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Infant Sleeping Position and the Risk of Sudden Infant Death Syndrome in California, 1997–2000

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To assess the association between infant sleeping position and risk of sudden infant death syndrome (SIDS) in an ethnically diverse US population, the authors conducted a population-based case-control study in 11 counties in California from May 1997 through April 2000. The authors conducted in-person interviews with the mothers of 185 SIDS cases and 312 randomly selected race/ethnicity- and age-matched controls to collect information on sleeping positions. Infants who had last been put down to sleep in the prone or side position were at greater risk of SIDS than were infants who had last been put down on their backs (adjusted odds ratio (AOR) = 2.6 (95% confidence interval (CI): 1.5, 4.5) and AOR = 2.0 (95% CI: 1.2, 3.4) for the prone and side positions, respectively). The risk of SIDS was especially high for an unstable side position in which an infant was placed on its side and found prone (AOR = 8.7, 95% CI: 3.3, 22.7). Infants who were usually placed on their backs to sleep but had last been put down in the prone or side position (an unaccustomed position) had a significantly high risk of SIDS (AOR = 8.2 (95% CI: 2.6, 26.0) and AOR = 6.9 (95% CI: 2.3, 20.6) for the prone and side positions, respectively). Infants placed in an unaccustomed prone or side sleeping position had a higher risk of SIDS than infants who were always placed prone or on the side.

case-control studies; infant; sleep; sudden infant death

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; SIDS, sudden infant death syndrome.

Since the recommendation of an American Academy of Pediatrics task force in 1992 that infants not be placed in the prone position to sleep (1) and the implementation of the national public education campaign "Back to Sleep" in 1994 (2, 3), the incidence of sudden infant death syndrome (SIDS) in the United States has declined by 44 percent, from 1.2 per 1,000 livebirths in 1992 to 0.67 per 1,000 in 1999 (3, 4). Although the decline in the incidence of SIDS has been attributed to the reduction in use of the prone sleeping position during the same period, evidence of an association between infant sleeping position and SIDS risk in the US population remains limited (5–9). The association of the prone sleeping position with SIDS risk was established largely on the basis of studies conducted outside of the United States, where populations and associated cultural practices are different. In addition, the question of whether a side sleeping position increases SIDS risk remains controversial (10, 11). Finally, the effect of changing an infant to an unaccustomed sleeping position has not been well studied.

To address the above questions, we conducted a population-based case-control study of sleeping position and SIDS in 11 counties in California.

MATERIALS AND METHODS

This study was reviewed and approved by the institutional review boards of Kaiser Permanente in Northern and

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Southern California and by the California State Committee for the Protection of Human Subjects.

From May 1997 through April 2000, we conducted a population-based case-control study in 10 counties in Northern California (Alameda, Contra Costa, Sacramento, San Francisco, Marin, San Mateo, Santa Clara, Monterey, San Joaquin, and Fresno) and Los Angeles County in Southern California. The participating counties were selected on the basis of their proximity to the two investigation centers, located in the San Francisco Bay Area in Northern California and Los Angeles County in Southern California.

All SIDS and presumed SIDS cases in the participating counties were identified from reports submitted to the California Department of Health Services. Some SIDS cases arising after October 1998 were also identified directly from the coroner's office in Los Angeles County. In California, all cases of infant death with a diagnosis of SIDS or presumed SIDS are required to be reported within 72 hours of diagnosis to the California SIDS Program, which in turn reports all newly diagnosed cases to the Epidemiology and Evaluation Section of the state Department of Health Services. California law requires that all final SIDS diagnoses meet the diagnostic definition of SIDS: "sudden unexpected death of an infant under 1 year of age which remains unexplained after a postmortem examination (autopsy), death scene investigation, and review of the medical history" (12, 13). Coroners in California are regularly trained to follow a standard protocol for SIDS diagnosis. All cases of infant death with an initial diagnosis of presumed SIDS are given a final diagnosis of either SIDS or some other cause of death after further evaluation by coroners or medical examiners. Only cases with a final diagnosis of SIDS were eligible for this study.

