Changes in the Timing of SIDS Deaths in 1989 and 1999: Indirect Evidence of Low Homicide Prevalence Among Reported Cases

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Summary

An unknown proportion of cases diagnosed as sudden infant death syndrome (SIDS) are misdiagnosed, and in some cases are homicides. Because recent SIDS prevention measures were unlikely to reduce homicides, changes in the reported timing of SIDS cases provide an indirect measure of covert homicides in this group.

This paper uses United States vital statistics microdata to explore these questions. The sample includes all reported infant deaths to singletons with birthweight exceeding 500 grams in the 1989 and 1999 U.S. birth cohorts. Deaths attributed to SIDS (N=7,708), homicide (N=597), or object inhalation and mechanical suffocation (N=860) are specifically examined. If reported SIDS cases were a mixture of "true" cases and misdiagnosed homicides, it is hypothesized that the age-at-death distribution of SIDS deaths would have changed to reflect greater prevalence of misdiagnosed homicide.

We find that the age-at-death distribution of reported SIDS cases was virtually unchanged in the two cohorts, showing no increase during periods of infancy when relative homicide risk is most pronounced. One cannot reject the hypothesis that the timing was drawn from the same distribution. (χ^2_{52} =62.2, p=0.157) Analogous results hold for infants born to in circumstances associated with high homicide risk. (χ^2_{50} =61.5, p=0.12)

The stable age-at-death distribution of reported SIDS cases between 1989 and 1999 suggests that covert homicides are a small fraction of reported SIDS cases.

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Introduction

When an infant unexpectedly dies of no apparent cause, a diagnosis of Sudden Infant Death Syndrome (SIDS) is often made. In the ideal procedure, SIDS diagnoses are made only after thorough case investigation, including an autopsy, death scene investigation, and clinical review.[1-4]

Even when such procedures are followed, SIDS can be difficult to distinguish from infant death due to suffocation or natural causes. Deaths due to object inhalation should be readily distinguishable from SIDS. However, confusion can arise in specific cases. Some unknown proportion of reported SIDS deaths are actually the result of child abuse by a parent or other caregiver.[5-8] Publicized cases have attracted public attention, exemplified by the *Newsweek* headline "The Nursery's Littlest Victims: Hundreds of Cases of 'Crib Death' or SIDS may in fact be infanticide,"[9] and by a series of controversial cases and overturned homicide convictions in Great Britain.[10]

Although covert homicides have been documented in specific instances, most published studies estimate that child abuse accounts for a small percentage of SIDS cases.[2] The American Academy of Pediatrics cites varying prevalence estimates, ranging from <1 percent to 5 percent of reported SIDS cases.[2] Meadow (1999) argued that such cases are more widespread, and suggests that the term "SIDS" should be revised or abandoned to encourage more thorough and candid investigation of anomalous deaths.[6]

An analysis of 1983-1987 Arkansas births concluded that 4.7 percent of SIDS cases reflected child abuse or neglect.[11] In similar fashion, O'Halloran and colleagues (1998)

investigate the prevalence of past child abuse and neglect reports involving caregivers for infants who die of SIDS.[12] These authors find no statistically significant difference in reporting between SIDS caregivers and a matching control group.

The Confidential Enquiry into Stillbirths and Deaths in Infancy (the CESDI SUDI study) provided the most comprehensive prevalence analysis of covert infant homicide.[13, 14] Examining all post-perinatal infant deaths in five English health regions, CESDI investigators concluded that maltreatment was the main cause of death in 6.4 percent of reported SIDS cases. In an additional 8.1 percent of reported SIDS cases, maltreatment was a contributing or alternative cause of death. Discussing these data, Levene and Bacon loosely estimate that the proportion of covert homicides among reported SIDS cases was approximately 10 percent. This estimate might be considered an upper bound, since CESDI investigators defined maltreatment broadly to include both intentional homicide and non-intentional causation through negligent care.[15]

Absent detailed investigation or further analysis retrospective data to scrutinize the true cause of death in reported SIDS cases, the true prevalence of covert homicides remains unknown. This paper, however, examines the question indirectly, by examining changes in the timing of SIDS deaths in the aftermath of the "Back-to-Sleep" Campaign. Between 1989 and 1999, the reported incidence of SIDS declined by more than half.[16] Although declining maternal smoking and other changes played a role in this decline, changes in infant sleep placement appear to be the central factor.[17-21] These SIDS prevention efforts play no obvious or reported role in preventing infant homicides

Examining all reported singleton SIDS deaths among birthweights exceeding 500 grams in two U.S. birth cohorts, this analysis exploits a remarkable epidemiological shift to scrutinize the mixture of causes that may be included in reported SIDS incidence rates.

Methods

Data regarding infant deaths are collected from public-use data distributed by the National Center for Health Statistics (NCHS). Data for the 1989 and 1999 U.S. birth cohorts are drawn from the Linked Birth Infant Death Files for the two years. These files contain matched individual-level data regarding more than 99 percent of live births in the United States. In cases of infant death, death certificate data are linked with infant birth certificate data, with successful linkage occurring in more than 97 percent of cases.

Twins and higher-plurality births are excluded from the current analysis because these births raise medical and epidemiological issues outside the current analysis. Infants born weighing 500 grams or less were also excluded because non-SIDS mortality is extremely high in this group, and because infant and fetal deaths may be difficult to distinguish at these birthweights.

Infant deaths are categorized based upon ICD-9 classification, grouped into 61 categories within the Perinatal Mortality datafiles. Using these classifications, Table 1 shows reported prevalence of SIDS, homicide (including all sources of assault, abuse, and other intentional acts), object inhalation and all forms of suffocation within the two birth cohorts.

Because SIDS incidence has sharply declined due to the Back-to-Sleep campaign and other factors, we hypothesize that the timing of SIDS deaths changed between the two survey years and was likely to include a higher proportion of homicide cases in the later year. Because homicides occur more uniformly than SIDS over the duration of infancy, we expect the timing of SIDS deaths to be more uniform for 1999 than in 1989. If reported SIDS cases are actually a mixture of “true” cases and misdiagnosed homicides, we would expect to see a more uniform

distribution as the incidence of "true" SIDS incidence declines in response to recent preventive measures.

The age-at-death distribution of reported SIDS cases are compared across the two birth cohorts using a χ^2 test to examine whether there were changes in the overall distribution. All analyses are conducted using PC-SAS, version 8.[22, 23] To obtain sufficient cell sizes for asymptotic tests, the timing of deaths during infancy is aggregated into 52 weekly categories. Different aggregation methods have no impact on the results.

Because the hazard rates associated with SIDS and known homicides do not closely correspond with well-studied distributions, we also performed a simple Monte Carlo simulation to examine the statistical power of χ^2 tests in detecting statistically significant differences between the two birth cohorts. We then constructed simulated 1989 and 1999 birth cohorts in which the assumed hazard rates corresponding to "true" SIDS cases and "true" homicide rates were constructed from the observed 1999 hazard rates of the two reported outcomes. We then varied the assumed proportion of covert homicides in a simulated cohort of reported SIDS cases in each birth cohort.

