increase in mortality resulting from suffocation and undetermined causes, particularly since 1999, are the result of a "diagnostic shift" in classification of SUIDs.[2,6–8] The etiology of this diagnostic shift is not fully known; however, it is thought to be a consequence of an increase in death scene investigations and the role of multidisciplinary child death review (CDR) programs in examining and consistently documenting the circumstances of child deaths, as well as more stringent adherence to the definition of SIDS.[2,6,7,9–11]

Recognition of the impact of hazards in the infant sleep environment on SUIDs has been increasing in the past several decades. Most of the etiological research on SUIDs has been conducted on deaths classified as SIDS. A recent review by Mitchell comprehensively summarized risk factors for SIDS, including modifiable risk factors related to the infant sleep environment such as prone sleep position, infants sharing a sleep surface with others, and the presence of blankets or other soft bedding.[12] Death certificate data have been used in conducting several large national studies of infant suffocation or deaths of undetermined causes.[2,13] Although use of death certificates allows calculation of rates, few data on sleep circumstances are available, even when written information from the cause of death section of the death certificate is analyzed.[2,4]

In a number of small studies, medical examiner records or CDR data from a single urban area or state have been used in assessing SUIDs.[9,14–17] Although these descriptive studies typically provide more detail on the circumstances of the sleep environment, they often involve small sample sizes that do not allow comparisons of characteristics across the 3 categories of SUIDs: SIDS, suffocation, and undetermined cause.

The Web-based National Child Death Review Case Reporting System (NCDR-CRS), developed to facilitate consistent collection and reporting of CDR program data, has been available to states since 2005 through the National Center for Child Death Review (NCCDR).[18] CDR typically involves a review of child deaths conducted by a local (e.g., county) or state-level multidisciplinary team. This reporting system includes important information, such as child and parent characteristics, presence of risk factors, and other pertinent circumstances (e.g., details on sleep circumstances), on all deaths related to the sleep environment.

The comprehensive compilation of relevant risk factors available in the NCDR-CRS presents a unique opportunity to examine the circumstances of SUIDs in the United States. We used these population-based multistate CDR program data to describe the characteristics and sleep circumstances of infants who die suddenly and unexpectedly and to assess similarities and differences in SUID risk factors among infants whose deaths are ultimately classified as resulting from SIDS, suffocation, or undetermined causes.

METHODS

We obtained our data from the NCDR-CRS. The development, features, and limitations of this data system have been described in detail elsewhere.[18] Briefly, the NCDR-CRS serves as a Web-based system for the collection, analysis, and reporting of CDR program data. Individual case reports are entered into the system by a CDR team member who attended the death review. Although the system contains more than 1700 data elements, many (e.g., risk factor details for mechanisms of common injury and natural-cause child deaths) are not pertinent to an analysis of SUIDs (a copy of the report form is available at http://www.childdeathreview.org/reports/CDRCaseReportForm2-1-11009.pdf). We selected covariates on the basis of their applicability to descriptive characteristics of the infant, caregiver, and sleep environment.

As of December 2010, 35 states were enrolled and entering data in the NCDR-CRS.[18] We asked 9 of these states (California, Delaware, Hawaii, Michigan, Nevada, Ohio, Pennsylvania, Tennessee, and Texas) for permission to use their deidentified data in aggregate for our analysis, and all agreed. Most of these states had been using the NCDR-CRS since it was launched in 2005 or began using it in early 2006; consequently, they had considerable experience with the system. As of June 2010, all 9 participating states confirmed that the data we used in our analyses were considered complete.

The study population included infants (defined as children younger than 1 year) who died between January 1, 2005, and December 31, 2008; whose death was identified as occurring while they were sleeping or in a sleeping environment; and whose cause of death, as recorded in the NCDR-CRS, was accidental asphyxia, SIDS, undetermined, or unknown. California, Texas, and Hawaii had not finalized their 2008 data in time for inclusion in this analysis, so only data from 2005 through 2007 were included from these 3 states. We excluded cases in which text narrative in the NCDR-CRS indicated the possibility of inflicted trauma.

A total of 3148 SUIDs met the study inclusion criteria; 12 deaths were excluded because of suspicion of inflicted injuries, resulting in 3136 deaths for analysis. We classified these 3136 SUIDs into 3 categories: SIDS (n = 960; 30.6%), suffocation (939; 29.9%), and undetermined cause (1237; 39.5%). The undetermined cause category included deaths recorded in the NCDR-CRS as cause undetermined and cause unknown.

