Firearm Availability and Unintentional Firearm Deaths, Suicide, and Homicide among 5–14 Year Olds

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Background: In the United States, only motor vehicle crashes and cancer claim more lives among children than do firearms. This national study attempts to determine whether firearm prevalence is related to rates of unintentional firearm deaths, suicides, and homicides among children.

Methods: Pooled cross-sectional time-series data (1988–1997) were used to estimate the association between the rate of violent death among 5–14 year olds and four proxies of firearm availability, across states and regions.

Results: A statistically significant association exists between gun availability and the rates of unintentional firearm deaths, homicides, and suicides. The elevated rates of suicide and homicide among children living in states with more guns is not entirely explained by a state's poverty, education, or urbanization and is driven by lethal firearm violence, not by lethal nonfirearm violence.

Conclusion: A disproportionately high number of 5–14 year olds died from suicide, homicide, and unintentional firearm deaths in states and regions where guns were more prevalent.

Key Words: Firearms, Guns, Children, Homicide, Suicide, Unintentional death, Accidents, Violence.

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In the United States, only motor vehicle crashes and cancer claim more lives among children 5–14 years old than do firearms.[1] Between 1988 and 1997, the last 10 years for which complete U.S. data are available, 6,817 children 5–14 years of age died from firearms.[1]

In contrast, children in other industrialized nations are not dying from guns. Compared with children 5–14 years old in other industrialized nations, the firearm-related homicide rate in the United States is 17 times higher, the firearm-related suicide rate 10 times higher, and the unintentional firearm-related death rate 9 times higher.[2] Overall, before a child in the United States reaches 15 years of age, he or she is 5 times more likely than a child in the rest of the industrialized world to be murdered, 2 times as likely to commit suicide and 12 times more likely to die a firearm-related death.[2,3]

Within the United States, case-control studies have found that the purchase of a handgun[4] and the presence of a handgun in the home are strongly associated with an increased risk of homicide and suicide among adults[5–7] and an increased risk of suicide among adolescents.[5–12] Cohort, cross-sectional, and interrupted time series studies suggest a strong link between the availability of guns and rates of homicide and suicide among adults[13–20] and with the rate of unintentional firearm death among all age groups.[21]

Case-control and cohort studies of lethal firearm violence have several advantages over cross-sectional studies, but they have been geographically limited and have not focused on children. Nationally representative cross-sectional studies, on the other hand, have been hampered by the lack of direct measures of gun availability at levels smaller than the nine census regions. Our study extends previous findings by focusing on children and by using three different state-level proxies for gun availability (one survey-based measure available for a nonrandom 21/50 states; two nonsurvey measures derived for all 50 states) and an additional survey-based regional-level measure of gun availability to explore the relationship between firearm availability and violent death among 5–14 year olds. State-level analyses adjust for state urbanization, poverty, and education levels.

MATERIALS AND METHODS

We used pooled cross-sectional time-series data from the 50 states over a 10-year period (1988–1997) to examine the association between four different measures of the availability of firearms and the corresponding rates of suicide, homicide, and unintentional firearm deaths among children 5–14 years old.

State- and year-specific population figures and data for the number of suicides (*International Classification of Diseases, Ninth Revision* [ICD-9] codes E950.0–E959), homicides (E960.0–E969), suicides by firearm (E955.0–E955.4), homicides by firearm (E965.0–E965.4), and unintentional deaths caused by firearm (E922.0–E922.9) come from the National Center for Health Statistics (NCHS) mortality files. Deaths from firearms of undetermined intention (ICD-9 E985) constitute less than 3% (186/6,187) of all firearm

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deaths among 5–14 year olds and are excluded from analyses. Region-specific population and mortality figures were derived by aggregating the corresponding state-based figures.

Two of our measures of firearm availability come from published survey-based estimates of household firearm ownership, one at the regional level and the other at the state level. Our regional survey-based measure of firearm availability, collected at the level of the nine census regions, comes from the average of reported household gun ownership rates between 1988 and 1997, as reported in the General Social Surveys (GSS).[22] At the state level, published data on reported household gun ownership rates are available for 21 states from the Behavioral Risk Factor Surveillance System (BRFSS) from the 1990s.[23] The 21 states for which the BRFSS obtained data on household gun ownership are a nonrandom sample of those states that self-selected to ask questions about household firearms. However, these states did not appear to select on the basis of the rates of violent death among children or the purported relationship between gun levels and violent death rates. The implications of this nonrandom selection cannot be evaluated directly. Nevertheless, since results from the BRFSS states are substantively similar to those obtained from the nationally representative gold-standard survey based estimates of household firearm ownership (GSS), the BRFSS estimates can be viewed as corroborating rather than primary evidence of the validity of the association observed with GSS estimates. Furthermore, as both the BRFSS the GSS measures are very highly correlated with each other and with our independently derived proxies, these measures as a group supply consistent findings about the association between firearm availability and violent death among children.