To simulate the impact of "Back to Sleep" in our simulation, we assumed a proportional decline in "true" SIDS cases of 56 percent. This matched the reported decline in reported SIDS prevalence in our 1989 and 1999 study samples. In our Monte Carlo simulation, we then replicated the χ^2 tests used in our paper, and examined the proportion of times we obtained significant differences in age-at-death at the ($p<0.05$) and ($p<0.01$) significance level. This approach may understate true statistical power of current methods, because the reference distribution used to simulate "true" SIDS cases may itself contain covert homicides.

Finally, as a robustness check, we also examined SIDS incidence within a population with characteristics associated with increased risk of (known) homicide. Some socioeconomic factors have been associated with such risks. For example, Overpeck *et al.* (1998) reported that infants born to unmarried teen mothers faced elevated homicide risk.[24] We determined the high-risk group by estimating a multiple logistic regression analysis of reported infant homicides within the 1999 birth cohort, identifying all infants with predicted probability of homicide exceeding 0.25 deaths per 1000. This threshold is more than 3 times the average homicide risk in the two cohorts. We then examined the age at death of reported SIDS cases within the 1989 and 1999 birth cohorts among infants identified as facing high homicide risk in our multivariable analysis.

Results

As shown in Table 1, reported infant deaths due to homicide, mechanical suffocation, and object inhalation were rare in both years. Out of 7.8 million singleton births in the two birth cohorts, the three causes together account for less than 0.2 deaths per 1000 live births. Although SIDS incidence declined between the two cohorts, SIDS remains far more prevalent than the combined total of the other three reported causes, and indeed remains the most prevalent cause of post-neonatal infant death.

As shown in Table 1, the proportion of SIDS infants born to African-American mothers increased between 1989 and 1999. The proportion of SIDS infants born to unmarried women, and to unmarried teens, also rose, partly because the proportion of all births to unmarried women also increased. In contrast, the proportion of SIDS cases born to smokers increased despite declining smoking prevalence among pregnant women.

Figure 1 shows the observed hazard rate of SIDS deaths for the 1989 and 1999 births cohorts. The figure displays SIDS incidence in deaths per million infant-days for each birth cohort. 1989 SIDS incidence is scaled to the left-hand vertical axis. As shown, SIDS incidence peaks between 9 and 11 weeks of life, with an incidence of approximately 12.4 deaths per million infant-days, with sharply declining hazard rates over the remainder of infancy.

1999 SIDS incidence is scaled to the right-hand vertical axis. SIDS incidence again peaks between 9 and 11 weeks of life, with an incidence of approximately 5.7 deaths per million infant-days. Incidence declined rapidly to less than 1 death per million infant-days between 24 and 26 weeks, and further declines later in infancy.

Figure 1 shows graphically that the SIDS hazard rate declined in remarkably proportionate fashion between the two birth cohorts. Although SIDS incidence dropped precipitously between the two birth cohorts, the two plotted hazard rates are virtually on top of each other. Although SIDS incidence dropped by more than half between the two years, the distribution of age-at-death among reported cases remained remarkably similar.80 percent of SIDS deaths occur between 30 and 160 days of life.

Throughout the first 6 months of life, the period in which more than 90 percent of reported SIDS deaths, the hazard rate declined by slightly more than half between the two cohorts. The ratio of 1989 to 1999 hazard rates was stable in every measured interval within this range. This ratio appeared slightly more variable after 6 months of life, reflecting the much small number of affected births and perhaps the unusual nature of reported SIDS deaths after 6 months of age.

Over the full interval of infancy, the statistical pattern can be scrutinized through hypothesis tests. If hazards declined proportionally, then the 1989 and 1999 timing of SIDS

death were drawn from a common distribution.[22, 23] This hypothesis is explored using a χ^2 test. To ensure adequate cell sizes, age of death is aggregated into integer units of weeks.

Despite a sample size of more than 7,708 SIDS deaths—virtually all known cases in the two birth cohorts, one cannot reject the hypothesis that age at death was drawn from the same underlying distribution in the two birth cohorts (χ^2_{52}=62.2, p=0.157). There is no evidence, graphically or based upon statistical tests, of relative increases in SIDS incidence near the beginning or end of infancy when the observed prevalence of homicide rivals the observed prevalence of SIDS. Results were especially strong if one confined attention to the first six months of pregnancy, where the age-at-death distributions were virtually identical (χ^2_{26}=27.7, p=0.372).

Figures 2 shows comparable results for reported homicides. Given small sizes, the histograms appear more variable than was observed for SIDS deaths. As was observed with SIDS, the age-at-death distribution of reported homicides is similar across the two birth cohorts. In homicides as with SIDS, one cannot reject the hypothesis that age at death was drawn from the same underlying distribution in the two birth cohorts (χ^2_{52}=53.6, p=0.414).

Compared with SIDS, relative homicide risk is high during the early neonatal period, and then slowly declines over the first six months of infancy, and then remains relatively flat over the remaining period of infancy. Thirty-one percent of reported homicides, compared with 7 percent of reported SIDS cases, occur in the last six months of infancy. Figure 3, which shows cumulative distribution functions in the two birth cohorts, illustrates the different shapes of the homicide and SIDS distributions.

Figure 4 shows hazard rates for inhalation and mechanical suffocation. Patterns are more variable for this outcome, partly reflecting smaller sample sizes. For this cause of death,

however, one does find a statistically significant difference in timing between the two birth cohorts (χ^2_{52}=58.33, p=0.0012). Diagnoses of death due to inhalation or mechanical suffocation notably increased between 5 and 15 weeks of life, the period of peak SIDS risk. This increased prevalence may reflect changing diagnostic patterns or heightened scrutiny of potential SIDS cases. However, the change over time in this hazard rate was extremely small when compared with changes in SIDS incidence over the same period.

Monte Carlo Analysis

We then performed a simple Monte Carlo simulation to examine statistical power. Figure 5 shows the results. If the proportion of covert homicides exceeded 12.5 percent of reported cases, one would detect statistically significant differences between the two birth cohorts 66 percent of the time, using a χ^2 test at the 5 percent significance level. If the proportion of covert homicides were to exceed 15 percent, statistical power exceeds 80 percent at both the 5 percent and 1 percent significance levels.

In contrast, statistical power falls rapidly as the assumed proportion of covert homicides dips below 12.5 percent. The current methodology lacks statistical power to reliably distinguish a distribution that contains 10 percent covert homicides from one that contains no such homicides.

Subgroup analysis

To further explore the issue of covert homicide, we examined 1989-1999 changes within a subgroup of infants with characteristics associated with elevated risk of (reported) homicide. If covert homicides are more likely to occur, and then be misdiagnosed as SIDS, among those

facing general homicide risks, one would expect the most pronounced distributional changes within this population.

Table 2 shows the results of our multiple logistic analysis of homicide risk in the 1999 birth cohort. (Analysis of the 1989 birth cohort is available from the author. It yields the same qualitative results.) Homicides were more common among low birthweight and very-low birthweight infants, and those born to mothers age 25 or younger, those born to unmarried mothers, African-American mothers, and mothers with limited years of education. Homicide risk was also associated with delayed receipt of prenatal care.

For comparison, Table 3 also shows the results of an identical specification to predict SIDS risk. Many of the same factors are associated with both homicide and SIDS risk. These similarities highlight the fact that neither cause of death is evenly distributed among American infants.