We generated frequencies and proportions for the 3 SUID categories according to child, caregiver, and sleep environment characteristics. In the case of many NCDR-CRS variables, "unknown" is an option and is useful for distinguishing factors that may have been discussed during the death review but for which review team members did not have information. Missing items denote those for which no response option was marked. When applicable, frequencies and proportions of unknown and missing responses are presented.

We conducted χ^2 analyses to assess whether SUID classifications differed significantly ($\alpha = .05$) for each covariate. One-way analysis of variance was used to assess differences in the mean ages of infants and caregivers across SUID categories. We then conducted multivariate logistic regression analyses. Adjusted odds ratios and 95% confidence intervals were calculated to assess the independent associations of covariates with SUIDs while controlling for other important covariates.

We conducted 2 logistic regression analyses, each with a different dichotomous dependent variable. One analysis compared deaths classified as suffocation with those classified as SIDS, and the other compared deaths with an undetermined cause with those classified as SIDS. SIDS was selected as the reference group in these analyses because of the literature describing the shift in classification of SUIDs from SIDS to suffocation and undetermined cause over the past 15 years. We sought to assess differences in infant, caregiver, and sleep environment characteristics that might contribute to this diagnostic shift.

We selected covariates for inclusion in the final, adjusted multivariate regression models in the same way. Initially, variables with a statistically significant χ^2 value in the descriptive analysis were individually entered into a logistic regression model that included year of death and state as independent variables. Covariates with a significant effect estimate, as evidenced by a 95% confidence interval that excluded 1.0, were selected for inclusion in the final regression model.

Data available in the NCDR-CRS on the position of the infant (e.g., under, between) that was most relevant to the infant's death and the people or objects in the infant sleep environment relevant to this position were included in the descriptive analyses only. The "position relevant to death" variable, which did not have a not applicable option, was coded as unknown or missing for 50% of SUID deaths. The response options for the follow-up variable identifying the objects or persons relevant to the position allowed more than one response for each death. Because of these limitations in coding and response options, no statistical tests were conducted to assess differences across categories of these variables, nor were they assessed for inclusion in the logistic regression models because there was no obvious reference category.

Several of the covariates of interest contained missing values. Because records with missing values are excluded from regression analyses, imputation of missing values generally produces less biased results and is recommended.[19] In preparation for conducting the multivariate analyses, we used multiple imputation to impute missing values.[20] SPSS version 18 (SPSS Inc, Chicago, IL) was used in conducting all of the analyses.

RESULTS

Of the 3136 SUIDs available for analysis, the majority occurred among male infants (57%) and infants younger than 4 months (71%). Forty-four percent of infants were identified as non-Hispanic White, whereas 32% were non-Hispanic Black and 19% were Hispanic. The majority of caregivers were female (83%) and

were the infant's biological parent (93%); 41% were younger than 25 years, but information on age was missing for 28% of caregivers. Only 24% of infants were sleeping in a crib or bassinette at the time of death; 47% were in an adult bed, and another 13% were on a couch or chair. Twenty-five percent of infants were on their back, and 35% were on their stomach; position was unknown in 26% of deaths and missing in 5%.

Seventeen percent of infants were noted to have a partially or fully obstructed airway, but this information was missing for 41% of deaths. Sixty-four percent of all SUID victims were sleeping on the same surface as another person or animal when they died, and 49% were further identified as sleeping with an adult. More than 50% of the deaths were referred to a medical examiner, and an autopsy was performed on 94% of the infants included in our analysis. Table 1 presents the frequency distribution and proportion of deaths according to cause of death category and child, caregiver, and other selected characteristics.

When assessed individually, covariates associated with classifications of suffocation and undetermined cause were remarkably similar. Child age and race were associated with both undetermined cause and suffocation, whereas presence of disability or chronic disease was not associated with either classification. None of the caregiver characteristics were individually associated with either suffocation or undetermined cause, but most of the incident characteristics were, with the exception of place of death, referral to a medical examiner (vs a coroner), and whether an autopsy was performed. Unadjusted odds ratios are presented in Table 2.