SIDS case infants identified during the study period whose mothers resided in one of the 11 participating California counties were eligible for the study. For practical reasons, we restricted participants to infant subjects whose mothers spoke either English or Spanish. We sent a letter to the mothers of all identified eligible SIDS cases to explain the purpose of the study and to invite their participation, as soon as we received notification from the state Department of Health Services each month. Before meeting with families, study staff first contacted public health nurses, who are required by California law to provide counseling to all families with a recent SIDS death. We obtained information from the public health nurses regarding any special circumstances of the eligible SIDS family and the best timing and method for contact. On the basis of this information, study interviewers contacted the mothers of eligible cases through either a telephone call or a home visit and scheduled an interview with those who agreed to participate. When a SIDS death had occurred while someone other than the mother was caring for the infant, we attempted to interview this person in addition to the mother.

Among 396 eligible SIDS cases, we were unable to locate the mothers of 99 cases (25 percent). In addition, 51 case mothers (13 percent) refused to participate in the study. Among possible reasons for refusal, the majority (67 percent) said their refusal was due to emotional difficulties. Another 46 case mothers (12 percent) initially agreed to participate but did not complete the interview. Other reasons for refusal included objections by husbands; some women gave no specific reason. Ultimately, 197 case mothers (50 percent) completed the interview. Because we lacked information on the prenatal history of the biologic mothers of SIDS infants who died in foster care families (n = 12), we excluded them from the final data analysis.

Controls, matched to the cases on maternal race/ethnicity (White, African-American, Hispanic, Asian, and other) and age (age at death for cases and age at interview for controls, ±2 weeks), were randomly selected from all eligible controls from birth certificates issued in the same county where the SIDS case had resided. Controls were selected only for those case infants whose mothers had completed an interview, with an intended ratio of two controls to one case. Because of refusals or the inability to locate controls, we often had to contact more than two eligible controls in order to complete two control interviews per case. Mothers of controls were also sent a letter explaining the purpose of the study and were then directly contacted by our staff. Among 756 eligible controls, we were unable to locate 242 (32 percent) mothers; 143 (19 percent) refused to participate, and 59 (8 percent) never completed the interview despite initially agreeing to participate. Among the refusals, most control mothers cited a lack of time or interest (82 percent); 8 percent stated that their husbands objected, 6 percent found it emotionally too difficult, and the remaining 4 percent gave other miscellaneous reasons. Finally, 312 (41 percent) control mothers completed the interview, and each case included in the analysis had at least one matched control. We did not have any controls from foster care families. Ultimately, 185 SIDS cases and 312 controls were included in the final analysis.

Data were gathered through in-person interviews conducted by experienced interviewers who were trained in grief counseling specifically related to SIDS. Interviewers also provided women with information about community resources available to SIDS families and made referrals to local agencies when requested. The interview was conducted at a place or time of the mother's choosing. The interview obtained extensive information from the mothers of cases and controls on infants' sleeping positions, including the position in which the infant had last been put down to sleep, the position in which the infant was found (for cases, this was when the infant was found dead; for controls, it was the reference sleep period), and changes in sleeping position since birth, during the 2 weeks before the reference date, and on the reference date. The day on which the controls were interviewed was the reference date when the controls were the same age (±2 weeks) as the corresponding cases at death. In addition, the control infant's reference sleep period was selected to be similar to the last sleep period of the corresponding SIDS infant. For example, if a case died during a sleep period between 8 p.m. and 8 a.m. the following day, the same sleep period from the corresponding controls was used as the reference sleep period. Finally, if the infant's last sleep had taken place in a day-care setting and the mother was unable to provide information on the last sleeping position, we sought her permission to interview caregivers in the

TABLE 1. Characteristics of the study population in a case-control study of sleeping position and sudden infant death syndrome, California, 1997–2000