We identified 1,348 SIDS cases within the 1989 birth cohort, and 546 SIDS cases in the 1999 birth cohort with predicted homicide probabilities exceeding 0.25 deaths per 1,000 births. As shown in Figure 6, the age-at-death distribution of SIDS deaths was quite similar across the two birth cohorts. There was an apparent slight increase in the proportion of SIDS cases after 180 days, but this increase was small and was not statistically significant. (χ^2_{50} =61.5, p=0.12)

Discussion

Infant homicides are sometimes misdiagnosed as SIDS deaths. Because such cases are misdiagnosed, resulting records provide no direct evidence to indicate the prevalence or correlates of such misclassification. How prevalent, then, is this pattern?

The present analysis provides strong indirect evidence based on a unique "natural experiment." With the recognition of prone sleep as a key risk-factor, SIDS incidence declined by more than half over the study period. Reduction in smoking by pregnant women has played a smaller, but also notable role. Neither of these changes is plausibly or empirically connected with the rate of infant homicide in the U.S. population.

Because the incidence of "true" SIDS sharply declined between 1989 and 1999, the age-at-death distribution of SIDS deaths would likely have changed if reported SIDS cases included a substantial proportion of causes unaffected by SIDS prevention efforts. In particular, because homicides are more uniformly distributed over the period of infancy, one would expect a more uniform distribution of reported SIDS deaths if these included a substantial fraction of covert homicides.

In fact, however, one observes remarkable stability in the timing of SIDS deaths in the two birth cohorts. Graphical evidence and more formal hypothesis tests imply that the two distributions were virtually identical. Within the entire population of SIDS cases, one cannot reject the hypothesis that the age-at-death distribution of SIDS deaths was unaltered between the two birth cohorts. The stability of this distribution is remarkable when one considers the large decline in SIDS incidence, changes in medical practices and technology, changing risk behavior, and changing socio-demographic characteristics of infants between the two cohorts.

As a robustness check, one obtains the same results within a high-risk subgroup with characteristics associated with known homicide risk. We found no graphical or statistical evidence of a changed age-at-death distribution within this high-risk subgroup.

Study Limitations

The sensitivity of the topics explored and the inherent shortcomings of available data require investigators to be especially conscious of study limitations in drawing epidemiological or policy conclusions.

♦ This analysis lacks statistical power to examine changes in infant mortality that are small when compared with the number of reported SIDS cases, but that may be large when compared with the prevalence of known infant homicides. Although the analysis included in this paper suggests that a small proportion of reported SIDS cases are homicides, it cannot address the converse proportion of homicides that are subsequently misdiagnosed as SIDS. If, for example, half of all reported infant homicides were misdiagnosed as SIDS, this would have amounted to approximately 6 percent of reported SIDS cases in the 1989 birth cohort.

Our Monte Carlo simulations suggest that the methods used in our analysis have the power to detect statistically significant changes in the overall distribution if homicides were at least 15 percent of 1989 reported SIDS cases. We obtain greater statistical power in the first 6 months of infancy, where the age-at-death distribution was especially stable across the two birth cohorts. This statistical analysis is the subject of further research.

Given the power limitations of our analysis, the present results provide an upper bound consistent with work of other researchers indicating that covert homicide accounts for less than 10 percent of reported SIDS cases.[2, 15]

♦ Several natural or accidental causes of death (other than homicide or other causes considered in this paper) can be misdiagnosed as SIDS. If the underlying distribution of these other diagnoses had changed between the 1989 and 1999 birth cohorts--or if the prevalence of such misdiagnosed cases had remained stable while the incidence of true SIDS cases had

declined--our statistical analysis might have indicated statistically significant changes in the age-at-death distribution regardless of the prevalence of covert homicides among reported SIDS cases.

As one referee carefully noted, statistically significant difference between the two cohorts would not, therefore, establish that covert homicides are common among reported SIDS cases. The possibility of diverse misdiagnosis among reported SIDS cases does not undermine the present findings because we found the opposite result. We could not reject the hypothesis that 1989 and 1999 reported SIDS cases were drawn from the same distribution. Out finding are especially striking when one considers the many medical, epidemiological, and social factors that changed between the two birth cohorts and might plausibly have altered the age-at-death distribution.

♦ Data are also drawn from public-use birth certificate files. Many pertinent factors in distinguishing covert homicides, such as those considered by Levene and Bacon (2004), are not available in our national dataset.[15] Birth certificates include parental socio-demographic characteristics and indicate such pertinent factors as maternal smoking in pregnancy. The data do not indicate the presence or absence of parental psychiatric disorders. Birth certificate data include limited data regarding the health of specific infants, and include virtually no information regarding parents' or siblings' medical histories pertinent to both SIDS and homicide risk.

♦ We do not have detailed information derived from autopsies and death scene investigations. The thoroughness of such investigation, or whether they even occurred, is not indicated in vital statistics data. The role of medical examiners, coroners, and others in investigating sudden infant deaths likely varies over time and across jurisdictions.[4]

Death scene investigations may also have changed between the two study years, particularly when published criteria to meet current case definitions were published in 1991.[1] If so, the nature of SIDS diagnosis may have been altered. For example, police and medical authorities may have become more vigilant in scrutinizing potential cases of homicide or accidental death. Authorities may also have become more vigilant in detecting homicides that follow known profiles, such as those involving infants after six months of age.

As discussed below, such changing practices were unlikely to have caused large biases in the current analysis. The reported prevalence of infant homicide remained quite stable over the study period, approximately 300 cases per year in each birth cohort, far below reported SIDS prevalence in the 1989 and 1999 birth cohorts.

Although infants should receive thorough autopsies before a SIDS diagnoses is made, we also have little information regarding these autopsies, or (in 1999 data) whether autopsies were performed. Our 1989 data indicate that autopsies were performed in 92 percent of reported SIDS cases. Unfortunately, for budgetary reasons the NCHS did not collect autopsy data for the 1999 birth cohort. However, 1990-1994 data indicated that more than 90 percent of reported SIDS cases in the U.S. were accompanied by autopsy, with increasing autopsy rates in later years.[25] Autopsy rates are apparently unavailable in subsequent years. It appears unlikely that autopsy rates have declined given intense attention to autopsy in SIDS deaths. Because the overwhelming majority of SIDS infants appear to receive autopsies, inclusion of non-autopsied infants is unlikely to have altered the results.

♦ Our non-experimental, pre-post study is potentially vulnerable to confounding trends. Changing law enforcement and child protective services policy, or changing circumstances of

vulnerable infants may have altered the underlying pattern of infant homicide. Social trends such as the crack epidemic may also have influenced infant homicide rates.

Two features of SIDS epidemiology suggest that confounding trends were unlikely to have biased the current results. Most fundamentally, SIDS incidence declined sharply within a short period during the early and mid-1990s. Data from many sources indicate that changes in infant sleep position were the most important cause of this change. No comparable changes were observed for other causes of death likely to be misclassified as SIDS. As a further robustness check, the analysis was replicated to compare 1989-1996 SIDS incidence (available from the author). Identical results were obtained to the present study. Our logistic regression analysis results were also quite similar to those reported by Pollack and Frohna (2001), who examined earlier birth cohorts.[26]

The Centers for Disease Control and Prevention (2001) reports that infant homicide incidence remained stable between 0.08 and 0.09 per 1000 live births from 1989 to 1998.[16] Incidence of reported suffocation and object inhalation—causes of death that might potentially be misclassified as SIDS or that might contain intentional deaths—were stable throughout the 1980s and 1990s, and remained below 0.09 deaths per 1000 live births throughout the 1990s. Even after the Back-to-Sleep campaign, the combined incidence of reported homicides, object inhalation, and suffocation amount to one-fifth of reported SIDS incidence in both study years. Many of these non-SIDs deaths involved traumatic injury or were otherwise readily distinguished from traditional SIDS deaths. It is therefore implausible that changing diagnostic or police practices could account for the large observed change in reported SIDS cases.