Table 2 also presents the results of the adjusted multivariate logistic regression models comparing deaths classified as suffocation and undetermined cause with deaths classified as SIDS. The incident characteristics most strongly associated with classification of suffocation deaths were sleep surface and airway obstruction. Deaths of infants put to sleep on a surface not intended for infant sleep (e.g., adult bed, couch) were approximately twice as likely to be classified as resulting from suffocation than as resulting from SIDS. Sleeping with an adult remained significant even after control for sleep surface and position, although the more general classification of sleeping with a person or animal did not. The magnitude of the association between child race and suffocation death was reduced after controlling for all significant sleep environment characteristics.

Regression results for classification of undetermined cause deaths were similar but with generally lower effect estimates than suffocation deaths, except that child race remained significantly elevated for both Hispanic and non-Hispanic Black infants relative to White infants (Table 2). After controlling for child age, race, and other sleep environment characteristics, infant sleep position and sleeping with a person or animal were not associated with classification of undetermined cause deaths. Similar to the results for suffocation deaths, sleeping with an adult remained significantly associated with classification of undetermined cause deaths relative to SIDS deaths.

DISCUSSION

Our descriptive analysis of population-based multistate CDR program data showed that only one quarter of SUID victims were sleeping in a crib or on their back when found; 70% of infants were on a surface not intended for infant sleep, and 64% with documentation of their position when found were on their stomach or side. Importantly, 64% of SUID victims in our study were sharing a sleep surface, and 49% of these infants were sleeping with an adult. Infants whose deaths were classified as resulting from suffocation or undetermined causes were significantly more likely than were those whose deaths were classified as resulting from SIDS to be found in an adult bed, a couch or chair, or another surface not intended for infant sleep; they were also significantly more likely to be sharing that sleep surface with an adult.

Our findings are largely consistent with those of other studies that have described the sleep environment and other characteristics of SUIDs documented in CDR or medical examiner data from single (urban or state) jurisdictions.[9,14–17] Although these studies are not all directly comparable to ours because they report details on only suffocation deaths,[15] omit SIDS[16] or undetermined cause deaths,[17] or do not report findings by final classification of death,[14] the key findings are consistent and indicate that a large proportion of SUIDs involve hazards in the sleep environment such as nonsupine sleep position, use of surfaces not intended for infant sleep, and the presence of people (bed sharing) or objects (bedding) in the sleep environment.

Our findings are also consistent with well-documented SIDS risk factors, although it is important to note that most studies identifying sleep risk factors for SIDS were conducted before the diagnostic shift in classifying SUIDs as suffocation and undetermined cause rather than SIDS.[12] In fact, it has been suggested that stricter adherence to the definition of SIDS might explain this diagnostic shift.[4] To be classified as SIDS, the sudden death of an infant must remain unexplained even after an autopsy, a thorough death scene investigation, and a review of the infant's clinical and medical history.[3]

In one example of strict adherence to the SIDS definition, the New York City Office of the Chief Medical Examiner classifies SUIDs according to a protocol that prohibits classifying a death as SIDS if any environmental events or sleep-related risk factors were present at the time of death.[16] Deaths are classified as suffocation when sufficient evidence of suffocation is present during the death scene investigation. Deaths in which there is insufficient evidence of suffocation but hazards in the environment are identified, such as an infant sleeping with others in an adult bed but no report or witness of overlay, would be classified as resulting from undetermined causes.

Medical examiners in other jurisdictions may be using similar criteria for classifying SUIDs, but such strict protocols are not universal. For example, in a study conducted in Kentucky, Shields et al. described a 3-month-old infant who "succumbed to sudden infant death syndrome" while sleeping with her mother,[21] a sleep-related circumstance defined as "consistent with SIDS" according to Kentucky's 2003 classification scheme for SUIDs.[22]

Our results are consistent with stricter adherence to the SIDS definition on the part of at least some of the death certifiers in the 9 states included in our analysis. That is, infants whose deaths were classified as suffocation were significantly more likely to be sleeping on a surface not intended for infant sleep, to be sharing that surface with an adult, and to have documentation of an obstructed airway when found.

