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# Firearm Injuries In Children And Adolescents: Health And Economic Consequences Among Survivors And Family Members

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**ABSTRACT** More US children and adolescents today die from firearms than any other cause, and many more sustain firearm injuries and survive. The clinical and economic impact of these firearm injuries on survivors and family members remains poorly understood. Using 2007–21 commercial health insurance claims data, we studied 2,052 child and adolescent survivors compared to 9,983 matched controls who did not incur firearm injuries, along with 6,209 family members of survivors compared to 29,877 matched controls, and 265 family members of decedents compared to 1,263 matched controls. Through one year after firearm injury, child and adolescent survivors experienced a 117 percent increase in pain disorders, a 68 percent increase in psychiatric disorders, and a 144 percent increase in substance use disorders relative to the controls. Survivors' health care spending increased by an average of \$34,884—a 17.1-fold increase—with 95 percent paid by insurers or employers. Parents of survivors experienced a 30–31 percent increase in psychiatric disorders, with 75 percent more mental health visits by mothers, and 5–14 percent reductions in mothers' and siblings' routine medical care. Family members of decedents experienced substantially larger 2.3- to 5.3-fold increases in psychiatric disorders, with at least 15.3-fold more mental health visits among parents. Firearm injuries in youth have notable health implications for the whole family, along with large effects on societal spending.

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**I**n 2020 more children and adolescents died from firearms than any other cause—an increase of 30 percent from 2019.<sup>1,2</sup> However, despite the increased attention being paid to this mounting death toll,<sup>3,4</sup> deaths are the tip of the iceberg in this public health crisis.

In addition to these fatalities, many more children are shot each year but survive. Although the US does not systematically compile data on non-fatal firearm injuries,<sup>5–7</sup> by one estimate, more than 80 percent of youth who sustain firearm injuries survive.<sup>8</sup> They are part of the more than 85,000 people each year in the US estimated to

survive firearm injuries—approximately twice the number of firearm fatalities.<sup>9–11</sup> Larger still is the population of family members, including parents and siblings, who grieve and who may experience other health effects from the trauma.<sup>12,13</sup> Yet, to date, rigorous evidence on the consequences of both nonfatal and fatal firearm injuries in children and adolescents, for survivors and for family members of survivors and decedents, remains scant.

Previous literature has often been limited by the lack of claims data to measure direct health care spending or the lack of quasi-experimental methods or control groups that provide a coun-

terfactual for causal inference.<sup>14–22</sup> In fact, most studies of firearm injury survivors have explicitly excluded children.<sup>23</sup> However, children and adolescents are increasingly exposed to firearms. An estimated thirty million children in the US live in households with firearms, with approximately 4.6 million of those children living in homes where at least one firearm is kept loaded and unlocked.<sup>24</sup> Since 2019, more than five million children newly live in homes with firearms, disproportionately in racial and ethnic minority households.<sup>25</sup> Living with firearms increases the risk for firearm injuries.<sup>26–28</sup> One recent study of nonfatal firearm injuries in a mostly adult population found that survivors and family members experienced an increase in mental health disorders after injury, along with increased health care spending.<sup>29</sup>

Understanding the health and health care consequences of firearm injuries in youth could help clinicians anticipate the mental and physical health needs of survivors.<sup>30,31</sup> It may also inform communities and clinicians about the health needs of family members—both those whose children or siblings survived and those whose children or siblings died. Such data would additionally inform payers, employers, and the policy community about the downstream toll of firearm injuries, which is economically significant.<sup>32,33</sup>

### Study Data And Methods

**DATA** We analyzed 2007–21 MarketScan commercial claims data, containing a large sample of people with employer-sponsored insurance in which family relationships among children, siblings, and parents are specified.<sup>34</sup> We defined exposure as an incident firearm injury in a child or adolescent, using the International Classification of Diseases, Ninth Revision, and International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, diagnosis and external cause of injury codes for firearm injuries (online appendix Methods 1).<sup>35</sup> Parents and siblings who were enrolled in the same insurance plan as the victim were also considered to have been exposed to the injury.