Moreover, the incidence of covert homicide would have had to decline in the same proportion as the decline in true SIDS deaths to observe the current results. Reported SIDS cases

mainly occur between 50 and 120 days of infant life, while homicide and suffocation occur more uniformly over infancy. Given these disparate patterns, declining prevalence of "true" SIDS cases would very likely have made the presence of other, misdiagnosed deaths more pronounced. To be undetected in the current analysis, confounding trends in deaths due to other causes would have had to be concentrated in the same period of peak SIDS risk. Although we observed a slight increase in reported cases of mechanical suffocation or object inhalation during this period of infancy, this change was quite small when compared to changes in reported SIDS incidence.

♦ This analysis relies upon birth and death certificate records that may be incomplete. Because SIDS is a diagnosis of exclusion, quality of vital statistics data is always of concern. Aside from homicide, some natural causes are difficult to distinguish from SIDS even after autopsy. Little direct evidence exists concerning the pattern of such misdiagnoses. However, existing research suggests that diagnostic patterns are stable over time.[27] Evaluation of fetal and infant mortality review (FIMR) may cast light on this problem.[28]

♦ The composition of the newborn population may have changed between 1989 and 1999. Advances in neonatal intensive care and other disciplines may have improved infant survival, and may therefore have influenced both SIDS and homicide risk. We test this hypothesis by running our analysis excluding the important but small group of infants with birthweight below 1,500 grams. Because these infants are the major consumers of NICU services, this group is especially sensitive to technological innovation. We obtained virtually identical results when we remove these infants from our sample.

Every infant death demands careful scrutiny, including skilled death scene investigation, autopsy, and investigation of the medical and family circumstances prior to infant death. Police and medical authorities must be alert to the possibility of homicide, accidental death, or death

due to other natural causes. Specific patterns--including prior reported SIDS deaths or apparent life-threatening events in the same care setting, evidence of neglect or abuse, or an unexplained death late in infancy—should trigger special concern.[2, 5, 6, 11, 13, 15]

The American Academy of Pediatrics has stated, “Parents of SIDS victims typically are anxious to provide unlimited information to professionals involved in death investigation or research. They also want and deserve to be approached in a nonaccusatory manner.”[2] The current results support previous findings that misdiagnosed homicide is uncommon among reported SIDS cases.

References

1. Willinger M, James LS, Catz C. Defining the sudden infant death syndrome (SIDS): Deliberations of an expert panel convened by the National Institute of Child Health and Human Development. *Pediatric Pathology.* 1991;11:677-684.

2. AAP. Distinguishing sudden infant death syndrome from child abuse fatalities. Committee on Child Abuse and Neglect. *Pediatrics.* 2001;107(2):437-441.

3. Kairys S, Alexander R, Block R, et al. American Academy of Pediatrics. Committee on Child Abuse and Neglect and Committee on Community Health Services. nvestigation and review of unexpected infant and child deaths. *Pediatrics.* 1999;104((5 Pt 1)):1158-1160.

4. CDC. Type of certifier and autopsy rates for sudden infant death syndrome--Washington, 1980-1994. *Mortality and Morbidity Weekly Report.* 1996;45(40):863-866.

5. Byard R, Krous H. Suffocation, shaking or sudden infant death syndrome: Can we tell the difference? *Journal of Paediatrics and Child Health.* 1999;35:432-433.

6. Meadow R. Unnatural sudden infant death. *Arch Dis Child.* 1999;80(1):7-14.

7. Southall D, Plunkett M, Banks M, Falkov A, Samuels M. Covert video recordings of life-threatening child abuse: lessons for child protection. *Pediatrics.* 1997;100(5):735-760.

8. Firstman R, Talan J. *The Death of Innocents*. New York: Bantam Books; 1997.

9. Begley S. The nursery's littlest victims. Hundreds of cases of 'crib death,' or SIDS, may in fact be infanticide. *Newsweek.* 1997;130(12):72-73.

10. Nelson L. Quashed convictions reignite row over British cot deaths. *Nature.* 2004;427(6973):384.

11. Perrot L, Nawojczyk S. Nonnatural death masquerading as SIDS (sudden infant death syndrome). *Am J Forensic Med Pathol.* 1988;9(2):105-111.

12. O'Halloran R, Ferratta F, Harris M, Ilbeigi P, Rom C. Child abuse reports in families with sudden infant death syndrome. *Am J Forensic Med Pathol.* 1998;19(1):57-62.

13. Fleming P, Blair P, Sidebotham P, Hayler T. Investigating sudden unexpected deaths in infancy and childhood and caring for bereaved families: an integrated multiagency approach. *British Medical Journal.* 2004;328(7435):331-334.

14. Fleming P, Blair P, Bacon C, Berry P. *Sudden unexpected deaths in infancy: the CESDI SUDI Studies 1993-1996.* London, England: Stationary office; 2000.

15. Levene S, Bacon J. Sudden unexpected death and covert homicide in infancy. *Archives of disease in children.* 2004;89(5):443-447.

16. CDC. CDC Wonder. Available at: http://wonder.cdc.gov. Accessed August 23, 2004.

17. Willinger M, Ko C, Hoffman H, Kessler R, Corwin M. Factors associated with caregivers' choice of infant sleep position, 1994-1998: the National Infant Sleep Position Study. *Journal of the American Medical Association.* 2000;283(16):2135-2142.

18. Willinger M, Hoffman H, Wu K, et al. Factors associated with the transition to nonprone sleep positions of infants in the United States: The national infants sleep position study. *JAMA.* 1998;280:329-335.

19. AAP Task Force on Infant Positioning and SIDS. Positioning and Sudden Infant Death Syndrome (SIDS): Update. *Pediatrics.* 1996;98:1216-1218.

20. Pollack H. Sudden Infant Death Syndrome, Maternal Smoking During Pregnancy, and the Associated Cost-Effectiveness of Smoking Cessation Interventions. *American Journal of Public Health.* 2001;91(3):432-436.

21. Gibson E, Fleming N, Fleming D, et al. Sudden infant death syndrome rates subsequent to the American Academy of Pediatrics supine sleep position. *Medical Care.* 1998;36(6):938-942.

22. Allison P. *Survival Analysis using the SAS System*: SAS Institute; 1995.

23. Stokes M, Davis E, S C, Koch G. Categorical Data Analysis Using the SAS System. *SAS Institute.* 1995.

24. Overpeck M, Brenner R, Trumble A, Trifiletti L, Berendes H. Risk factors for infant homicide in the United States. *New England Journal of Medicine.* 1998;339(17):1211-1216.

25. Scott C, Iyasu S, Rowley D, Atrash H. Postneonatal mortality surveillance--United States, 1980-1994. *Mortality and Morbidity Weekly Report.* 1998;47(2):15-30.