Variable	Cases (n = 185)		Controls (n = 312)		Odds ratio*	95% confidence interval*
	No.	%	No.	%		
Maternal characteristics						
Race/ethnicity						
White	58	31.4	119	38.1		
African-American	35	18.9	59	18.9		
Hispanic	61	33.0	98	31.4		
Asian	18	9.7	26	8.3		
Other	13	7.0	10	3.2		
Maternal age (years)						
<20	25	13.5	27	8.7	1.9	1.0, 3.9
20–24	55	29.7	54	17.3	2.1	1.2, 3.7
25–29	44	23.8	91	29.2	1.0†	
30–35	37	20.0	83	26.6	0.9	0.5, 1.6
≥35	24	13.0	57	18.3	0.9	0.5, 1.7
Maternal education						
High school or less	112	61.2	156	50.2	2.0	1.2, 3.3
Some college	40	21.9	70	22.5	1.6	0.9, 2.9
College graduate	31	16.9	85	27.3	1.0†	
Marital status						
Married	93	55.7	206	72.2	1.0†	
Living as married/regular partner	61	36.5	72	25.3	1.9	1.2, 2.9
Never married/separated/divorced/widowed	13	7.8	7	2.5	4.1	1.5, 11.8
Annual income						
<$20,000	73	41.5	86	29.3	2.4	1.5, 3.9
$20,000–$50,000	58	33.0	83	28.2	1.9	1.2, 3.2
>$50,000	45	25.6	125	42.5	1.0†	
Region						
Northern California	115	62.2	211	67.6		
Southern California	70	37.8	101	32.4		$p < 0.2$
Physical abuse during or after index pregnancy						
No	146	88.5	285	95.0	1.0†	
Yes	19	11.5	15	5.0	2.5	1.2, 5.3
Parity (no. of prior births)						
0	57	30.8	132	42.3	1.0†	
1	69	37.3	96	30.8	1.7	1.1, 2.6
2	32	17.3	52	16.7	1.4	0.8, 2.5
≥3	27	14.6	32	10.3	2.0	1.0, 3.7

Table continues

day-care setting for information on the infant's last sleeping position.

We also collected information on factors that might modify the relation between infant sleeping position and SIDS risk, such as type of mattress, bedding materials, room- or bed-sharing, thermal factors (room temperature, use of heating or air conditioning, and wrapping of the baby), exposure to passive smoking, and infant sickness. Information on potentially confounding factors was also collected, including data on maternal prenatal history, previous pregnancies, sociodemographic characteristics, and the infant's medical history.

The median interval between the occurrence of death and the interview of SIDS mothers was 3.8 months, since many grieving mothers of SIDS victims were unable or unwilling to participate in the study immediately after the death of their

TABLE 1. Continued

Variable	Cases (n = 185)		Controls (n = 312)		Odds ratio*	95% confidence interval*
	No.	%	No.	%		
Index pregnancy						
Urinary tract infection during pregnancy						
No	148	80.9	263	84.3	1.0†	
Yes	35	19.1	49	15.7	1.3	0.8, 2.1
Gestational age (weeks) at initial prenatal care visit						
<12	120	65.6	239	77.6	1.0†	
≥12	63	34.4	69	22.4	1.8	1.2, 2.8
Smoking status during pregnancy						
Nonsmoker	114	64.8	218	72.7	1.0†	
Former smoker	26	14.8	50	16.7	1.0	0.6, 1.7
Lower cumulative no. (<1,200) of cigarettes	9	5.1	23	7.7	0.8	0.3, 1.8
Higher cumulative no. (≥1,200) of cigarettes	27 (15.3)		9 (3.0)		5.7	2.5, 13.6
Any alcohol use during pregnancy						
No	125	67.9	195	63.9	1.0†	
Yes	59	32.1	110	36.1	0.8	0.6, 1.3
Any binge drinking (≥4 drinks/day) during pregnancy						
No	160	90.9	263	93.9	1.0†	
Yes	16	9.1	17	6.1	1.6	0.7, 3.3
Infant characteristics						
Mean age‡ in days	98 (59)§		104 (56)			p = 0.25
Infant age‡ (months)						
≤1	45	24.3	60	19.2		
2–3	90	48.7	155	49.7		
≥4	50	27.0	97	31.1		
Infant sex						
Male	107	57.8	177	56.7	1.1	0.7, 1.5
Female	78	42.2	135	43.3	1.0†	
Mean birth weight (g)	2,980 (715)		3,331 (524)			p < 0.0001
Birth weight (g)						
≥2,500	150	81.1	297	95.2	1.0†	
<2,500	35	18.9	15	4.8	4.6	2.4, 9.2
Gestational age (weeks)						
≥37	140	79.1	284	91.9	1.0†	
<37	37	20.9	25	8.1	3.0	1.7, 5.4
Infant sickness during previous 48 hours						
No sickness	108	59.0	196	62.8	1.0†	
Sick	66	36.1	109	34.9	1.1	0.7, 1.7
Sick with fever	9	4.9	7	2.2	2.3	0.8, 7.2