Direct measures of household firearm ownership are not available at the state level for all 50 states. When all 50 states are analyzed (at the state level), proxies for firearm availability are two derived measures: (1) Cook's Index, developed and previously validated at the city level;[16] and (2) the fraction of all suicides that involve a gun. Both of these measures have been used in cross-sectional studies within the United States,[24–27] and Cook's Index has also been independently correlated with household gun ownership levels across 14 industrialized nations.[28]

Cook's Index for a given state in a given year is calculated by averaging (over all age groups) the percentage of all suicides committed with a firearm and the percentage of all homicides committed with a firearm. That is, Cooks Index = (fraction of suicides with guns + fraction of homicides with guns)/2. In our investigation of childhood mortality rates, to avoid having violent deaths among children appear in both the dependent and the key independent variables, we used a modified Cook's Index that excluded suicides and homicides among children 0–19 years of age from the calculation. Since 5–14 year old children account for less than 2% of all suicides and homicides, it is not surprising that analyses using the modified index were qualitatively and quantitatively similar to those using a Cook's Index derived from all age groups. All results presented are based on the modified index.

The second mortality-derived estimate of firearm availability is closely related to Cook's Index: the fraction of suicides that are gun related. This proxy is referred to as FS/S in the text to indicate that it is the number of firearm suicides in a given state-year (among adults) divided by the total number of suicides in that state-year (among adults). The proxy FS/S is based on the assumption that firearms are likely to be more readily available in states where guns make up a larger fraction of all suicides than in states where guns make up a smaller fraction of all suicides—independent of the number or rate of suicides in a state. A state's FS/S and Cook's Index reflect the distribution of firearm vs. nonfirearm means of suicide (in the case of FS/S) and the distribution of firearm vs. nonfirearm means of suicide and homicide (in the case of Cook's Index). Neither FS/S nor Cook's Index inherently reflects the rate of suicides or homicides in a state and so do not bias our testing of the null hypothesis, i.e., that there is no relationship between gun availability and overall suicide rates. FS/S merely reflects the distribution of these means.

That FS/S does not by construction (i.e., in itself) bias the overall associations is corroborated by the results of a Monte Carlo-type simulation of 10,000 recursive loops in which positive random numbers are generated for the number of suicides, firearm suicides, and total population in the 50 states. These random numbers are generated so that $FS < S$. As expected, the correlation between overall suicide rates and FS/S is zero.

Qualitatively and statistically similar results were obtained whether Cook's Index (and FS/S) assumed the average Cook's Index (average FS/S) for each state over the 10-year study period, a 5-year rolling average, or a specific value for each state-year. We present results using 10-year averaged values for all our proxies because the gun stock in the United States is so high (over 200 million guns) that changes in a state's stock are likely to be quite small from year to year, and because using a 5-year rolling average would require us to drop data from 1996 and 1997. The 10-year averaged measures yielded regressions that were qualitatively similar to regressions using 5-year rolling averages and also to regressions in which we used the specific Cook's Index (FS/S) for each state-year.

To make the comparisons among our four proxies more intuitive, all were standardized so that each proxy has a mean of zero and a SD of 1. The raw average values (1988–1997) for Cook's Index, FS/S, and the BRFSS survey-based gun ownership levels are presented out to 2 decimal points in Table 1, ranked according to Cook's Index. The dependent variable used in our analyses is the number of deaths per population per state-year among 5–14 year olds. Distributions of death rates were skewed and variances were greater than the means. Consequently, negative binomial models were used (rather than Poisson).

Table 1 **State-Level Proxies of Firearm Availability, Average (Nonstandardized) Values 1988–1997, Ranked by Cook's Index**

Mean (SD)	Cook's Index 0.61 (0.09)	BRFSS 0.39 (0.14)	FS/S 0.61 (0.12)	Firearm Death Rate 1.99 (0.85)[a]
Hawaii	0.37		0.29	0.51
Massachusetts	0.40		0.31	0.54
New Jersey	0.43	0.12	0.35	0.51
Rhode Island	0.45	0.14	0.36	0.54
Delaware	0.48	0.28	0.48	1.62
South Dakota	0.48		0.63	1.92
Minnesota	0.52		0.51	1.36
New York	0.53	0.14	0.37	0.94
Iowa	0.54		0.55	1.05
New Hampshire	0.54		0.57	0.57
Connecticut	0.56	0.18	0.44	1.09
Illinois	0.56		0.47	2.19
North Dakota	0.56		0.59	2.54
Colorado	0.57	0.38	0.57	1.92
Maine	0.57		0.61	1.56
Washington	0.58		0.57	1.49
Wisconsin	0.58	0.49	0.54	1.48
Utah	0.58		0.59	2.02
New Mexico	0.59	0.43	0.63	2.43
Pennsylvania	0.60	0.41	0.55	1.10
Oregon	0.60	0.49	0.61	2.05
Nebraska	0.61		0.58	1.98
California	0.61	0.30	0.53	2.00
Ohio	0.62		0.60	1.38
Alaska	0.63		0.70	3.97
Michigan	0.63	0.46	0.57	1.87
Montana	0.63		0.67	3.81
Maryland	0.63		0.56	1.33
Florida	0.64		0.60	1.98
Nevada	0.65		0.67	2.51
Kansas	0.65	0.41	0.64	2.10
Vermont	0.65		0.67	1.35
Oklahoma	0.65	0.54	0.69	2.65
Indiana	0.66	0.40	0.63	1.65
Arizona	0.67	0.33	0.67	2.57
Idaho	0.67	0.57	0.71	3.52
Missouri	0.68		0.65	2.20
South Carolina	0.69		0.72	2.58
Texas	0.69		0.68	2.37
Virginia	0.69		0.68	1.71
Wyoming	0.70		0.74	3.05
North Carolina	0.70		0.72	2.13
Georgia	0.72		0.74	2.10
Tennessee	0.72		0.74	2.58
Kentucky	0.72	0.49	0.74	1.90
West Virginia	0.73	0.51	0.75	1.88
Arkansas	0.73		0.75	3.15
Mississippi	0.74	0.55	0.80	3.33
Alabama	0.75		0.78	3.01
Louisiana	0.75	0.53	0.76	3.33

[a] The overall firearm death rate among 5–14 year olds.