26. Pollack H, Frohna J. A competing risk model of sudden infant death syndrome incidence in two US birth cohorts. *Journal of Pediatrics.* 2001;138(5):661-667.

27. Byard R, Beal S. Has changing diagnostic preference been responsible for the recent fall in incidence of sudden infant death syndrome in South Australia? *Journal of Paediatrics and Child Health.* 1995;31:197-199.

28. Buckley K, Chapin J. Fetal and infant mortality review: an evolving process. *Maternal and Child Health Journal.* 1999;3(3):173-176.

	Full Live Birth Cohort		Sudden Infant Death Syndrome		Homicide		Inhalation & Suffocation	
Birth Cohort	1989	1999	1989	1999	1989	1999	1989	1999
% Mother African-American	15.0	14.7	25.2	29.0	40.4	36.9	31.0	38.3
% Mother Hispanic/Latino	13.3	19.6	8.44	11.4	11.1	15.6	7.8	10.5
% Mother Married at Birth	72.9	66.8	52.6	41.6	33.8	33.1	53.2	35.8
% Mother HS graduate	69.9	76.8	47.5	58.9	46.3	54.4	54.8	56.2
% Mother Col. Graduate	15.8	23.4	6.1	7.5	1.7	3.8	7.2	4.5
Mother age 13-19 at birth	12.9	12.4	24.3	25.4	32.1	28.8	22.7	26.1
Mother age 20-25 at birth	33.0	30.1	41.5	42.9	43.9	48.1	40.6	40.9
Mother age 30-34 at birth	20.8	22.3	11.6	11.7	9.0	4.4	13.6	11.5
Mother age 35-40 at birth	7.7	11.6	3.7	5.6	2.1	3.4	3.7	6.0
Mother age 41+ at birth	0.7	1.3	0.4	0.5	0.7	0.6	0.3	0.4
Mother indicated smoking in pregnancy	2.0	9.4	27.2	30.6	19.9	16.9	23.0	31.9
Mother initiated first-trimester prenatal care	73.9	80.7	57.3	66.3	40.4	57.5	57.8	67.1
Initiated 3rd-trimester/no prenatal care	6.3	3.7	13.6	9.2	21.6	11.3	13.6	8.6
61-category diagnostic code for cause of death	---	---	590	135	650, 660, 670	152-156	620, 630	146, 147, 148
N	3,948,555	3,829,353	5,320 (1.35 per 1000 live births)	2,388 (0.62 per 1000 live births)	287 (0.07 per 1000 live births)	320 (0.08 per 1000 live births)	374 (0.09 per 1000 live births)	486 (0.13 per 1000 live births)

Table 1: Characteristics of Study Infants by Year and Cause of Death
(Source: 1989 and 1999 U.S. Birth Cohorts, Linked Birth Infant Death Files)

	1999 Homicide Risk	1999 SIDS Risk
	Adjusted odds ratio	Adjusted odds ratio
	[95% confidence interval]	[95% confidence interval]
Teen mother	1.52*	1.77***
	[1.03, 2.23]	[1.53, 2.05]
Mother age 20-25	1.63**	1.69***
	[1.17, 2.28]	[1.49, 1.92]
Mother age 26-29	1.00	1.00
	(Referent)	(Referent)
Mother age 30-34	0.35***	0.93
	[0.19, 0.63]	[0.79, 1.09]
Mother age 35-40	0.49*	0.80*
	[0.26, 0.95]	[0.66, 0.98]
Mother age 41+	0.73	0.62
	[0.18, 3.02]	[0.35, 1.10]
Mother married at birth	0.65**	0.78***
	[0.49, 0.85]	[0.71, 0.87]
Mother unmarried at birth	1.00	1.00
	(Referent)	(Referent)
Mother African-American	1.79***	1.49***
	[1.36, 2.35]	[1.35, 1.66]
Mother Hispanic/Latino	0.67*	0.54***
	[0.48, 0.95]	[0.47, 0.63]
Mother other (nonwhite)	1.16	0.92
	[0.71, 1.91]	[0.76, 1.11]
Mother non-Hispanic white	1.00	1.00
	(Referent)	(Referent)
First-Trimester initiation of prenatal care	0.56***	0.74***
	[[0.44, 0.72]	[0.67, 0.82]
Second-trimester initiation of prenatal care	1.00	1.00
	(Referent)	(Referent)
Third-trimester initiation/no prenatal care	1.31	1.34***
	[0.89, 1.91]	[1.15, 1.57]
Mother smoked during pregnancy	1.25	2.84***
	[0.92, 1.71]	[2.58, 3.12]
Birthweight below 2,501 grams	2.02***	2.17***
	[1.43, 2.83]	[1.92, 2.44]
Birthweight below 1,501 grams	2.64***	1.31*
	[1.51, 4.61]	[1.03, 1.66]
Birthweight no less than 2,501 grams	1.00	1.00
	(Referent)	(Referent)
Mother high school graduate	0.67**	0.72***
	[0.53, 0.86]	[0.65, 0.79]
Mother college graduate	0.39**	0.61***
	[0.21, 0.72]	[0.52, 0.73]
Mother non-high-school graduate	1.00	1.00
	(Referent)	(Referent)

Table 3: Multivariate analysis of Infant Homicide and SIDS risk
(Data from 1999 U.S. birth cohort, *p<0.05, **p<0.01, ***p<0.001)