We thus defined three cohorts of exposed people. First, child and adolescent survivors of firearm injuries were people ages 0–19 who were enrolled as dependents on their insurance plan for at least one year before and one year after sustaining an incident firearm injury. Second, family members of these survivors included parents and siblings who were concurrently enrolled before and after their child's or sibling's incident firearm injury. The third cohort comprised family members of children and adoles-

cents who died from firearm injuries. Because death attributable to a firearm injury might not be immediate (for example, deaths that follow a hospitalization after injury), we defined death in a child or adolescent using their disenrollment from their family's insurance plan within three months of firearm injury, provided that their family members (at a minimum the primary policy holder) remained enrolled in their employer-sponsored coverage from the same insurer within the same employer through one year post-injury. Of note, children and adolescents who died before receiving health care (that is, deceased at the scene of injury) were not identifiable using claims data.

**MATCHED CONTROL GROUPS** In each of the three cohorts, we matched each exposed individual to up to five unexposed control individuals, without replacement, using risk set matching. Using data from the month immediately before the firearm injury, we exact matched on the year, month, plan type, prescription drug coverage, dependent status, sex, and Metropolitan Statistical Area (MSA) of the individual. We then balanced the means of age and preinjury medical spending between exposed and unexposed (control) individuals, as these were continuous variables. In sensitivity analyses, we replaced preinjury medical spending in the match with the preinjury Diagnostic Cost Group risk score, which reflects expected spending and is derived from age, sex, and clinical diagnoses. Using an optimization approach to matching that respects the temporal structure of the data, we balanced the covariate distance between exposed and unexposed individuals<sup>36,37</sup> (appendix Methods 2).<sup>35</sup> This matching methodology, which improves on conventional matching strategies, enabled us to align the timing of exposure to firearm injury across individuals, directly balance the distributions of the covariates, and maximize the size of the matched study cohorts.<sup>38</sup> We assessed covariate balance before and after matching by calculating the absolute standardized mean difference of the matched variables.

**OUTCOMES** Our primary outcomes of interest were health and health care. Health outcomes included pain disorders (including musculoskeletal pain, headache, and other pain syndromes), psychiatric disorders (including trauma- and stressor-related disorders such as posttraumatic stress disorder and adjustment disorder, mood disorders such as major depressive disorder, and other psychiatric disorders), and substance use disorders (including alcohol or drug dependence and abuse) (appendix Methods 3).<sup>35</sup> Health care outcomes included spending and use. Spending reflected paid amounts using the negotiated prices between insurers

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and hospitals or physicians, adjusted for inflation to 2021 US dollars. Patient cost sharing (part of spending) was the sum of deductibles, copayments, and coinsurance.

Within spending, secondary outcomes included categories of utilization: hospitalizations, procedures, office visits, emergency department visits, mental health visits (including psychotherapy and psychiatric services), imaging, laboratory tests, and other services defined using Current Procedural Terminology codes. Utilization also included days prescribed of pain and psychiatric medications. Pain medications included salicylates, nonsteroidal anti-inflammatory drugs, opioids, and other analgesics. Psychiatric medications included anticonvulsants, antidepressants, antipsychotics, stimulants, barbiturates, benzodiazepines, and other anxiolytic and antimanic agents.

**STATISTICAL ANALYSIS** We used an ordinary least squares model to compute the difference in changes in outcomes between each exposed cohort and its matched controls—the difference-in-differences attributable to firearm injury—through one year after injury. Our linear model adjusted for preinjury age and medical spending (the two factors that were not exact matched), with all other covariates exact matched. Standard errors were clustered at the MSA level—a conservative choice, as MSAs represent a less granular unit of clustering than alternatives such as the family.

Subgroup analyses examined heterogeneity in findings by the severity of firearm injury, type of family member, and documented intent behind the firearm injury. Severity of injury was dichotomized in two ways. First, we constructed a binary measure of severity based on whether the index hospitalization after injury involved intensive care unit (ICU) services, defined by any revenue code specific to the ICU setting. Second, we separated nonfatal from fatal firearm injuries through our cohort definitions. Family members were further specified as mothers, fathers, and siblings. Last, we evaluated heterogeneity by the documented intent, specifically intentional (assault, self-harm, and law enforcement firearm injuries) and unintentional, although we caution that diagnosis codes might not accurately capture the intent behind firearm injuries.<sup>39</sup>

Our methodology was consistent with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guideline for observational studies.<sup>40</sup> We reported two-sided *p* values for health outcomes of survivors, with <0.05 considered statistically significant, and 95% confidence intervals for all other outcomes. Analyses used R, version 4.0.2, and Stata, version 16.1. This research was approved by the

Harvard Medical School Institutional Review Board.