TABLE 1—Child, Caregiver, and Incident Characteristics, by Cause of Death Category: Sudden Unexpected Infant Deaths, 9 US States, 2005–2008

	Sudden Unexpected Infant Death Category				
	Sudden Infant Death Syndrome, No. (%) or Mean	Suffocation, No. (%) or Mean	Undetermined, No. (%) or Mean	Total, No. (%) or Mean	*P*[a]
Total	960 (30.6)	939 (29.9)	1237 (39.5)	3136 (100)	
Child characteristic					
Age at death, mo					<.001
< 2	264 (27.5)	331 (35.3)	420 (34.0)	1015 (32.4)	
2–3	409 (42.6)	331 (35.3)	468 (37.8)	1208 (38.5)	
4–5	191 (19.9)	147 (15.7)	216 (17.5)	554 (17.7)	
6–7	71 (7.4)	71 (7.6)	82 (6.6)	224 (7.1)	
≥ 8	25 (2.6)	59 (6.3)	51 (4.1)	135 (4.3)	
Mean age at death, mo	3.3	3.3	3.2	3.3	.51
Gender					.73
Male	555 (57.8)	531 (56.6)	712 (57.6)	1798 (57.3)	
Female	395 (41.1)	406 (43.2)	517 (41.8)	1318 (42.0)	
Missing	10 (1.0)	2 (0.2)	8 (0.6)	20 (0.6)	
Race/ethnicity					<.001
White, non-Hispanic	479 (49.9)	440 (46.9)	451 (36.5)	1370 (43.7)	
Black, non-Hispanic	249 (25.9)	327 (34.8)	414 (33.5)	990 (31.6)	
Hispanic	163 (17.0)	123 (13.1)	294 (23.8)	580 (18.5)	
Other	47 (4.9)	41 (4.4)	66 (5.3)	154 (4.9)	
Missing	22 (2.3)	8 (0.8)	12 (1.0)	42 (1.3)	
Gestational age, wk					.07
≥ 37	491 (51.2)	484 (51.5)	653 (52.8)	1628 (51.9)	
< 37	172 (17.9)	145 (15.4)	227 (18.4)	544 (17.4)	
Missing	297 (30.9)	310 (33.0)	357 (28.9)	964 (30.7)	
Disability or chronic illness					<.001
No	624 (65.0)	689 (73.4)	866 (70.0)	2179 (69.5)	
Yes	34 (3.5)	38 (4.0)	78 (6.3)	150 (4.8)	
Missing	302 (31.5)	212 (22.6)	293 (23.7)	807 (25.7)	
Primary caregiver characteristic[b]					
Relationship to deceased					.55
Biological parent	894 (93.1)	872 (92.9)	1164 (94.1)	2930 (93.4)	
Other	31 (3.2)	30 (3.2)	40 (3.2)	101 (3.2)	
Missing	35 (3.7)	37 (3.9)	33 (2.7)	105 (3.4)	
Gender					<.001
Male	121 (12.6)	91 (9.7)	103 (8.3)	315 (10.0)	
Female	768 (80.0)	757 (80.6)	1064 (86.0)	2589 (82.6)	
Missing	71 (7.4)	91 (9.7)	70 (5.7)	232 (7.4)	
Age, y					.001
< 20	106 (11.0)	115 (12.3)	204 (16.5)	425 (13.6)	
20–24	264 (27.5)	252 (26.8)	344 (27.8)	860 (27.4)	
25–29	161 (16.8)	166 (17.7)	198 (16.0)	525 (16.7)	
30–35	71 (7.4)	76 (8.1)	114 (9.2)	261 (8.3)	
35–39	43 (4.5)	27 (2.9)	53 (4.3)	123 (3.9)	
≥ 40	16 (1.7)	14 (1.5)	23 (1.9)	53 (1.7)	
Missing	299 (31.1)	289 (30.8)	301 (24.3)	889 (28.4)	
Mean age, y	25.0	24.7	24.6	24.7	.43