A state's homicide, suicide, and unintentional firearm death rates in a given year are not independent from rates in that state in other years. To account for this nonindependence, standard errors in regressions were corrected by clustering observations (by state in the regressions presented in Table 2; by region in Table 3).

Primary analyses use incidence rate ratios (IRR), obtained by exponentiating beta coefficients in the negative binomial regressions, to express the magnitude of the association between a state's suicide, homicide, and unintentional firearm death rate and that state's standardized proxy for gun availability. Since the SD of each of the standardized proxies

Table 2 Crude and Multivariate Adjusted Incidence Rate Ratios (IRRs) of State-Level Homicide, Suicide, and Unintentional Gun Deaths among 5–14 Year Olds in the United States, by State-Level Proxies of Firearm Availability (1988–1997)

	No. of States	Firearm	Nonfirearm	Total
Homicide rate				
Bivariate				
Cook's Index	50	1.29 (1.16, 1.43)***	1.04 (0.96, 1.14)	1.19 (1.10, 1.29)***
FS/S	50	1.18 (1.04, 1.34)**	1.00 (0.93, 1.09)	1.11 (1.01, 1.22)*
Household gun	21	1.11 (0.93, 1.32)	0.99 (0.90, 1.09)	1.06 (0.94, 1.19)
Multivariate				
Cook's Index	50	1.31 (1.17, 1.47)***	1.03 (0.93, 1.15)	1.19 (1.09, 1.30)***
FS/S	50	1.23 (1.06, 1.41)**	1.02 (0.91, 1.13)	1.14 (1.03, 1.28)*
Household gun	21	1.23 (1.06, 1.42)**	1.00 (0.89, 1.13)	1.13 (1.01, 1.26)*
Suicide rate				
Bivariate				
Cook's Index	50	1.38 (1.14, 1.66)***	0.93 (0.85, 1.02)	1.13 (1.00, 1.27)*
FS/S	50	1.53 (1.32, 1.77)***	0.99 (0.90, 1.09)	1.23 (1.11, 1.36)***
Household gun	21	1.86 (1.53, 2.25)***	1.09 (0.94, 1.26)	1.40 (1.22, 1.61)***
Multivariate				
Cook's Index	50	1.48 (1.23, 1.79)***	1.03 (0.92, 1.14)	1.21 (1.08, 1.35)**
FS/S	50	1.64 (1.40, 1.92)***	1.08 (0.97, 1.21)	1.31 (1.18, 1.45)***
Household gun	21	1.67 (1.29, 2.17)***	1.03 (0.88, 1.20)	1.27 (1.06, 1.53)*
Unintentional firearm death rate				
Bivariate				
Cook's Index	50	1.89 (1.60, 2.22)***		
FS/S	50	1.99 (1.78, 2.22)***		
Household gun	21	2.11 (1.82, 2.44)***		
Multivariate				
Cook's Index	50	1.54 (1.27, 1.85)***		
FS/S	50	1.64 (1.39, 1.92)***		
Household gun	21	1.64 (1.27, 2.13)***		

In the multivariate analyses, incidence rate ratios are adjusted for the percentage of a state's population living in poverty, the percentage of the adult population with at least a high school education, and the percentage of the state's population living in urban areas.

IRRs represent the percentage change in the dependent variable (e.g., the suicide rate) for a unit change in the independent variable (i.e., for a change of 1 SD of the proxy under consideration).

Gun availability is measured using three different state-level proxies: (1) Cook's Index, calculated using mortality statistics among the adult U.S. population, and defined as the average of two proportions: (1/2) * [(firearm suicides/all suicides) + (firearm homicides/all homicides)]; (2) FS/S, the percentage of suicides among adults that are firearm suicides; and (3) the percentage of household that reported owning a firearm in the BRFSS survey of a nonrandom 21 states (Household gun). These 21 states are CT, DE, NJ, NY, PA, RI, IN, KS, MI, WI, KY, LO, OK, WV, AZ, CA, CO, ID, NM, OR, WA. These three proxies are standardized so that their mean equals zero and their SD equals 1.

IRRs correspond to the standardized proxies, which range from 4.3 SD for Cook's Index to 4.0 SD for FS/S to 3.2 SD for Household gun levels.

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

is, by construction, equal to 1, the reported IRRs represent the percentage change in the dependent variable (e.g., the suicide rate) for a unit change in the independent variable (i.e., for a change of 1 SD of the proxy under consideration). Because the proxies differ somewhat from each other in their ranges (and a given proxy will have a different range when considered at the state vs. the regional level), comparisons of IRRs must take into account the range of the particular proxy under the conditions specified. The relevant ranges are specified in the legends for each table.