**SENSITIVITY ANALYSES** We replicated the main estimates and 95% confidence intervals, using randomization tests, by obtaining Hodges-Lehmann estimates and by inverting the permutational *t* test on the changes in outcomes between exposed and control groups.<sup>41,42</sup> We tested sensitivity to unmeasured confounding using Rosenbaum bounds, which quantified how influential an unobserved confounder would need to be to explain away a significant finding.<sup>43–45</sup> This is captured by a parameter gamma, which is the magnitude by which an unobserved covariate would need to increase the odds of exposure to a firearm injury among matched individuals for a finding to no longer be statistically significant (appendix Methods 4).<sup>35,46–48</sup> Finally, as noted above, we tested the sensitivity of findings to using the preinjury risk score rather than preinjury medical spending in the matching algorithm.

**LIMITATIONS** We note several limitations. First, although more than 50 percent of US children are covered by commercial insurance, our findings might not generalize to children with Medicaid, other insurance, or no insurance. The latter may have different risks for injury and access to care. Second, despite rigorous matching, our observational results remained subject to potential confounding. However, given our methodology, an unmeasured confounder must substantially change the probability of exposure, conditional on our covariate balance, to render the estimated impact of firearm injuries statistically indistinguishable from zero.<sup>29</sup> The visual trend break in the outcomes after firearm injury further provides reassurance. Third, to the extent that parents or siblings may have been disconnected from a child or adolescent victim on the same insurance plan (for example, living apart), our estimated spillover effects on family members would likely be conservative. Fourth, our findings on family members of children and adolescents who died might not generalize, as those who died before reaching health care were, by definition, absent from claims, limiting us to inferring deaths among the subset of who died after receiving some health care. Fifth, we observed prescription drugs dispensed, rather than consumed. Misuse and diversion were also unobservable. Sixth, our data did not contain race or ethnicity information. Finally, we lacked longer follow-up, which would involve trade-offs with sample size and susceptibility to confounders further removed from the firearm injury.

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### Study Results

**POPULATION** We identified 2,052 child and adolescent survivors (ages 0–19) matched to 9,983 controls, 6,209 family members of survivors matched to 29,877 controls, and 265 family members of decedents matched to 1,263 controls. All individuals were continuously enrolled in the employer-sponsored insurance plan from at least one year before through one year after the child’s or adolescent’s firearm injury (appendix figure 1, appendix table 1).<sup>35</sup>

Survivors averaged 15.7 years of age and 84.6 percent male, with a Diagnostic Cost Group risk score of 0.4 (lower scores indicate lower expected health care spending). Family members of survivors averaged 29.2 years of age (parents, 44.2 years; siblings, 14.5 years; data not shown) and 49.5 percent male, with a 0.5 risk score (appendix table 1).<sup>35</sup> Family members of decedents averaged 30.8 years of age and were 49.8 percent male with a 0.5 average risk score. Between 85 percent and 94 percent of enrollees had prescription drug coverage. Preferred provider organization, health maintenance organization, and high-deductible health plans ac-

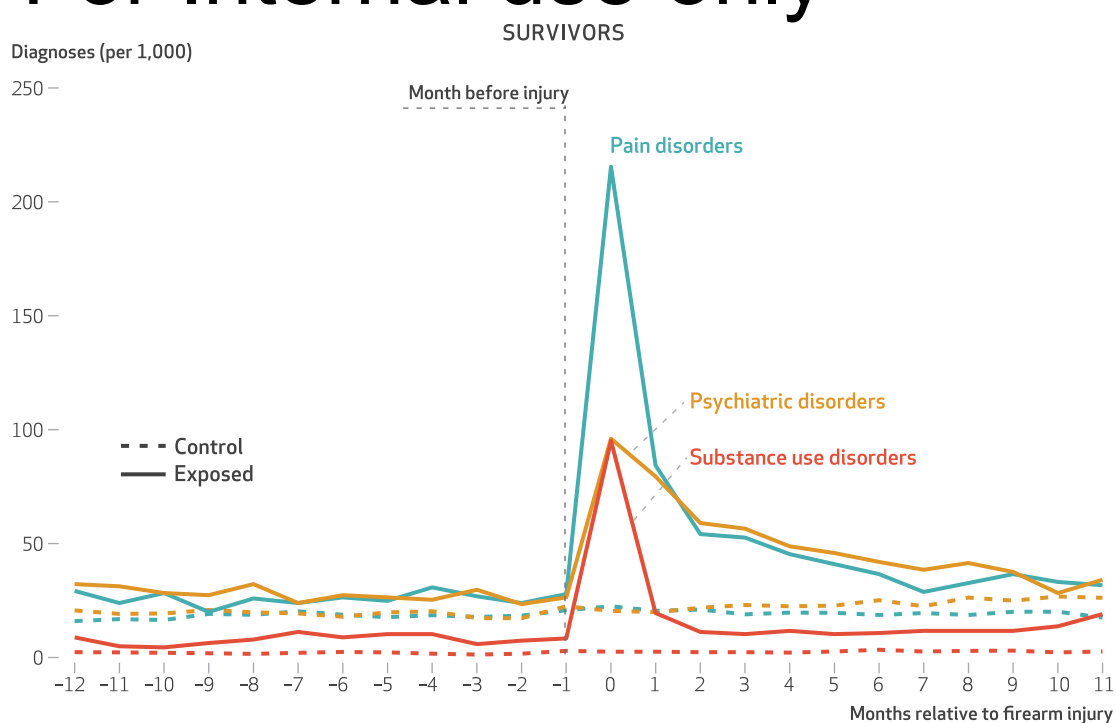
counted for nearly 90 percent of enrollees (appendix table 1).<sup>35</sup> The exposed and unexposed cohorts were closely balanced on these characteristics (appendix table 2).<sup>35</sup>