Continued

TABLE 1—*Continued*

	Incident characteristic				
Place of death					<.001
Child's home	706 (73.5)	785 (83.6)	966 (78.1)	2457 (78.4)	
Friend's or relative's home	67 (7.0)	84 (9.0)	125 (10.1)	276 (8.8)	
Other	79 (8.2)	36 (3.8)	90 (7.3)	205 (6.5)	
Missing	108 (11.3)	34 (3.6)	56 (4.5)	198 (6.3)	
Infant sleep surface					<.001
Crib/bassinette	362 (37.7)	129 (13.7)	253 (20.5)	744 (23.7)	
Adult bed	322 (33.5)	486 (51.8)	658 (53.2)	1466 (46.8)	
Couch/chair	78 (8.1)	177 (18.8)	144 (11.6)	399 (12.7)	
Other	104 (10.8)	92 (9.8)	120 (9.7)	316 (10.1)	
Missing	94 (9.8)	55 (5.9)	62 (5.0)	211 (6.7)	
Position when found					<.001
On back	267 (27.8)	156 (16.6)	364 (29.4)	787 (25.1)	
On stomach	325 (33.9)	359 (38.2)	399 (32.3)	1083 (34.5)	
On side	73 (7.6)	85 (9.1)	153 (12.4)	311 (9.9)	
Unknown	258 (26.8)	267 (28.4)	281 (22.7)	806 (25.7)	
Missing	37 (3.9)	72 (7.7)	40 (3.2)	149 (4.8)	
Airway condition[c]					<.001
Unobstructed	314 (32.7)	95 (10.1)	328 (26.5)	737 (23.5)	
Partially obstructed	27 (2.8)	68 (7.2)	115 (9.3)	210 (6.7)	
Fully obstructed	21 (2.2)	204 (21.7)	86 (7.0)	311 (9.9)	
Unknown	181 (18.9)	162 (17.3)	253 (20.5)	596 (19.0)	
Missing	417 (43.4)	410 (43.7)	455 (36.8)	1282 (40.9)	
Infant sleeping with person/animal[d]					.001
No	29 (3.0)	13 (1.4)	29 (2.3)	71 (2.3)	
Yes	472 (49.2)	699 (74.4)	838 (67.7)	2009 (64.1)	
Missing	459 (47.8)	227 (24.2)	370 (29.9)	1056 (33.7)	
Infant sleeping with adult[e]					<.001
No/unknown/missing	662 (69.0)	365 (38.9)	559 (45.2)	1586 (50.6)	
Yes	298 (31.0)	574 (61.1)	678 (54.8)	1550 (49.4)	
Position relevant to death					
On top of[f]	100 (10.4)	67 (7.1)	152 (12.3)	319 (10.2)	
Under/between/tangled	75 (7.8)	277 (29.5)	191 (15.5)	543 (17.3)	
Wedged/pressed/rolled into	54 (5.6)	296 (31.5)	158 (12.8)	508 (16.2)	
Other	85 (8.9)	41 (4.4)	83 (6.7)	209 (6.7)	
Unknown	245 (25.5)	151 (16.1)	326 (26.4)	722 (23.0)	
Missing[g]	401 (41.8)	107 (11.4)	327 (26.4)	835 (26.6)	
Presence of people/objects in infant sleeping place[h]					
Adults	188 (19.6)	403 (42.9)	414 (33.5)	1005 (32.1)	
Children	31 (3.2)	85 (9.1)	104 (8.4)	220 (7.0)	
Soft bedding	225 (23.4)	307 (32.7)	414 (33.5)	946 (30.2)	
Mattress	107 (11.1)	148 (15.8)	129 (10.4)	384 (12.2)	
Couch/chair	43 (4.5)	97 (10.3)	64 (5.2)	204 (6.5)	
Crib rail/wall	7 (0.7)	44 (4.7)	11 (0.9)	62 (2.0)	
Other	59 (6.1)	107 (11.4)	79 (6.4)	245 (7.8)	
None listed	463 (48.2)	113 (12.0)	390 (31.5)	966 (30.8)	

Continued

TABLE 1—*Continued*

Authority to whom death was referred					<.001
Medical examiner	485 (50.5)	535 (57.0)	632 (51.1)	1652 (52.7)	
Coroner	335 (34.9)	333 (35.5)	539 (43.6)	1207 (38.5)	
Missing	140 (14.6)	71 (7.6)	66 (5.3)	277 (8.8)	
Autopsy performed					<.001
No	4 (0.4)	11 (1.2)	8 (0.6)	23 (0.7)	
Yes	850 (88.5)	901 (96.0)	1201 (97.1)	2952 (94.1)	
Missing	106 (11.0)	27 (2.9)	28 (2.3)	161 (5.1)	
Year of death					<.001
2005	286 (29.8)	213 (22.7)	301 (24.3)	800 (25.5)	
2006	262 (27.3)	238 (25.3)	317 (25.6)	817 (26.1)	
2007	299 (31.1)	301 (32.1)	432 (34.9)	1032 (32.9)	
2008	113 (11.8)	187 (19.9)	187 (15.1)	487 (15.5)	