In the state-based analyses, multivariable analyses adjust for other independent variables that have been found to be associated with violent death, including the percentage of the population living in poverty,[29] the percentage of the adult population with at least a high school education,[30] and the percentage of the state's population living in urban areas.[31,32] When data for these control variables were not available for all years, values for missing observations were interpolated from surrounding years. Whether interpolations were linear interpolations from the surrounding years or averages of the 4 years closest to the missing year did not materially affect results. Linear interpolations were used in the data presented. Data for control variables come from the Statistical Abstracts of the United States (education, poverty, and urbanicity). In the region-based analyses we do not control for other variables because of the small number of observations.

Mortality data were electronically available in 5-year age groupings. The age-groupings we could choose from in evaluating the effect of firearm availability on violent death among children were children aged 0–4, 5–9, 10–14, and

Table 3 **Crude Incidence Rate Ratios (IRRs) of Regional-Level Homicide, Suicide, and Unintentional Gun Deaths among 5–14 Year Olds in the United States, by Region-Level Proxies of Firearm Availability (1988–1997)**

	Firearm	Nonfirearm	Total
Homicide rate			
Cook	1.26 (1.08, 1.45)**	1.06 (0.99, 1.14)~	1.18 (1.06, 1.31)**
FS/S	1.20 (1.02, 1.41)*	1.04 (0.97, 1.11)	1.14 (1.02, 1.28)**
GSS	1.18 (0.97, 1.42)~	1.03 (0.96, 1.10)	1.11 (0.97, 1.26)
Suicide rate			
Cook	1.39 (1.12, 1.73)**	0.95 (0.83, 1.09)	1.15 (0.99, 1.34)~
FS/S	1.49 (1.20, 1.84)***	1.00 (0.85, 1.18)	1.23 (1.04, 1.46)*
GSS	1.46 (1.14, 1.86)**	0.99 (0.83, 1.18)	1.21 (1.01, 1.46)*
Unintentional firearm death rate			
Cook	1.90 (1.57, 2.30)***		
FS/S	1.88 (1.61, 2.19)***		
GSS	1.85 (1.50, 2.30)***		

Gun availability is measured using four different regional-level proxies, three derived by aggregating state-level proxies into appropriate regions and one regionally gathered survey estimate of household gun ownership rates. The three aggregated state-level proxies are (1) Cook's Index, calculated using mortality statistics among the adult US population, and defined as the average of two proportions: (1/2) * [(firearm suicides/all suicides) + (firearm homicides/all homicides)]; (2) FS/S, the percentage of suicides among adults that are firearm suicides; and (3) the percentage of household that reported owning a firearm in the BRFSS survey of a nonrandom 21 states (household gun). These 21 states are: CT, DE, NJ, NY, PA, RI, IN, KS, MI, WI, KY, LO, OK, WV, AZ, CA, CO, ID, NM, or WA. All proxies in this table are standardized at the regional level so that their mean equals zero and their SD equals 1.

IRRs correspond to the standardized proxies. When all three state-level proxies are collapsed into the nine official census regions the range for all standardized proxies is approximately equal: 3.5, 3.1, 3.4, 3.4 for Cook's Index, FS/S, the GSS regional-survey based estimates of all guns and handguns, respectively.

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ~ $p < 0.1$.

15–19. There are several reasons we did not include children under age 5 in our evaluation. Evaluating the relationship between firearm availability on suicide in 0–4 year olds is impossible, since death among children in this age group is never attributed to suicide. Similarly, homicide in this age group is largely attributable to shaken baby syndrome or similar trauma, a far less common means among older children. Nevertheless, when we evaluated the relationship between firearm availability and violent death among 0–14 year olds we obtained results very similar to those among 5–14 year olds. We did not include 15–19 year olds in our evaluation because the social and cultural forces that influence violence among this age group are so different from those that affect younger children.

RESULTS

Over the 10-year study period (1988–1997), 6,817 children 5–14 years of age were killed with firearms in the United States (3,447 firearm homicides, 1,588 firearm suicides, and 1,782 unintentional firearm deaths). An additional 1,889 children died from nonfirearm homicide; 1,328 from nonfirearm suicides.

Regardless of the proxy chosen, in the multivariate analyses at the state level, we found a positive and statistically significant association between gun availability and state-level rates of unintentional firearm deaths, homicides, firearm homicides, suicides, and firearm suicides among children (Table 2). The increased rate of homicide and suicide in states with high gun levels was accounted for by significantly elevated firearm (but not nonfirearm) suicide and homicide rates (Table 2). Results from the 21-state BRFSS sample are significant even though they do not include three out of five of the states with the highest gun levels and three out of five states with the lowest gun levels (as ranked by Cook's Index).

At the regional level we still generally observe, regardless of the proxy chosen, a positive and statistically significant association between gun availability and the level of unintentional firearm deaths and suicides among children (Table 3). The only exception is for the homicide rate. Results with the GSS proxy are similar to those obtained with the other proxies, but the firearm availability–homicide relationship is not statistically significant (Table 3).

Table 4 compares the actual number of children 5–14 years old who died from unintentional firearm deaths, suicides, and homicides (1988–1997) in the five states with the highest Cook's Index values to the corresponding rates in the five states with the lowest Cook's Index values. These states are chosen on the basis of their extreme firearm ownership levels, not on the basis of their extreme violent death rates among children. Although the number of children in the two groups was similar, compared with children living in the low-gun states (Hawaii, Massachusetts, Rhode Island, New Jersey, and Delaware), children living in the high-gun states (Louisiana, Alabama, Mississippi, Arkansas, and West Virginia) were 16 times as likely to die from unintentional firearm injury, 7 times as likely to die from firearm suicide, 3 times as likely to die from firearm homicide and, overall, twice as likely to die from suicide and homicide.