* Odds ratios and 95% confidence intervals were unadjusted.
† Reference category.
‡ Age at death for cases and age at interview for controls.
§ Numbers in parentheses, standard deviation.

children. Since the reference date for controls was the interview day, there was no recall interval for controls.

To simplify analytical procedures and to avoid loss of statistical power due to loss of matched sets, we used uncon-

ditional logistic regression analysis to adjust for confounding factors. Since cases and controls were matched only on race/ethnicity and age at the reference date, with a limited number of categories, the matching variables were included in all models. We compared results from conditional and unconditional logistic regression analyses that used the same set of subjects, and results were very similar. Adjustment variables were included in the models if they confounded the association between infant sleeping position and SIDS risk in our data (e.g., changing the odds ratio by more than 20 percent). Some known risk factors for SIDS were not included in the final models because their inclusion in the model did not affect the estimate of the relation between sleeping position and SIDS risk (see the footnotes of each table).

To assess potential bias due to low participation, we analyzed linked California birth-death certificate data for 1996–2000, which covered the entire study period. We identified all SIDS cases and all livebirths from the 11 participating counties as the underlying source population for our cases and controls, respectively. Because the race/ethnicity of our controls might not have reflected the race/ethnicity of the underlying population due to matching, we selected the source population controls on the basis of the racial/ethnic composition of all cases from the source population.

RESULTS

Table 1 shows the characteristics of our study population. As expected, cases and controls were comparable in terms of maternal race/ethnicity and infant age at the reference date, because of matching. The median age difference between cases at death and the matched controls at interview was 6 days. Mothers of SIDS cases were more likely to be less than 25 years old, to lack a complete college education, to be unmarried, and have a lower income. Mothers of cases also had more prior livebirths, smoked more heavily during the index pregnancy, started prenatal care later, and were more likely to have been physically abused during or after the index pregnancy. SIDS cases were more likely than controls to have a low birth weight (<2,500 g), to be born prematurely, and to be sick with fever 48 hours before the reference date. The mean birth weight in SIDS cases (2,980 g) was lower than that in controls (3,331 g). There were no differences between cases and controls in terms of sex, maternal fever, urinary tract infection, or alcohol intake during the index pregnancy, although binge drinking was slightly more prevalent among mothers of cases than among mothers of controls.

Table 2 shows the relation between the position the infant was placed in during the last sleep period and risk of SIDS. After adjustment for matching variables (race/ethnicity and infant age), known confounders, and demographic variables, the prone and side sleeping positions were both associated with more than twice the risk of SIDS in comparison with the supine (back) sleeping position (adjusted odds ratio (AOR) = 2.6 (95 percent confidence interval (CI): 1.5, 4.5) and AOR = 2.0 (95 percent CI: 1.2, 3.4) for the prone and side positions, respectively). The strength of the associations with the last-put-down prone and side sleeping positions varied among racial/ethnic groups: Risk of SIDS was increased for the prone sleeping position in all racial/ethnic groups except African Americans. Risk of SIDS was increased for the side sleeping position among White infants and possibly African-American infants but not among Hispanic, Asian, or Pacific Islander infants. However, the sample sizes in individual racial/ethnic categories were small, and the estimates had wider confidence intervals. Consequently, the interaction between prone sleeping position and African-American race/ethnicity did not reach statistical significance ($p = 0.14$), nor did the interaction between side sleeping position and Hispanic/Asian/Pacific Islander race/ethnicity ($p = 0.49$).