**SURVIVORS** Among child and adolescent survivors of firearm injuries, diagnoses of pain disorders increased by 30.3 per 1,000 (95% CI: 23.3, 37.3) relative to controls, or a 117 percent increase ( $p < 0.001$ ) from baseline. Psychiatric disorders increased by 18.8 per 1,000 (95% CI: 11.6, 26.0) relative to controls—a 68 percent increase ( $p < 0.001$ ) from the baseline of 27.8 per 1,000 preinjury. Substance use disorders increased by 11.3 per 1,000 (95% CI: 7.1, 15.5) relative to controls—a 144 percent increase ( $p < 0.001$ ) from the preinjury baseline of 7.8 per 1,000 (exhibits 1 and 2).

The increases in pain and psychiatric disorders among survivors were more pronounced after more severe firearm injuries (those involving ICU care) than less severe injuries (non-ICU) (appendix figure 2).<sup>35</sup> Pain disorders increased by 293 percent from baseline (73.1 additional diagnoses per 1,000; 95% CI: 55.0, 91.1) after more severe injuries and 95 percent (24.8 addi-

**EXHIBIT 1**

Pain, psychiatric, and substance use disorders among child and adolescent survivors before and after firearm injury, 2007–21



**SOURCE** Authors’ analysis of MarketScan commercial claims data, 2007–21. **NOTES** Unadjusted health outcomes are shown by event month, along with those of matched controls. The vertical line indicates the month just before firearm injury. Pain disorders included musculoskeletal pain, headache, and other pain syndromes. Psychiatric disorders included trauma- and stressor-related disorders such as posttraumatic stress disorder and adjustment disorder, mood disorders such as major depressive disorder, and other psychiatric disorders. Substance use disorders included alcohol or drug dependence and abuse.

**EXHIBIT 2**

**Changes in health and health care among survivors and family members after firearm injuries to children and adolescents in the US, 2007–21**