Table 4 **Homicide, Suicide, and Unintentional Gun Deaths among 5–14 Year Olds: The Five U.S. States with the Highest vs. the Lowest Average Cook's Index of Gun Availability (1988–1997)[a]**

	High-Gun States	Low-Gun States	Mortality Rate Ratio (High-Gun:Low-Gun)
Total population of 5–14 Year olds (1988–1997)	23 Million	22 Million	
Suicides			
Gun suicides	153	22	6.7
Nongun suicides	69	82	0.8
Total	222	104	2.0
Homicides			
Gun homicides	298	86	3.3
Nongun homicides	143	110	1.3
Total	441	196	2.2
Unintentional firearm deaths	253	15	16.3

[a] The five states with the highest average gun levels (1988–1997) were Louisiana, Alabama, Mississippi, Arkansas, and West Virginia. The five states with the lowest average gun levels were Hawaii, Massachusetts, Rhode Island, New Jersey, and Delaware.

Our firearm proxies give similar results, since they are highly correlated (Table 1). Not only are Cook's Index and (its component) FS/S highly correlated, but these proxies are also highly correlated with survey-based measures. At the state level, the correlation coefficient for the BRFSS survey-based estimates of household firearm ownership (among the 21 states for which data are available) is 0.81 with Cook's Index and 0.89 with FS/S. Considering the subgroup of 21 states for which BRFSS provides household firearm ownership levels, the five states with the highest household ownership levels according to the BRFSS are the same five states with the highest FS/S and constitute four out of five of the states with the highest Cook's Index. Similarly, the five states with the lowest household gun levels according to the BRFSS correspond to the same five states with the lowest levels according to both FS/S and Cook's Index. At the regional level, our modified Cook's Index and FS/S are also highly correlated with household firearm ownership levels reported in the GSS (correlation coefficient = 0.91 and 0.96, respectively).

DISCUSSION

The present study examines the relationship between firearm availability and violent death among children within the United States. We found that each of our four proxies leads to the same conclusion: children 5–14 years old were more likely to die from unintentional firearm injuries, suicides and homicides if they lived in states (or regions) with more rather than fewer guns. In contrast, nonfirearm homicides and nonfirearm suicides were not significantly associated with the availability of guns. The relationship between guns and violent death among children remains statistically significant even after controlling for state-level poverty, education, and urbanization.

If, as has been suggested for adolescents and adults,[33–35] suicides among children are commonly impulsive acts, the easier it is to find lethal means, such as firearms, the more suicides there might be. On the other hand, if the choice of firearm has less to do with the availability of the weapon than with the strength of the intent, persons determined to kill others or themselves will work harder to get a gun where guns are less available, or will substitute other lethal means. Consistent with some,[13,15,17–20] but not all,[36] previous studies among U.S. adults, we found that not only firearm-related but also overall suicide rates were significantly associated with state gun levels, suggesting that among 5–14 year olds substitution of equally lethal means for guns is incomplete.

Despite the strong and robust association between lethal firearm violence and state gun levels, we failed to find a statistically significant relationship between state gun levels and either nonfirearm homicide or nonfirearm suicide among 5–14 year olds (Table 2). To the extent that rates of nonfirearm lethal violence reflect violent tendencies, our study indicates that 5–14 year old children living in high-gun states are not significantly more lethally violent toward themselves than are children in low-gun states, nor are they significantly more likely to be victims of lethal nongun attacks. Rather, the disproportionately high level of overall lethal violence where guns are more available suggests that where there are more guns, violence is more likely to turn lethal.

Our proxies for firearm availability are even more strongly associated with the rate of unintentional firearm death than with the rate of intentional firearm deaths (Tables 2–4). Over the 10-year study interval, 6,817 children between 5 and 14 years of age died from firearms, 1,782 from unintentional firearm injury alone. We could find no data to suggest that where there are more guns parents care less about their children's welfare. Yet, unintentional firearm deaths are an order of magnitude greater in high-gun compared with low-gun states (Table 4).

Our study includes both survey-based reports of household firearm ownership rates and estimates of firearm availability that rely on mortality data. We used Cook's Index and FS/S because these proxies allow us to analyze data from all 50 states. In addition, using measures that rely on different estimating mechanisms may capture different (perhaps complementary) aspects of the relevant variable. The extent to which Cook's Index or FS/S captures some aspects of firearm availability better (or less well) than do survey-based estimates of household gun ownership rates is unknown. In any event, household gun ownership levels (BRFSS and GSS measures) and our mortality-derived estimates (Cook's Index and FS/S) are highly correlated, suggesting that they are providing information about the same construct, at least in this age group. We obtained substantively and statistically similar results with all four proxies.