Note. Percentages may not add to 100% because of rounding.
[a]*P* values were determined from a χ^2 test for all categorical variables and from a 1-way analysis of variance for continuous variables.
[b]The National Child Death Review Case Reporting System (NCDR-CRS) allows recording data on 2 primary caregivers. The data reported in this table summarize the information reported for primary caregiver 1. No caregiver 2 data were entered for 39% of the deaths analyzed. Among those with caregiver 2 data, 91% of the caregivers were identified as biological parents, and 82% were male.
[c]Prior to January 1, 2008, documenting that the infant's face was "unobstructed" was the only option related to airway condition. Data entered with this option were placed in the "unobstructed by person or object" category when more specific airway questions were added on January 1, 2008.
[d]The response options for this question were changed with the release of version 2.1 of the database in January 2010. Prior to that, only "yes" responses were recorded; there was not an option for "no" or "unknown." Some states may have used the later form in completing reviews of 2005–2008 deaths.
[e]This variable is completed only if the response to "infant sleeping with person/animal" is checked yes. It is not possible to distinguish "no" responses from missing data for this variable.
[f]This response option was added to the NCDR-CRS on January 1, 2008.
[g]This may reflect circumstances for which the question on position was not applicable.
[h]Because more than one item could be recorded, totals are greater than 100%.

In addition, the proportion of infant suffocation deaths for which there was documentation that the infant was found under, between, or tangled in or wedged, pressed, or rolled into people or objects such as soft bedding was 2-fold higher than the proportion of undetermined cause deaths and 4-fold higher than the proportion of SIDS deaths. These results indicate that although sleep-related risk factors were present for some of the deaths classified as SIDS, deaths with clearly documented hazards in the sleep environment were more likely to be classified as suffocation or, to a lesser extent, undetermined cause.

It is notable that the percentage of deaths in each SUID category differed from percentages reported previously in the literature. Shapiro-Mendoza et al. reported that, in 2004, 59% of SUIDs were classified as SIDS, 14% as suffocation, and 27% as unknown cause,[2] whereas in our 2005 to 2008 data 31% were classified as SIDS, 29% as suffocation, and 39% as undetermined. This difference is likely caused, at least in part, by the different data sources used; Shapiro-Mendoza et al. reported cause-specific mortality data from death certificates, and we used data from CDR programs.

The National Center for Health Statistics (NCHS) assigns *International Classification of Diseases* (ICD) codes to death certificates based on the reported underlying cause of death. The SIDS code (R95) is assigned to death certificates with such designations as "infant death unknown cause" and "sudden unexpected infant death."[4] As a result, deaths identified as cause unknown in the NCDR-CRS might be coded as SIDS on the death certificate. This would result in a higher proportion of SUIDs being classified as SIDS in national mortality statistics than in CDR data. Another explanation for the inconsistency might be a continuation of the diagnostic shift from classification of SIDS to classification of suffocation or undetermined cause, given that nationally available mortality data typically lag several years and that we used CDR data from 2005 to 2008.

Limitations and Strengths

Our study is not without limitations. For example, although many state CDR programs attempt to review all child deaths, not all reviews are completed, and not all data are entered by the end of a calendar year (in fact, data on some deaths are not entered for more than a year after the death occurs). In addition, not all counties in one of the states included in our analysis participate in the NCDR-CRS. As a result of this lag time and incomplete coverage, we could not confidently determine an appropriate denominator for the deaths included in our study, precluding calculation of mortality rates. Furthermore, without access to a nonaffected comparison group, risk cannot be determined. As a result, our analyses focused only on identifying the proportions of deaths in each of the 3 SUID categories across infant, caregiver, and sleep environment characteristics.