For usual sleeping position during the 2 weeks before the last sleep period, the adjusted odds ratios associated with a prone or side sleeping position were not elevated (AOR = 0.7 (95 percent CI: 0.4, 1.1) for a usual side sleeping position and AOR = 0.9 (95 percent CI: 0.5, 1.6) for a usual prone sleeping position) (table 3). To examine the association between an unaccustomed prone or side sleeping position and risk of SIDS, we compared usual sleeping position during the period 2 weeks prior to the last sleep with the position the infant had been placed in for the last sleep. Risk of SIDS was increased for infants who had been switched from a usual back (low-risk) sleeping position to a side or prone (high-risk) position during the last sleep (table 3). The increase in risk was especially high among infants for whom the switch had been from a usual back sleeping position to either a prone position (AOR = 8.2, 95 percent CI: 2.6, 26) or a side position (AOR = 6.9, 95 percent CI: 2.3, 20.6) during the last sleep. In contrast, there appeared to be a lower risk of SIDS among infants who had been switched from a usual prone or side sleeping position to a back sleeping position, although the confidence interval was wide and included 1.0 (AOR = 0.3 (95 percent CI: 0.1, 1.0) for a switch from side to back and AOR = 0.7 (95 percent CI: 0.1, 6.5) for a switch from prone to back). Infants who were usually put down to sleep in the prone position and had remained in the prone position during the last sleep period had a modestly increased risk of SIDS (table 3).

To investigate the underlying mechanisms, we further evaluated whether the increased risk of SIDS associated with the side sleeping position was due to the instability of the side position and to the infant's turning to a prone sleeping position. We compared the last-put-down sleeping position with the sleeping position in which the infant had been found (table 4). Results indicated that, although the side sleeping position may not be as safe as the back sleeping position, most of the increase in risk associated with the side sleeping position was due to the instability of the side sleeping position, which entailed infants' turning to the prone sleeping position (a secondary prone position).

Both cases and controls in day-care settings were more likely to have been placed on their backs for the last sleep than those who had last slept at home (37.5 percent at day care vs. 29.6 percent at home among cases and 63.6 percent at day care vs. 55.8 percent at home among controls).

Table 5 presents the associations between SIDS and several characteristics on which data were available from birth certificates in participants and the source population. The odds ratios obtained from the participating cases and controls were

TABLE 2. Risk of sudden infant death syndrome according to the position in which the infant was last put down to sleep, by maternal race/ethnicity, California, 1997–2000

	Position in which infant was last put down to sleep	Cases (n = 166)		Controls (n = 310)		Odds ratio*	95% confidence interval
		No.	%	No.	%		
Total study population							
	Back	52	31.3	175	56.5	1.0†	
	Side	59	35.5	80	25.8	2.0	1.2, 3.4
	Prone	55	33.1	55	17.7	2.6	1.5, 4.5
Maternal race/ethnicity							
White							
	Back	13	26.5	74	62.2	1.0†	
	Side	17	34.7	24	20.2	3.1	1.2, 7.9
	Prone	19	38.8	21	17.6	3.6	1.4, 9.6
African-American							
	Back	8	25.0	25	42.4	1.0†	
	Side	14	43.8	15	25.4	4.5	0.9, 22.5
	Prone	10	31.3	19	32.2	1.3	0.3, 6.0
Hispanic							
	Back	19	32.8	50	51.6	1.0†	
	Side	20	34.5	34	35.1	1.1	0.4, 2.7
	Prone	19	32.8	13	13.4	3.3	1.2, 9.5
Asian, Pacific Islander, or other							
	Back	12	44.4	26	74.3	1.0†	
	Side	8	29.6	7	20.0	1.7	0.2, 15.8
	Prone	7	25.9	2	5.7	29.3	0.4, 999.9

* Estimates were adjusted for maternal race/ethnicity (except in models stratified by race/ethnicity), infant age, maternal age, education, smoking during the index pregnancy, region, and birth date. Further adjustment for parity, marital status, infant birth weight, infant sex, and season at death or interview did not appreciably alter the results.

† Reference category.

largely comparable to those obtained from all eligible cases and matched controls, except for male sex, which was no longer a risk factor in the participating population.