Our findings are robust (Tables 2–4). The proxy chosen does not drive the regression results. Regressions are also not driven by either the largest states or the states most extreme in gun levels. Statistically significant and qualitatively consistent results were produced regardless of whether the data analyzed were all 50 states, the 40 largest, or the 40 smallest states; excluding the 5 states with the highest (or lowest) Cook's Index (or FS/S) did not materially or statistically alter our findings. Even when we used the survey-based estimates of household firearm ownership rates among only 21 states (or among only nine regions), we obtained similar results. Including the 186 (2.6%) firearm deaths coded as firearm deaths of undetermined origin (ICD-9 E985) did not alter our findings, regardless of whether these deaths were included as firearm suicides, firearm homicides, or unintentional firearm deaths. Although we do not know exactly how measures of household firearm ownership relate to the availability of firearms to children, it is remarkable that despite the crudeness of our measures, survey based and proxy alike, we consistently see a relationship between these measures and the rate of violent death among children.

The use of FS/S as a proxy of firearm assumes nothing about the relative rate of overall suicides in a state. If in state A for every 100 suicides 90 are firearm suicides and in state B for every 100 suicides 10 are firearm suicides, use of the proxy FS/S assumes only that guns are more readily available in state A than in state B. The null hypothesis (which we set out to test) states that gun availability does not influence the overall suicide rate, i.e., that if people really want to commit suicide they will find the means. FS/S merely reflects the distribution of these means. Therefore, FS/S does not, per se, bias our testing—and ultimate rejection—of the null hypothesis. Even at the level of the nine census regions, the null hypothesis can be rejected: overall suicide rates are higher where there are more guns, whatever measure of firearm availability is chosen. These findings are consistent with those of others who have described incomplete substitution as an explanation for decreases in suicide rates when a particularly lethal means is restricted.[37–40]

A potentially more problematic issue is that of reverse causation, though only in the case of homicide (reverse causation is not a problem for suicide or for unintentional firearm deaths). It might be that where homicide rates are higher, individuals (most likely individuals older than our cohort) are more likely to obtain guns in the belief that they are protecting themselves and their families. In this case, the direction of any causal relationship between high gun levels and high homicide rates cannot be determined. In addition, homicide rates among children are not expected to be independent of homicide rates among adults in the same state; hence the removal of 5–14 year olds from the calculation of Cook's Index and FS/S is only a partial solution to the problem of reverse causation. Nevertheless, our finding that all our proxies for gun availability are significantly related to a state's rate of gun-homicide and overall homicide but not to the rate of nongun homicide is consistent with firearm availability playing some causal role in homicide rates among children.

Drawing causal inferences from group data to individual behaviors is generally referred to as the "ecological fallacy."[41–44] For example, although the poverty rate in a given state with a high unintentional gun death rate may be disproportionately high, that does not prove that the actual individuals in this state who are dying from guns are disproportionately poor. On the other hand, if a person dies from gunfire, that particular individual did come in contact with a bullet. The ecological fallacy is thus not likely to be a major issue with our analyses.

Another limitation of our study is that our analyses may not account for some reasons that states with higher household gun levels have higher violent death rates. Although we include some state-level confounders (poverty, urbanization, and education), these represent only a small number of the characteristics likely to affect suicides, homicides, or unintentional firearm deaths. We do not, for example, account for parenting practices, domestic abuse, or firearm storage patterns. It is not clear, however, whether accounting for these or other state-level characteristics would revise the magnitude of observed association upward or downward.

Many geographic U.S. studies find a positive and statistically significant relationship between gun density measures and overall homicide[45] and suicide[46] rates. Consistent with these studies, we find that of the 6,817 children 5–14 years killed with firearms between 1988 and 1997, a disproportionately large number, per population, died in states where guns were more prevalent, regardless of the proxy chosen to estimate firearm availability. Moreover, the elevated rates of suicide and homicide among children living in states with more guns appears to be driven by lethal firearm violence, not by nonfirearm violence. Our findings suggest that, on average, where there are more guns children are not protected from becoming, but are rather much more likely to become, victims of lethal violence.

REFERENCES

1. National Center for Injury Prevention and Control, Centers for Disease Control and Prevention: Injury Mortality Statistics. Available at http://wonder.cdc.gov/mortsql.shtml.
2. Centers for Disease Control and Prevention. Rates of homicide, suicide, and firearm-related deaths among children: 26 industrialized countries. *MMWR Morb Mortal Wkly Rep.* 1997;46:101–105.
3. Krug EG, Dahlberg LL, Powell KE. Childhood homicide, suicide, and firearm deaths: an international comparison [published erratum appears in *World Health Stat Q.* 1997;50:210]. *World Health Stat Q.* 1996;49:230–235.
4. Cummings P, Koepsell TD, Grossman DC, Savarino J, Thompson RS. The association between the purchase of a handgun and homicide or suicide. *Am J Public Health.* 1997;87:974–978.
5. Kellermann AL, Rivara FP, Somes G, et al. Suicide in the home in relation to gun ownership. *N Engl J Med.* 1992;327:467–472.
6. Kellermann AL, Rivara FP, Rushforth NB, et al. Gun ownership as a risk factor for homicide in the home. *N Engl J Med.* 1993; 329:1084–1091.