The NCDR-CRS is a relatively new system and has grown rapidly in a short time. In her description of the system, Covington explained the potential limitations of the data in detail.[18] Of note, data quality can differ across states, particularly states new to the system. Although data from more than 3000 infant deaths were available for our analysis, inclusion of data from only 9 states may limit the generalizability of our results, especially given some of the

TABLE 2—Unadjusted and Adjusted Odds Ratios Comparing Suffocation and Undetermined Cause Deaths With SIDS Deaths, by Child and Incident Characteristics: 9 US States, 2005–2008

	Suffocation vs SIDS, OR (95% CI)	Suffocation vs SIDS,[a] AOR (95% CI)	Undetermined Cause vs SIDS, OR (95% CI)	Undetermined Cause vs SIDS,[b] AOR (95% CI)
Child characteristic				
Age at death, mo				
< 2 (Ref)	1.0	1.0	1.0	1.0
2–3	0.6 (0.5, 0.8)	0.7 (0.6, 1.0)	0.7 (0.6, 0.8)	0.8 (0.6, 1.0)
4–5	0.6 (0.5, 0.8)	0.9 (0.6, 1.2)	0.7 (0.5, 0.9)	0.9 (0.7, 1.2)
6–7	0.8 (0.5, 1.2)	1.2 (0.8, 1.9)	0.7 (0.5, 1.0)	0.9 (0.6, 1.3)
≥ 8	1.7 (1.0, 2.9)	2.6 (1.5, 4.7)	1.1 (0.6, 1.8)	1.4 (0.8, 2.3)
Race/ethnicity				
White, non-Hispanic (Ref)	1.0	1.0	1.0	1.0
Black, non-Hispanic	1.3 (0.9, 1.7)	1.2 (0.8, 1.7)	1.9 (1.4, 2.4)	1.9 (1.4, 2.5)
Hispanic	1.6 (1.3, 2.0)	1.2 (0.9, 1.6)	2.0 (1.6, 2.5)	1.8 (1.4, 2.3)
Other	0.9 (0.5, 1.4)	0.7 (0.4, 1.3)	0.9 (0.6, 1.5)	1.0 (0.6, 1.6)
Incident characteristic				
Infant sleep surface				
Crib/bassinette (Ref)	1.0	1.0	1.0	1.0
Adult bed	4.3 (3.3, 5.7)	2.3 (1.6, 3.2)	2.8 (2.2, 3.4)	1.5 (1.2, 2.0)
Couch/chair	6.3 (4.2, 9.4)	2.8 (1.7, 4.8)	2.7 (1.9, 3.8)	1.6 (1.1, 2.4)
Other	2.3 (1.6, 3.4)	1.9 (1.2, 2.8)	1.6 (1.1, 2.2)	1.4 (1.0, 1.9)
Position when found				
On back (Ref)	1.0	1.0	1.0	1.0
On stomach	1.7 (1.3, 2.3)	1.8 (1.3, 2.6)	1.0 (0.8, 1.2)	1.1 (0.8, 1.4)
On side	1.9 (1.3, 3.0)	1.7 (1.0, 2.8)	1.4 (1.0, 1.9)	1.3 (0.9, 1.8)
Unknown	1.9 (1.4, 2.6)	1.3 (0.9, 1.9)	0.9 (0.7, 1.2)	0.8 (0.6, 1.1)
Airway condition				
Unobstructed (Ref)	1.0	1.0	1.0	1.0
Partially obstructed	3.3 (2.0, 5.4)	3.1 (1.8, 5.4)	2.1 (1.3, 3.3)	1.8 (1.1, 2.9)
Fully obstructed	6.9 (4.7, 10.0)	4.8 (3.3, 7.0)	1.8 (1.3, 3.3)	1.6 (1.1, 2.3)
Unknown	2.1 (1.6, 2.9)	1.7 (1.2, 2.3)	1.2 (0.9, 1.6)	1.2 (0.9, 1.6)
Infant sleeping with person/animal				
No (Ref)	1.0	1.0	1.0	1.0
Yes	3.7 (2.3, 5.9)	1.3 (0.7, 2.4)	2.1 (1.5, 3.1)	1.2 (0.8, 1.8)
Infant sleeping with adult				
No (Ref)	1.0	1.0	1.0	1.0
Yes	3.7 (3.0, 4.6)	2.7 (2.0, 3.5)	2.9 (2.4, 3.4)	2.2 (1.7, 2.8)

Note. AOR = adjusted odds ratio; CI = confidence interval; OR = odds ratio; SIDS = sudden infant death syndrome. Unadjusted ORs were obtained from individual logistic regression models that contained the variable listed as well as the covariates year of death and state; thus, year of death and state were controlled in each logistic regression model. AORs were obtained from logistic regression models that contained all of the variables listed as well as the covariates year of death and state.