	Exposed group: survivors or family members		Unexposed group: matched controls		Difference in changes between groups <sup>a</sup>		
	12 months preinjury	12 months postinjury	12 months preinjury	12 months postinjury	Estimate	95% CI	% change
Survivors (no.)	2,052	2,052	9,983	9,983			
Health (per 1,000)							
Pain disorders	26.0	57.7	18.2	19.7	30.3	23.3, 37.3	116.7
Psychiatric disorders	27.8	50.6	19.5	23.5	18.8	11.6, 26.0	67.7
Substance use disorders	7.8	19.7	2.0	2.6	11.3	7.1, 15.5	143.6
Health care (\$ per person)							
Spending	170	3,119	123	165	2,907	2,494, 3,320	1,712.5
Patient cost sharing	32	165	24	26	132	119, 145	417.9
Utilization (per 1,000)							
Hospitalizations	2.6	39.6	1.5	1.5	37.1	33.1, 41.0	1,449.2
Procedures	42.4	149.1	35.0	38.1	103.7	92.4, 114.9	244.8
Office visits	205.4	398.4	190.5	200.0	183.5	152.7, 214.4	89.4
ED visits	37.4	132.7	17.4	18.2	94.5	88.3, 100.6	252.6
Mental health visits	61.9	90.0	39.6	48.1	19.5	3.0, 36.0	31.5
Imaging	52.6	279.4	36.0	40.1	222.7	210.0, 235.4	423.1
Lab tests	198.0	518.5	156.8	187.3	290.1	206.5, 373.6	146.5
Other tests	37.7	79.8	51.9	54.9	39.1	24.3, 53.9	103.6
Home health	1.0	46.8	0.7	0.5	46.0	23.5, 68.4	4,718.7
Transportation	7.6	95.9	2.4	2.7	88.0	80.9, 95.2	1,165.6
Rx drug days (per person)							
Pain medications	0.2	1.1	0.2	0.2	0.9	0.6, 1.1	411.1
Psychiatric medications	2.7	3.7	2.6	2.7	0.9	0.4, 1.5	34.6
Family members of survivors							
Health (per 1,000)							
Mothers (no.)	1,655	1,655	7,771	7,771			
Psychiatric disorders	34.7	49.1	30.2	34.1	10.8	4.8, 15.9	29.8
Substance use disorders	4.8	6.5	3.5	4.1	1.0	-0.5, 2.5	20.3
Fathers (no.)	1,410	1,410	6,691	6,691			
Psychiatric disorders	21.3	30.6	15.6	18.3	6.6	1.7, 11.5	31.0
Substance use disorders	7.3	9.3	4.1	5.2	1.0	-1.1, 3.1	14.1
Siblings (no.)	3,144	3,144	15,415	15,415			
Psychiatric disorders	17.5	22.3	17.6	22.4	0.0	-3.3, 3.2	-0.2
Substance use disorders	3.4	3.7	1.9	2.4	-0.2	-1.4, 1.0	-5.4
Family members of decedents							
Health (per 1,000)							
Mothers (no.)	74	74	339	339			
Psychiatric disorders	45.0	215.1	33.4	42.3	161.2	94.6, 227.8	357.9
Substance use disorders	4.5	10.1	1.0	2.9	3.7	-7.8, 15.2	81.3
Fathers (no.)	76	76	373	373			
Psychiatric disorders	12.1	78.9	10.9	13.6	64.2	21.4, 107.1	532.3
Substance use disorders	5.5	6.6	1.6	2.2	0.4	-8.3, 9.2	7.8
Siblings (no.)	115	115	551	551			
Psychiatric disorders	15.9	56.5	23.6	28.0	36.2	8.7, 63.7	227.0
Substance use disorders	2.9	0.7	0.6	0.9	-2.5	-6.9, 2.0	-85.4

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**SOURCE** Authors' analysis of MarketScan commercial claims data, 2007–21. **NOTES** Preinjury and postinjury outcomes reflect monthly averages. All individuals were continuously enrolled for at least 12 months before and 12 months after the survivor's incident firearm injury. Standard errors were clustered at the Metropolitan Statistical Area level. Estimates were scaled to percent changes relative to the average outcome in the exposed group (survivors or family members) preinjury. Spending and cost sharing were adjusted to 2021 US dollars. Pain, psychiatric, and substance use disorders are defined in the exhibit 1 notes. Pain and psychiatric medications are listed in the text. Results for pain disorders among family members of survivors are in appendix tables 6–8 (see note 35 in text). ED is emergency department. <sup>a</sup>Reported in rows only where estimates are presented.

tional diagnoses per 1,000; 95% CI: 18.2, 31.3) after less severe injuries. Analogously, psychiatric disorders increased by 321 percent (99.4 additional diagnoses per 1,000; 95% CI: 63.6, 135.3) after more severe injuries and 31 percent

(8.4 additional diagnoses per 1,000, 95% CI: 3.0, 13.8) after less severe injuries (appendix table 3).<sup>35</sup> The increase in substance use disorders was fairly similar between types of injury: 15.6 additional diagnoses per 1,000 (a 102 percent in-

crease) after more severe injuries and 10.7 additional diagnoses per 1,000 (a 156 percent increase) after less severe injuries.