DISCUSSION

To our knowledge, this population-based case-control study was the first comprehensive examination of infant sleeping position in relation to SIDS risk in a US population and was the first to be conducted completely after the national public health campaign "Back to Sleep" was initiated in 1994 to promote the supine (back) sleeping position. It also provided us with an opportunity to examine the relation between sleeping position and SIDS in a racially and ethnically diverse population. The results provide strong evidence confirming an association between the prone sleeping position and an increased risk of SIDS. The study shows that risk of SIDS is also increased for infants placed in the side position, although the data suggest that the increased risk for the side position may be due to the instability of this position and the tendency of infants placed in the side position to turn to a prone position. Most importantly, the study demonstrates that infants who are put to sleep in an unaccustomed prone or side position are at greater risk of SIDS than those who are always put to sleep in the prone or side position (an accustomed prone or side position).

The limitations of this study include a low participation rate, potential recall bias, and a limited ability to examine risk in specific racial/ethnic groups because of the small sample size. The participation rates were 50 percent among eligible cases and 41 percent among eligible controls. To the extent that participation was associated with both case/control status and infant sleeping position, our findings could be biased.

To examine the potential bias, we made the following comparisons. First, we compared the distributions of the ages at death of the participating cases and the cases from the source population. The distributions were similar and reflected the expected pattern for SIDS cases. For participating cases and source cases, respectively, 25.2 percent and 26.5 percent were ≤1 month of age, 49.1 percent and 44.6 percent were 2–3 months of age, 16.8 percent and 17.0 percent were 4–5 months of age, and 9.0 percent and 12.1 percent were ≥6 months of age. The distributions of the

TABLE 3. Risk of sudden infant death syndrome according to the positions in which the infant was usually put down to sleep and last put down to sleep, California, 1997–2000

Usual sleeping position (during the 2 weeks prior to reference date)	Last sleeping position	Cases (n = 165)		Controls (n = 310)		Odds ratio*	95% confidence interval
		No.	%	No.	%		
Back		79	47.9	159	51.3	1.0†	
Side		51	30.9	94	30.3	0.7	0.4, 1.1
Prone		35	21.2	57	18.4	0.9	0.5, 1.6
Back	Back	47	28.5	147	47.4	1.0†	
	Side	16	9.7	7	2.2	6.9	2.3, 20.6
	Prone	16	9.7	5	1.6	8.2	2.6, 26.0
Side	Back	4	2.4	20	6.5	0.3	0.1, 1.0
	Side	40	24.2	67	21.6	1.2	0.7, 2.3
	Prone	7	4.2	7	2.3	1.8	0.5, 6.4
Prone	Back	1	0.6	8	2.6	0.7	0.1, 6.5
	Side	3	1.8	6	1.9	1.4	0.3, 7.7
	Prone	31	18.8	43	13.9	1.5	0.8, 3.0

* Estimates were adjusted for race, infant age, maternal age, education, smoking during the index pregnancy, region, and birth date. Further adjustment for parity, marital status, infant birth weight, infant sex, season at death or interview, and infant sickness during the previous 48 hours did not appreciably alter the results.

† Reference category.

participating cases and source cases according to season of death were nearly identical: 27.4 percent and 27.3 percent for December–February, 26.8 percent and 26.2 percent for March–May, 20.1 percent and 21.6 percent for June–August, and 25.7 percent and 25.0 percent for September–November. Second, we compared the odds ratios obtained from our study population with those obtained from the source population, assuming that we were able to recruit all cases and their matched controls. Table 5 suggests that results obtained from our study were largely comparable to those obtained from all eligible cases and matched controls, except for male sex. Finally, we compared our data to two additional reported population measurements. One study reported that in California, approximately 19.1 percent of all SIDS cases died in a day-care setting (14). Among our participating cases, 20.6 percent died in a day-care setting. Another population-based study has shown that the prevalence of the prone sleeping position in the United States in 1998 was 17 percent among White infants and 32 percent among African American infants (3). In our participating controls, the prevalence of the prone sleeping position was 17.7 percent among White infants and 32.2 percent among African-American infants. Therefore, evidence from the above comparisons seems to suggest that the potential bias due to the low participation rate may be limited.