[a]Area under the receiver operator curve for this multivariate model: 0.80 (95% CI = 0.78, 0.82).

[b]Area under the receiver operator curve for this multivariate model: 0.74 (95% CI = 0.72, 0.76).

documented differences in classification of SUIDs by jurisdiction.[16,22]

In addition, the database includes more than 1700 data elements, and large proportions of missing data are more likely when novice users are responsible for entering information into the system. The observation that the proportion of missing data submitted by a state decreases with time was a factor in selecting states that had participated in the database from early in its existence. Even so, several of the variables reported had large proportions of missing data, and we did not include other sleep environment data elements because they involved even larger proportions of missing data. Our imputation of missing data in our regression analyses allowed inclusion of all SUIDs and likely produced less biased results.[19] The reasons particular data elements involve large proportions of missing data are not known at this time; however, our findings can be used

in future state training initiatives to improve data quality.

Finally, given the nature of the NCDR-CRS, only information on deceased infants was available for analysis. Although survey data are now available that describe usual infant sleep practices among living infants,[23,24] the etiological component of infant sleep environment characteristics with respect to risk of SUIDs cannot be determined without an analytic study in which the sleep environment and other characteristics of infants who die suddenly and unexpectedly are compared with the same characteristics in living infants. Such an investigation is beyond the scope of the NCDR-CRS data.

Despite their limitations, the NCDR-CRS data have a number of inherent strengths. For instance, these data are population based and consist of standard elements that allow aggregation of data across states. The NCCDR provides training and support for NCDR-CRS users, including a comprehensive data dictionary to facilitate consistency in completion of data elements across jurisdictions. The number of states participating in the NCDR-CRS continues to grow, and states are continually gaining experience in using the system; thus, although the NCDR-CRS data are relatively new, they have the potential to inform our understanding of the circumstances and risk factors associated with all causes of child death, particularly injury deaths. The use of these collective data for prevention is a goal of the NCCDR.

To our knowledge, this is the first population-based study in which CDR data from multiple states have been used to examine infant, caregiver, and sleep circumstances and to compare them across 3 SUID categories. Notably, we included sleep environment details for more than 3000 infant deaths, a sufficiently large number to allow calculation of stable proportions of specific infant, caregiver, and sleep environment characteristics stratified by SUID category and assessment of independent associations of key sleep environment risk factors.

This study makes an important contribution to the existing SIDS research and to the growing evidence from smaller SUID studies that identify hazards in the infant sleep environment as likely contributors to SUIDs. As such, our findings have important implications for preventing injuries and reducing SUID mortality. We identified modifiable sleep environment risk factors in a large proportion of SUIDs, regardless of the ultimate cause of death classification.

Conclusions

From a public health standpoint, it is not only important but at times more prudent to focus on prevention before etiology is definitively determined. Scientists have been attempting to determine the cause of SIDS for decades. Given the across-jurisdiction variability in application of SIDS definitions in the United States and the mounting evidence that sleep environment hazards probably contribute not only to SIDS but to all SUIDs, there is a critical need to develop effective interventions for ensuring a safe sleep environment for all infants.

The American Academy of Pediatrics recently published expanded recommendations on safe infant sleep practices that include placing infants supine on a firm crib mattress without soft bedding or other objects in the crib; bed sharing during sleep is discouraged.[25] Mitchell, going one step further, suggested that the most significant reductions in SUIDs would be achieved if the practice of infant bed sharing were eliminated.[12] Despite these expert recommendations, challenges to reducing hazards in the infant sleep environment remain, as evidenced by infant sleep surveys documenting a continual increase in infant bed sharing in the United States since 1993.[23,24] Future research should focus on development of novel interventions that facilitate behavior change and result in a safe infant sleep environment. ■

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Contributors

P. G. Schnitzer conducted the analyses and drafted the article. H. K. Dykstra prepared the data for analysis and assisted with the analyses. All of the authors contributed to the conceptualization of the study, to the interpretation of the results, and to revised drafts of the article.

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