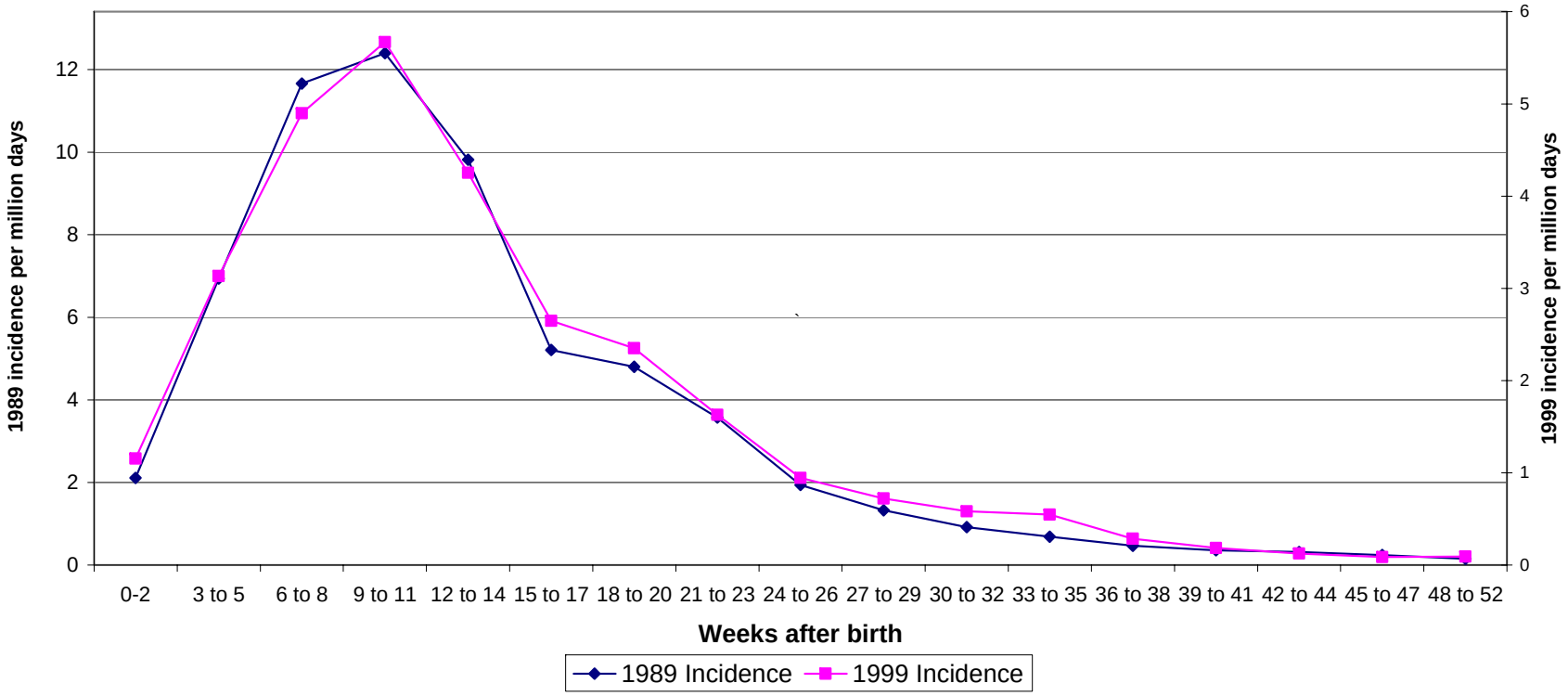

Figure 1: Reported Timing of SIDS Deaths, 1989 and 1999 Singleton U.S. Birth Cohorts

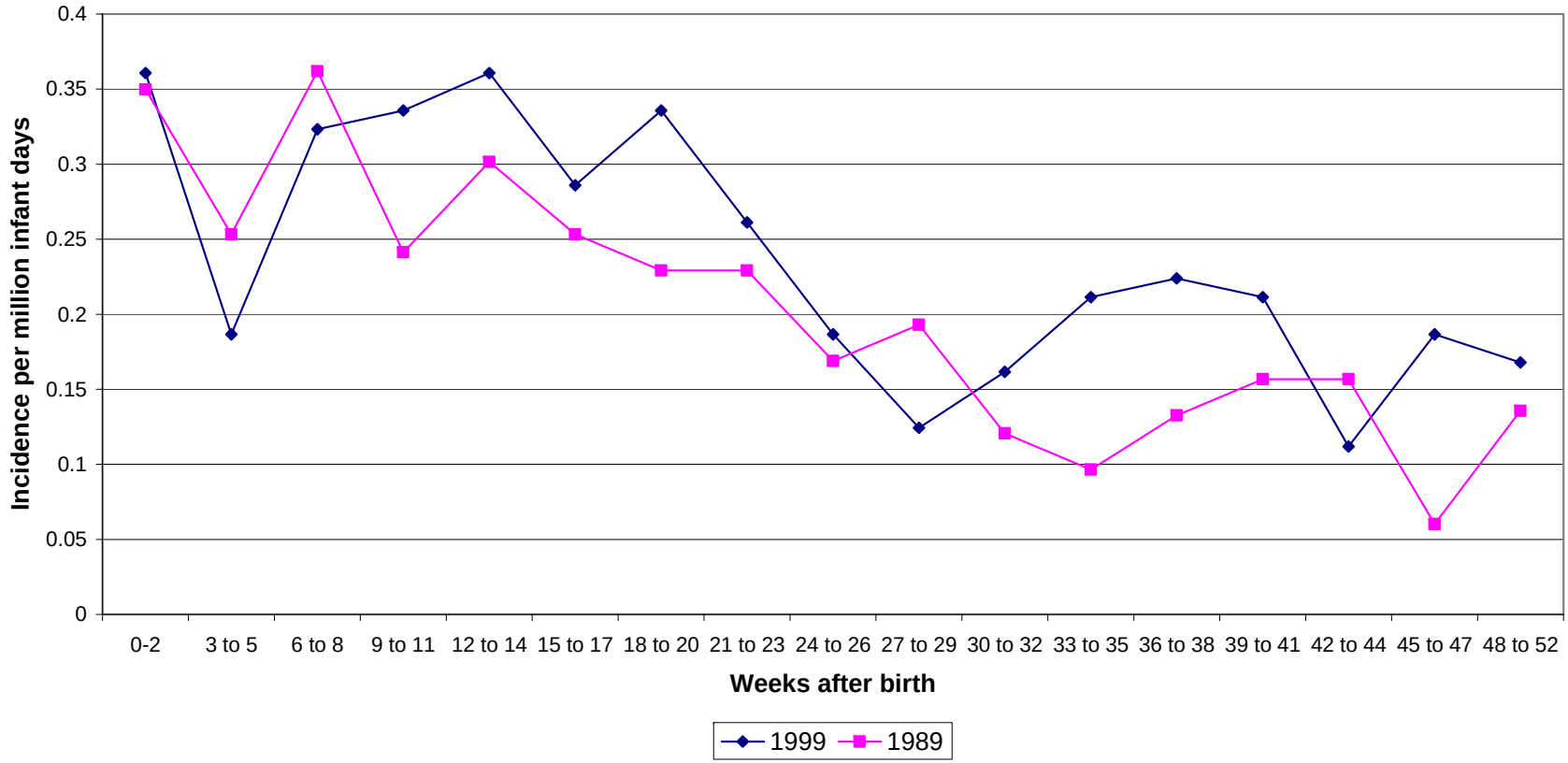

Figure 2: Reported Timing of Infant Homicides, 1989 and 1999 Singleton U.S. Birth Cohorts