Our study design increased the accuracy of recall of sleeping position by control mothers. However, it also created differences in recall periods between case and control mothers. To assess this potential bias, we reanalyzed the data using only the 63 case infants whose self-reported sleeping position was confirmed by the available coroner's records, which were collected soon after death. Despite the significantly reduced sample size, the results were essentially the same as those from the overall study population:

TABLE 4. Risk of sudden infant death syndrome in relation to a side sleeping position, California, 1997–2000

Sleeping position variable	Cases (n = 164)		Controls (n = 310)		Odds ratio*	95% confidence interval
	No.	%	No.	%		
Last put down to sleep on back, irrespective of position in which infant was found	52	31.7	175	56.5	1.0†	
Last put down to sleep prone, irrespective of found position	55	33.5	55	17.7	2.6	1.4, 4.6
Last put down on side, last found on side	28	17.1	36	11.6	1.5	0.8, 3.1
Last put down on side, last found on back	10	6.1	34	11.0	0.7	0.3, 1.7
Last put down on side, last found prone	19	11.6	10	3.2	8.7	3.3, 22.7

* Estimates were adjusted for race, infant age, maternal age, education, smoking during the index pregnancy, region, and birth date. Further adjustment for parity, marital status, infant birth weight, infant sex, and season at death or interview did not appreciably alter the results.

† Reference category.

TABLE 5. Relation between selected risk factors and sudden infant death syndrome among study participants and the source population in a population-based case-control study of sleeping position and sudden infant death syndrome, California, 1997–2000

Risk factor*	Participants† (179 cases and 304 controls)		Source population‡ (all 348 cases and 10,010 ethnically matched controls)§	
	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
Maternal age <20 years	2.1	1.2, 3.6	1.5	1.1, 2.0
Mother's education ≤12th grade	1.9	1.3, 2.8	1.7	1.4, 2.2
Parity ≥3	2.6	1.6, 4.4	1.8	1.4, 2.3
Birth weight <2,500 g	4.8	2.6, 9.1	3.2	2.4, 4.2
Male infant sex	1.0	0.7, 1.4	1.5	1.2, 1.8
Gestational age at initial prenatal visit >5 months	1.5	0.8, 2.5	1.6	1.1, 2.0

* For comparability, information on characteristics for both participants and the source population was based on California birth and death certificate data from 1996–2000.

† We were unable to link to California birth or death certificate data for six participating cases and eight participating controls.

‡ The source population included the following participating counties: Alameda, Contra Costa, Fresno, Los Angeles, Marin, Monterey, Sacramento, San Francisco, San Joaquin, San Mateo, and Santa Clara.

§ Controls from the source population were matched to participating cases on race/ethnicity. Controls from the source population that were matched to all cases on race/ethnicity were also used for comparison, and results were similar (data available upon request).

For the side sleeping position, the adjusted odds ratio was 2.2 in the reanalysis of the subgroup versus 2.1 in the overall population, and for the prone sleeping position, the adjusted odds ratio was 2.8 versus 2.5. The kappa statistic for agreement between the interview and the coroner's report was 0.54 (95 percent CI: 0.40, 0.68).

The small sample size and the correspondingly wide confidence intervals for risk estimates among separate racial/ethnic groups limit our ability to draw conclusions for individual racial/ethnic groups. Nevertheless, a case-control study of SIDS in Chicago, Illinois, also observed a stronger association between the prone sleeping position and SIDS risk in non-African Americans compared with African Americans (15). These observations do raise questions for future investigation concerning the role of race/ethnicity in determining the contribution of sleeping position to SIDS risk.

The association between SIDS and the prone and side last-put-down sleeping positions has been reported in many studies conducted outside of the United States (8, 9, 16–18). Previous studies carried out overseas have also reported that infants usually placed nonprone and then placed prone, in an unaccustomed prone sleeping position, are at higher risk of SIDS than infants who are always placed prone (19, 20). We examined all nine combinations between usual sleeping position and last-put-down sleeping position (table 3). Usual sleeping position in the 2 weeks prior to the reference date was not associated with SIDS risk in our study population. This finding is consistent with a report from an earlier California study (7) that asked about usual sleeping position but not last sleeping position and found no increase in the risk of SIDS in relation to usual sleeping position. In our study, when usual sleeping position was further categorized on the basis of the last-put-down position, a pattern emerged. If an infant was switched from a usually low-risk position (the back position) to an unaccustomed high-risk position (the prone or side position), his/her SIDS risk was increased seven- to eightfold in comparison with an infant who was always put down to sleep on his or her back (table 3). Interestingly, infants placed in an unaccustomed prone or side sleeping position were at significantly higher risk of SIDS (AOR = 8.2 (95 percent CI: 2.6, 26.0) and AOR = 6.9 (95 percent CI: 2.3, 20.6), respectively) than those who were always placed in the prone or side sleeping position (AOR = 1.5 (95 percent CI: 0.8, 3.0) and AOR = 1.2 (95 percent CI: 0.7, 2.3), respectively) (table 3).