7. Bailey JE, Kellermann AL, Somes GW, Banton JG, Rivara FP, Rushforth NP. Risk factors for violent death of women in the home. *Arch Intern Med.* 1997;157:777–782.
8. Brent DA, Perper JA, Goldstein CE, et al. Risk factors for adolescent suicide: a comparison of adolescent suicide victims with suicidal inpatients. *Arch Gen Psychiatry.* 1988;45:581–588.
9. Brent DA, Perper JA, Allman CJ, Moritz GM, Wartella ME, Zelenak JP. The presence and accessibility of firearms in the homes of adolescent suicides: a case-control study. *JAMA.* 1991;266:2989–2995.
10. Brent DA, Perper J, Moritz G, Baugher M, Allman C. Suicide in adolescents with no apparent psychopathology. *J Am Acad Child Adolesc Psychiatry.* 1993;32:494–500.
11. Brent DA, Perper JA, Moritz G, Baugher M, Schweers J, Roth C. Firearms and adolescent suicide: a community case-control study. *Am J Dis Child.* 1993;147:1066–1071.
12. Bukstein OG, Brent DA, Perper JA, et al. Risk factors for completed suicide among adolescents with a lifetime history of substance abuse: a case-control study. *Acta Psychiatr Scand.* 1993;88:403–408.
13. Loftin C, McDowall D, Wiersema B, Cottey TJ. Effects of restrictive licensing of handguns on homicide and suicide in the District of Columbia. *N Engl J Med.* 1991;325:1615–1620.
14. Sloan JH, Kellermann AL, Reay DT, et al. Handgun regulations, crime, assaults, and homicide: a tale of two cities. *N Engl J Med.* 1988;319:1256–1262.
15. Wintemute GJ, Parham CA, Beaumont JJ, Wright M, Drake C. Mortality among recent purchasers of handguns. *N Engl J Med.* 1999;341:1583–1589.
16. Cook P. The effect of gun availability on robbery and robber murder: a cross sectional study of 50 cities. *Policy Stud Rev Annu.* 1979;3:743–781.
17. Clark R, Jones P. Suicide and the increased availability of handguns in the United States. *Soc Sci Med.* 1989;28:805–809.
18. Boor M, Bair JH. Suicide rates, handgun control laws, and sociodemographic variables. *Psychol Rep.* 1990;66(3 pt 1):923–930.
19. Markush RE, Bartolucci AA. Firearms and suicide in the United States. *Am J Public Health.* 1984;74:123–127.
20. Marzuk PM, Leon AC, Tardiff K, Morgan EB, Stajic M, Mann JJ. The effect of access to lethal methods of injury on suicide rates. *Arch Gen Psychiatry.* 1992;49:451–458.
21. Miller M, Azrael D, Hemenway D. Firearm availability and unintentional firearm deaths. *Accid Anal Prev.* 2001;33:447–484.
22. Davis J, Smith T. *General Social Surveys, 1972–1998* [machine-readable data file]. Principal Investigator James A. Davis; Director and Co-Principal Investigator, Tom W. Smith; Sponsored by National Science foundation—NORC ed.—Chicago: National Opinion Research Center [producer]; Storrs, CT: The Roper Center for Public Opinion Research, University of Connecticut [distributor]; 1998.
23. Powell KE, Jacklin BC, Nelson DE, Bland S. State estimates of household exposure to firearms, loaded firearms, and handguns, 1991 through 1995. *Am J Public Health.* 1998;88:969–972.
24. Lester D. Gun control, gun ownership, and suicide prevention. *Suicide Life Threat Behav.* 1988;18:176–180.
25. Lester D. Gun ownership and suicide in the United States. *Psychol Med.* 1989;19:519–521.
26. Lester D. Relationship between firearm availability and primary and secondary murder. *Psychol Rep.* 1990;67:490.
27. Lester D. The availability of firearms and the use of firearms for suicide: a study of 20 countries. *Acta Psychiatr Scand.* 1990;81:146–147.
28. Killias M. International correlations between gun ownership and rates of homicide and suicide. *Can Med Assoc J.* 1993;148:1721–1725.
29. Young TJ. Poverty, suicide, and homicide among Native Americans. *Psychol Rep.* 1990;67(3 pt 2):1153–1154.
30. Saucer PR. Education and suicide: the quality of life among modern Americans. *Psychol Rep.* 1993;73:637–638.
31. Fingerhut LA, Ingram DD, Feldman JJ. Homicide rates among US teenagers and young adults: differences by mechanism, level of urbanization, race, and sex, 1987 through 1995. *JAMA.* 1998; 280:423–427.
32. Fingerhut LA, Jones C, Makuc DM. Firearm and motor vehicle injury mortality: variations by state, race, and ethnicity—United States, 1990–91. *Adv Data.* 1994;242:1–12.
33. Browning CH. Handguns and homicide: a public health problem. *JAMA.* 1976;236:2198–2200.
34. Baker SP. Without guns, do people kill people? [editorial]. *Am J Public Health.* 1985;75:587–588.
35. Adelson L. The gun and the sanctity of human life; or the bullet as pathogen. *Pharos.* 1980;43:15–25.
36. Sloan JH, Rivara FP, Reay DT, Ferris JA, Kellermann AL. Firearm regulations and rates of suicide: a comparison of two metropolitan areas. *N Engl J Med.* 1990;322:369–373.
37. Rich CL, Young JG, Fowler RC, et al. Guns and suicide: possible effects of some specific legislation. *Am J Psychiatry.* 1990;147:342–346.
38. Carrington PJ, Moyer S. Gun control and suicide in Ontario. *Am J Psychiatry.* 1994;15:606–608.
39. Gunnell D, Middleton N, Frankel S. Method availability and the prevention of suicide: a re-analysis of secular trends in England and Wales 1950–1975. *Soc Psychiatry Psychiatr Epidemiol.* 2000; 35:437–443.
40. Hassall C, Trethowan WH. Suicide in Birmingham. *BMJ.* 1972; 1:717–718.
41. Schwartz S. The fallacy of the ecological fallacy: the potential misuse of a concept and the consequences. *Am J Public Health.* 1994;84:819–824.
42. Piantadosi S, Byar DP, Green SB. The ecological fallacy. *Am J Epidemiol.* 1988;127:893–904.
43. Kalimo E, Bice TW. Causal analysis and ecological fallacy in cross-national epidemiological research. *Scand J Soc Med.* 1973;1:17–24.
44. Dutton DG. Patriarchy and wife assault: the ecological fallacy. *Violence Vict.* 1994;9:167–82.
45. Ohsfeldt R, Morrisey M. Firearms, firearms injury and gun control: a critical survey of the literature. *Adv Health Econ Health Serv Res.* 1992;13:65–82.
46. Miller M, Hemenway D. The relationship between firearms and suicide: a review of the literature. *Aggression Violent Behav.* 1999; 4:59–75.