Spending averaged \$170 per survivor per month before firearm injury and \$3,119 per survivor per month after injury. Relative to controls, spending increased by \$2,907 per survivor per month (95% CI: 2,494, 3,320), or a 17.1-fold increase from baseline through year 1. Patient cost sharing increased by \$132 per survivor per month (95% CI: 119, 145) or 4.2-fold (exhibit 2 and appendix figure 3).<sup>35</sup> These increases were driven by a \$26,809 spike in spending and a \$1,281 spike in cost sharing in the first month of injury, which equaled a 158.0-fold and 40.5-fold increase from baseline, respectively (appendix table 4).<sup>35</sup> Overall, 95 percent of the additional spending was paid by insurers (often self-insured employers) and the remainder through cost sharing.

All categories of utilization increased over the course of one year after firearm injury among survivors relative to controls. Survivors were hospitalized 37.1 more times per 1,000 per month (95% CI: 33.1, 41.0)—a 14.5-fold increase. Survivors also had 183.5 more office visits per 1,000 per month (95% CI: 152.7, 214.4), or an 89 percent increase; 94.5 more emergency department visits per 1,000 per month (95% CI: 88.3, 100.6), or a 25 percent increase; and 9.5 more mental health visits per 1,000 per month (95% CI: 3.0, 36.0), or a 32 percent increase. In addition, survivors incurred a 245 percent increase in procedures; a 423 percent increase in imaging; a 147 percent increase in laboratory tests; and large increases in other tests, home health, and medical transportation. Survivors also received a 411 percent increase in prescription pain medication days and 35 percent increase in psychiatric medication days relative to controls.

These spending and utilization changes were generally larger after more severe firearm injuries (those involving ICU care) (appendix table 3) and firearm injuries documented as intentional (assault, self-harm, and law enforcement-related) (appendix table 5).<sup>35</sup>

Male and female youth survivors experienced similar increases in pain disorders (117 percent and 115 percent, respectively) and psychiatric disorders (69 percent and 65 percent, respectively) relative to controls. Their increases in substance use disorders relative to controls were similar in magnitude but proportionally larger in girls (264 percent) than in boys (134 percent), explained by a lower baseline prevalence among girls. The differential increase in spending was larger among boys (\$3,024 per month, an 18.1-fold increase) than girls (\$2,263 per month, a

12.4-fold increase) (appendix figure 4, appendix tables 3 and 5).<sup>35</sup>

**FAMILY MEMBERS OF SURVIVORS** Exhibit 3 presents the unadjusted pain, psychiatric, and substance use disorders outcomes of family members of children and adolescents before and after the latter's firearm injury. Mothers of survivors experienced a 30 percent increase in diagnosed psychiatric disorders (10.3 additional diagnoses per 1,000 mothers; 95% CI: 4.8, 15.9) relative to controls in the year after their child's firearm injury (exhibit 2). Fathers of survivors similarly had a 31 percent (6.6 diagnoses per 1,000) differential increase in psychiatric disorders (95% CI: 1.7, 11.5). These increases were larger after more severe firearm injuries in their children (appendix figure 5).<sup>35</sup>

Mothers of survivors also had a 75 percent increase in mental health visits (17.0 additional visits per 1,000 per month; 95% CI: 5.1, 29.0). Meanwhile, their routine office visits declined by 6 percent, imaging by 14 percent, and laboratory tests by 9 percent relative to controls. Fathers of survivors exhibited less statistically precise changes in utilization (appendix tables 6 and 7).<sup>35</sup>

Siblings of survivors did not experience increased psychiatric illness over the first year. However, they also reduced their use of more routine medical care. Siblings had 11 percent fewer procedures (driven by a 14 percent reduction among sisters), 7 percent fewer office visits (driven by a 9 percent reduction among brothers), and 14 percent fewer other tests (driven by a 23 percent reduction among sisters) relative to control (appendix tables 8 and 9).<sup>35</sup>