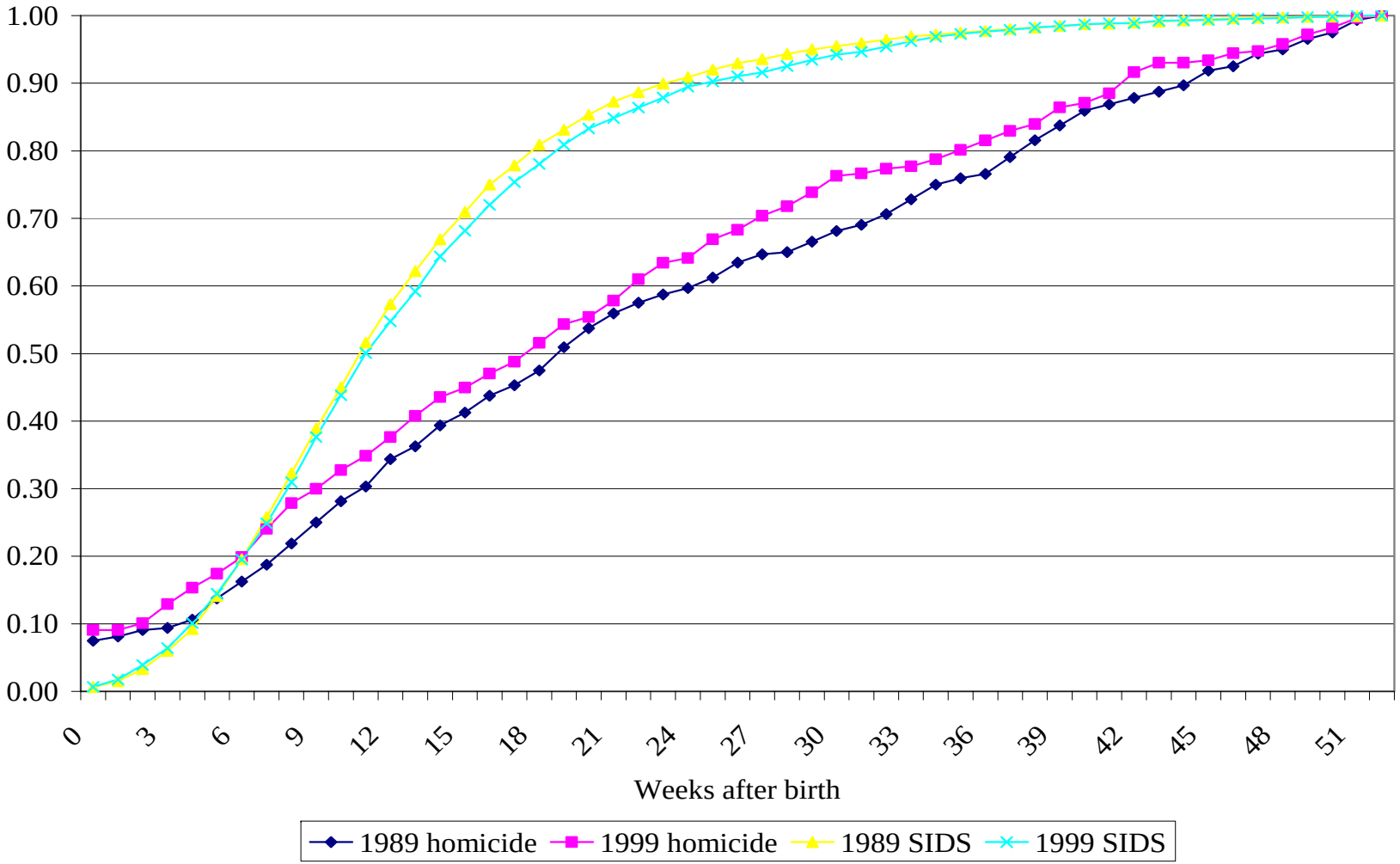

Figure 3: Cumulative Distribution Functions for Homicide and SIDS deaths, 1989 and 1999 Singleton U.S. Birth Cohorts

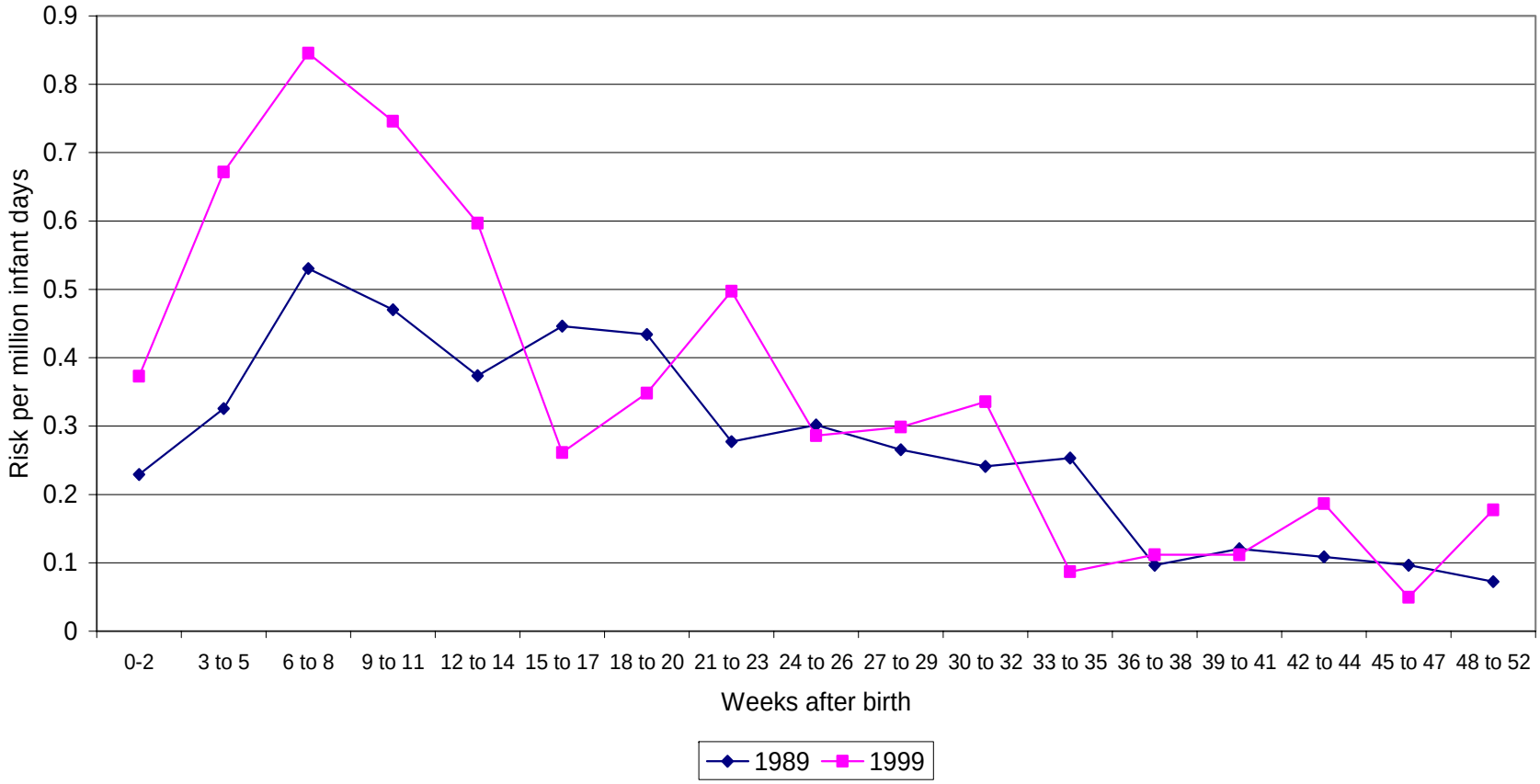

Figure 4: Reported Timing of Suffocation and Inhalation Deaths, 1989 and 1999 U.S. Singleton Birth Cohorts