EDITORIAL COMMENT
Firearm Availability and Childhood Death

Violence is a significant problem that trauma surgeons and other health care professionals see literally everyday. When firearms mix with violence, the outcome is much more likely to be lethal.[1] In the United States, we live in an excessively violent society[2] that also happens to be the world's largest market for civilian firearms.[3] Yet, at the same time, we are committed to improving the health and welfare of our children. *Are we really to believe then that plentiful firearms and healthy children can coexist?*

The study by Miller and colleagues provides important information to help answer this question. These authors use four measures of firearm "availability" (two survey and two derived measures) to indicate firearm availability at both the state and regional level. As the authors indicate, these are rather crude measures of firearm availability and provide aggregate data only. The derived measures (a modified Cook Index and the FS/S) are estimates of firearm availability based on the fractions of adult homicides and/or adult suicides that are firearm-related in each state. The authors take appropriate care in describing the derivation, testing, and limitations of these measures, noting (although not in detail) that their high correlation with survey data on firearm availability support their use. The use of derived measures is clearly a limitation. However, these measures are some of the best available, since, unlike motor vehicles, civilian ownership of firearms is not archived for any serviceable length of time by federal or state data agencies.

During the 10-year study period, Miller and colleagues found that 6,817 children between the ages of 5 and 14 years of age were killed with firearms in the United States, outstripping those who were killed by non-firearm homicide or suicide. Even controlling for poverty, urbanization, and education (known correlates of firearm violence), a strong, positive association between firearm availability and firearm death was found in this age group at the state and regional levels. However, factors not controlled for in this study may have modified the relationship between firearm availability and firearm death, as indicated by the very high rates in Alaska, Idaho, and Montana, states not ranking in the top 10 high gun availability states. Future studies are needed to identify other risk factors that contribute to the exceptionally high firearm death rates for 5- to 14-year-olds in these states.

Although no conclusions about cause and effect can be made, this study provides compelling evidence that states with high firearm availability are states with high childhood firearm death rates. As trauma professionals we cannot and should not ignore the fact that children living in the five highest gun availability states are estimated to be 16 times more likely to die from unintentional firearm injury, 7 times more likely to die from firearm suicide, and 3 times more likely to die from homicide compared with those living in the five lowest gun availability states. These findings reinforce the belief that high levels of firearm availability place our children at risk and seriously undermine attempts to improve their health and welfare.

The lethality of firearm violence and its toll on the nation's children should rouse trauma surgeons and other health care professionals to transfer some of the assertive spirit they display during trauma resuscitations to other, more proactive injury prevention activities. This study, along with lessons learned from successfully reducing the toll of motor vehicle crashes,[4] point to three specific steps that can be taken. First, comprehensive data about all violent deaths is critical to building the scientific foundation for prevention. At the federal level, the National Violent Death Reporting System, modeled after the Fatality Analysis Reporting System (FARS), is being proposed as a critical step in providing detailed data about violent injury throughout the United States. We can support this endeavor through grassroots efforts and by working directly with our federal and state officials. Second, civilian registration of all firearms would provide valuable and accurate data on firearm availability. Registering a firearm should be no different from registering a car and should not infringe on legal firearm ownership. Finally, community-specific data applicable to our own "home towns" is crucial to dispelling local myths about firearms and firearm violence. Combining data from trauma centers, local medical examiners/coroners, police, and crime labs is vital to understanding and disseminating accurate profiles of firearm violence in our communities. Only then can we develop meaningful interventions. If we, as health care professionals are to safeguard and promote healthy lives for our children, these steps seem obvious. Their accomplishment await only our determination, support, and energy.

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REFERENCES

1. Gotsch KE, Annest JL, Mercy JA, Ryan GW. Surveillance for fatal and nonfatal firearm-related injuries – United States, 1993–1998. *MMWR Surveill Summ.* 2001;50(SS-2):1–36.
2. Krug EG, Powell KE, Dahlberg LL. Firearm-related deaths in the United States and 35 other high- and upper-middle-income countries. *Int J Epidemiology.* 1998;27:214–221.
3. Diaz T. *Making a Killing: The Business of Guns in America.* New York, NY: New Press; 1999:69–84.
4. Morbidity and Mortality Weekly Report. Motor-vehicle safety: A 20th century public health achievement. *MMWR Morb Mortal Wkly Rep.* 1999;48:369–374.