Case infants who died in an unaccustomed prone or side sleeping position accounted for approximately 25 percent of all SIDS cases. However, the unaccustomed prone sleeping position accounted for 43 percent (23/54) of the last-put-down prone sleeping positions among SIDS cases. Therefore, preventing an unaccustomed prone or side sleeping position should be an important part of public education messages promoting the back sleeping position to reduce SIDS risk. For example, all caregivers of an infant should be consistent regarding the infant's sleeping position, to avoid the accidental use of an unaccustomed prone or side sleeping position.

In examining differences between the last-put-down and last-found sleeping positions, we found that the risk of the side sleeping position depended on the stability of the position during sleep. While a stable side sleeping position (i.e., the infant's remaining in the side position throughout the sleep period) was not associated with a significantly increased risk of SIDS, the risk of SIDS was significantly increased if the infant turned from its side to the prone posi-

tion (a secondary prone position) during sleep. One previous study reported that SIDS case infants placed in the side position were more likely to turn to the prone position during sleep than were control infants. However, no detailed analysis including odds ratios was provided for this association (20). Our finding indicates that prevention should also be focused on avoidance of the secondary prone sleeping position. While it may be desirable to advocate the back sleeping position to every parent, there may be some parents who oppose the back sleeping position for reasons of culture or tradition. For those parents, an emphasis on preventing the side position from turning into the prone position is warranted by our data. However, actual mechanisms for maintaining a stable side sleeping position will need to be carefully examined after the risks and benefits of any proposed methods have been balanced.

Among the 29 infants who changed from the side sleeping position to the prone sleeping position (a secondary prone position) (table 4), 10 (35 percent) had usually been placed on their backs to sleep. In other words, approximately 35 percent of secondary prone sleeping positions in this case were also unaccustomed side sleeping positions. Therefore, some of the risk of SIDS associated with a secondary prone sleeping position may in fact reflect the risk associated with an unaccustomed side sleeping position. The mechanism for an association between SIDS risk and an unaccustomed prone sleeping position or a secondary prone sleeping position (from an initial side position) is not well understood. Infants who are usually placed in the back sleeping position develop their motor skills later than infants who are usually placed in the prone sleeping position (21, 22). It may be more difficult for some of these infants to lift their heads when placed prone, leading to accidental asphyxia due to the rebreathing of carbon dioxide (19). Burns and Lipsett (23) have postulated that the development of defensive behaviors for protecting the airway depends on both an intact neural substrate and an environmental opportunity for learning. This theory regarding the development of airway protective responses may also apply to physiologic adaptations. It has been reported that infants' sleep physiology is different when they are sleeping in the prone position than when they are sleeping in the back position (24–27). It is conceivable that some infants who are used to the back sleeping position may have difficulty adjusting to the environmental and physical stresses associated with the prone sleeping position, including reductions in airway protection reflexes (28), vasomotor tone (26), ventilatory response to asphyxia (25), and arousal response (24, 27), as well as an increase in heat stress and heart rate (26).

In conclusion, our population-based case-control study provides new insight into the relation between infant sleeping position and SIDS risk in a culturally diverse US population in the post "Back to Sleep"-campaign era. Findings from our study indicate that avoiding an unstable side sleeping position and unaccustomed prone and side sleeping positions should be emphasized in public health education efforts designed to decrease the risk of SIDS. Uncovering the factors that make a small proportion of infants vulnerable to the prone sleeping position will be the next challenge for future research.

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