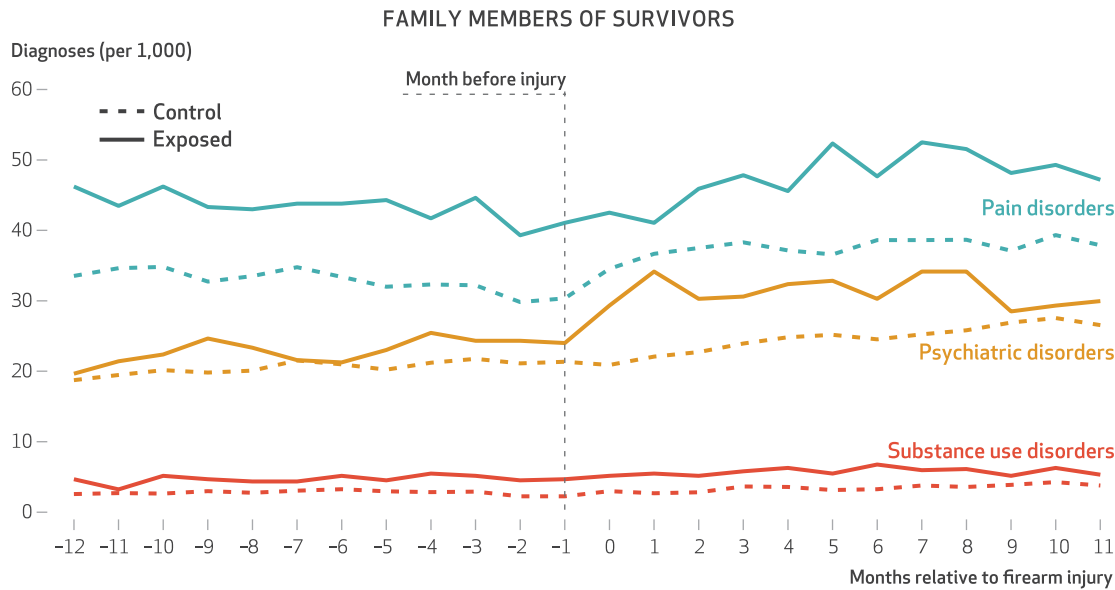
**FAMILY MEMBERS OF DECEDENTS** Family members of children and adolescents who died after firearm injuries exhibited even larger changes in health (exhibit 4). Mothers of youth who died exhibited a 161.2 per 1,000 increase in psychiatric disorders (95% CI: 94.6, 227.8) relative to controls—a 3.6-fold increase (exhibit 2). These mothers also used 378.3 more mental health visits per 1,000 per month (95% CI: 164.7, 591.9) relative to controls—a 15.3-fold increase. Furthermore, they were prescribed 6.7 more days of psychiatric medications per month (95% CI: 2.4, 11.1), a 112 percent increase (appendix figure 6, appendix table 10).<sup>35</sup>

Fathers of children and adolescents who died demonstrated a 64.2 per 1,000, or 5.3-fold, increase in psychiatric disorders (95% CI: 21.4, 107.1) relative to controls (exhibit 2). They also used 94.9 more mental health visits per 1,000 per month (95% CI: 11.2, 178.7). Given fathers' rare use of mental health care at baseline, this represented an 86.6-fold increase. Fathers received 3.1 additional days of psychiatric medications per

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**EXHIBIT 3**

**Pain, psychiatric, and substance use disorders among family members of child and adolescent survivors before and after the survivor's firearm injury, 2007–21**



**SOURCE** Authors' analysis of MarketScan commercial claims data, 2007–21. **NOTES** Unadjusted health outcomes are shown by event month, along with those of matched controls. The vertical line indicates the month just before the firearm injury. Pain, psychiatric, and substance use disorders are defined in the exhibit 1 notes.

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month (95% CI: -0.1, 6.1), a 126 percent increase that was less statistically precise (appendix figure 6, appendix table 10).<sup>35</sup>

Siblings of deceased youth experienced a 36.2 per 1,000 or 2.3-fold increase in psychiatric disorders (95% CI: 8.7, 63.7) (exhibit 2), with an increase of 75.9 mental health visits per 1,000 per month, or a 138 percent increase, that was less statistically precise (95% CI: -7.7, 159.5) relative to controls. No differential changes in spending or other utilization were observed (appendix table 10).<sup>35</sup>