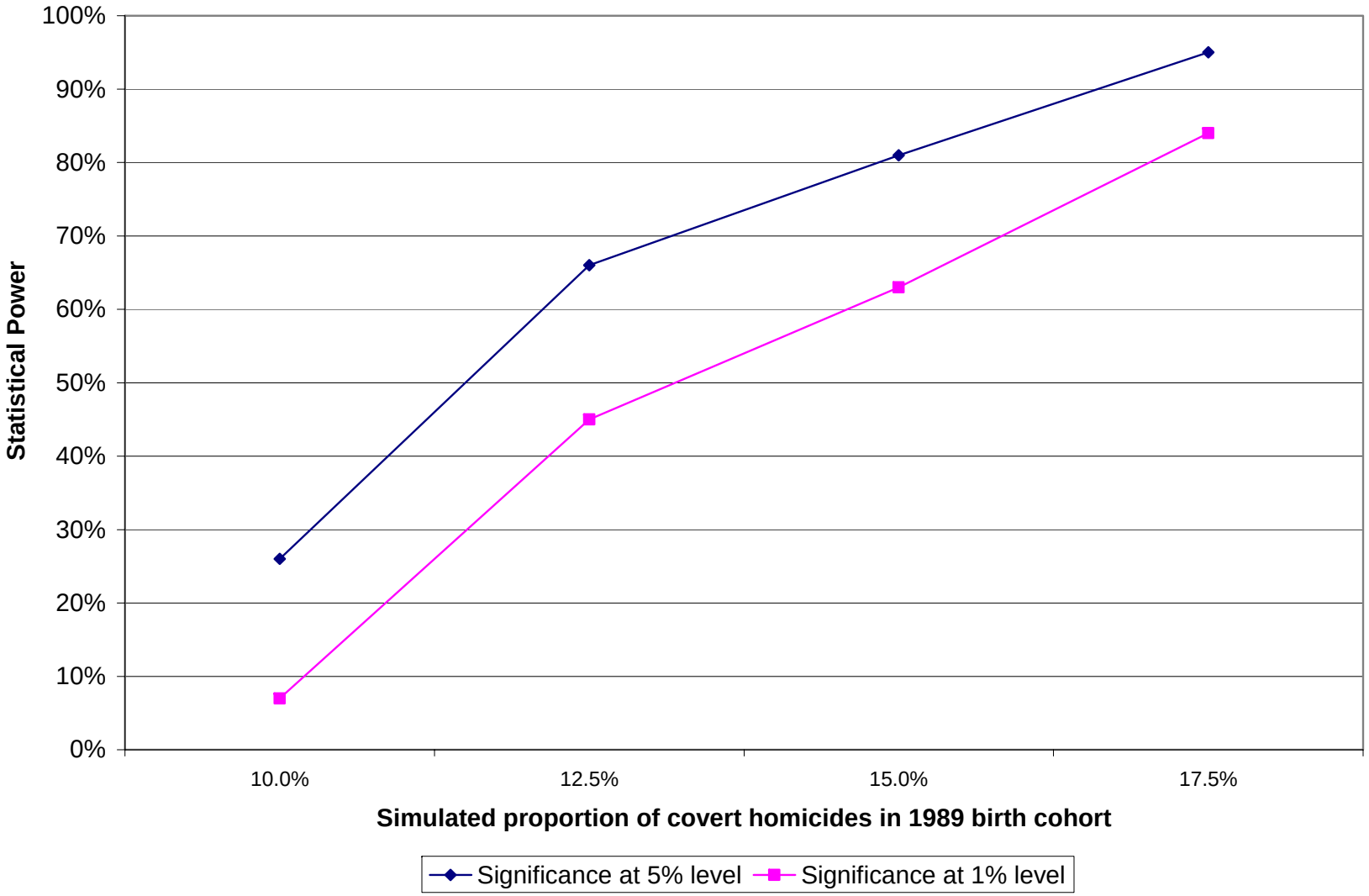

Figure 6: Monte Carlo power analysis of χ^2 test in detecting covert homicides

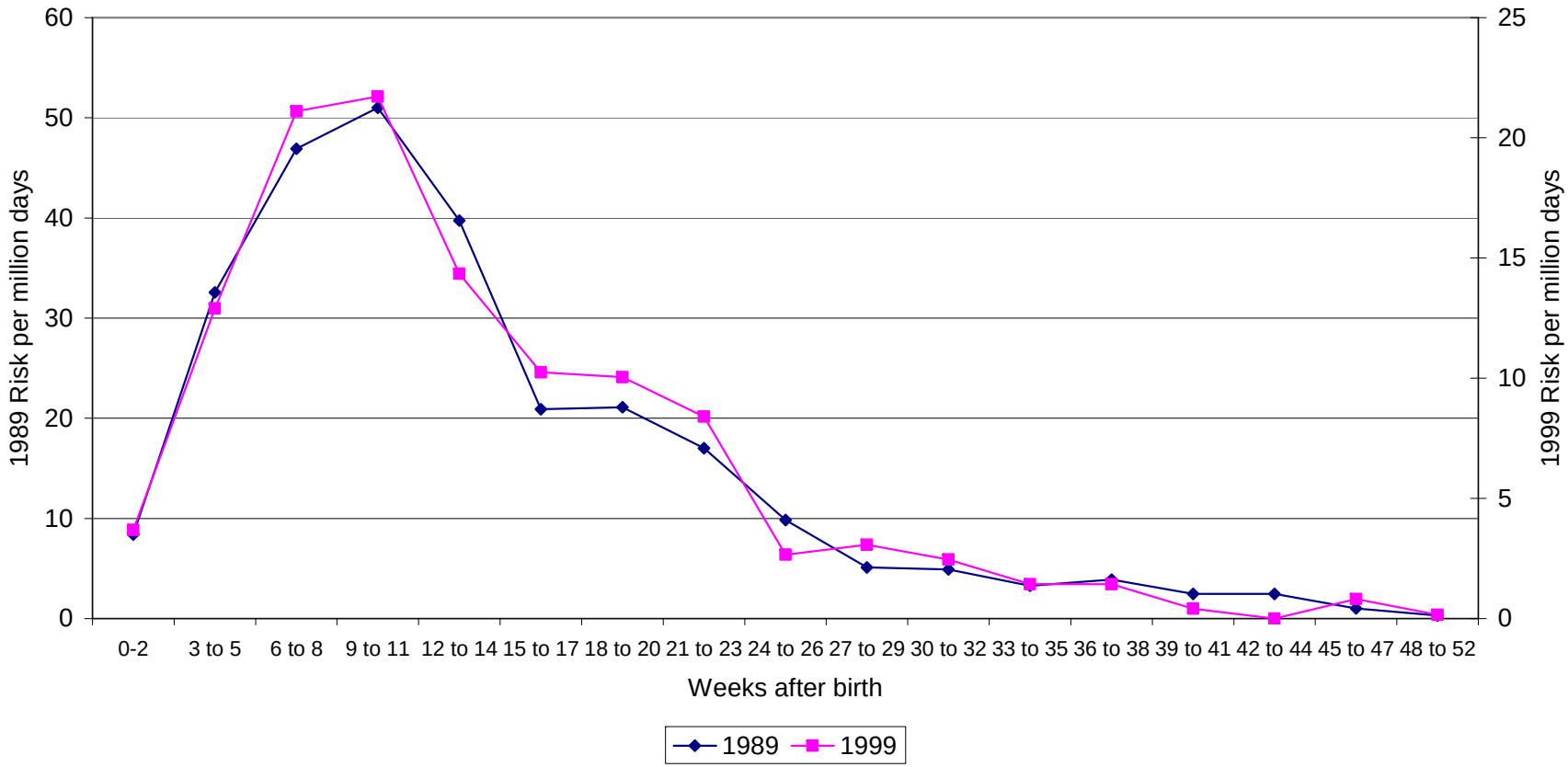

Figure 6: Reported Timing of SIDS Deaths in high homicide risk subgroup: 1989 and 1999 U.S. Singleton Birth Cohorts