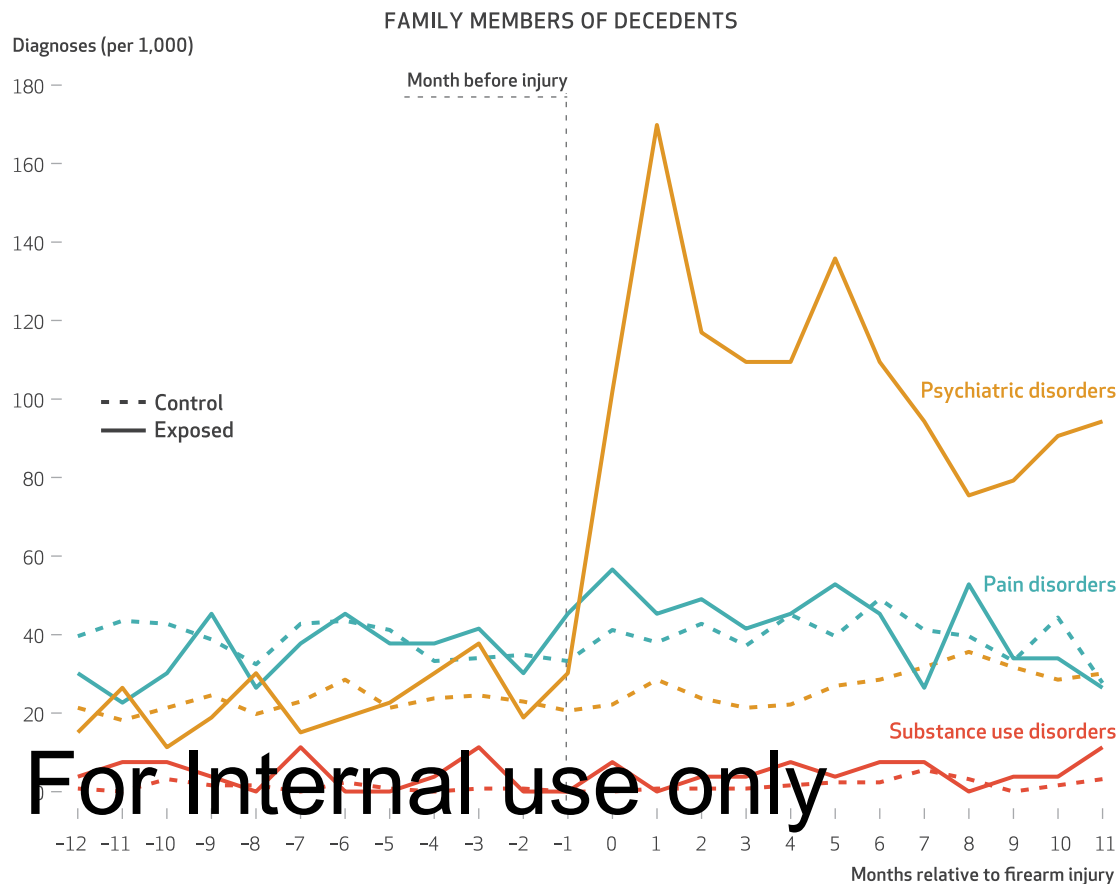
**SENSITIVITY ANALYSES** Sensitivity analyses produced very similar results across all cohorts. Calculations of sensitivity to potential unmeasured confounding showed that an unmeasured confounder would need to increase the odds of exposure to firearm injury by a factor of 2–3 for health outcomes and 17–31 for spending among survivors and matched controls to explain away statistically significant findings (appendix table 11).<sup>35</sup> Family members of deceased children and adolescents, who experienced larger changes in health, demonstrated less sensitivity to potential unmeasured confounding than did family members of survivors (appendix table 12).<sup>35</sup> Finally, using preinjury risk scores rather than preinjury spending in the match yielded qualitatively similar results (appendix figure 7, appendix table 13).<sup>35</sup>

In 2007–21 data, firearm injuries in US children and adolescents with commercial health insurance were associated with substantial health and economic consequences for victims, families, and society. Survivors experienced large increases in pain, psychiatric disorders, and substance use disorders, roughly similar among boys and girls. Parents of survivors also incurred increases in psychiatric disorders after their children's firearm injuries. These changes were more pronounced after more severe firearm injuries. Moreover, not only did mothers of survivors use more mental health care, but mothers and siblings of survivors reduced their use of plausibly routine medical care, consistent with the crowding out of more routine care or substitution by more acute mental health needs. After fatal firearm injuries in youth, parents and siblings experienced substantially larger increases in psychiatric disorders and mental health care use.

Firearm injuries were expensive for families and insurers, the latter of whom, in this employer-sponsored insurance context, were mostly self-insured employers in which health care spending is ultimately financed by forgone wages. Through the first year after firearm injury, survivors, on average, incurred an increase of \$34,884 (a seventeenfold increase) in health

EXHIBIT 4

Pain, psychiatric, and substance use disorders among family members of child and adolescent decedents before and after a fatal firearm injury, 2007-21



**SOURCE** Authors' analysis of MarketScan commercial claims data, 2007-21. **NOTES** Unadjusted health outcomes are shown by event month, along with those of matched controls. The vertical line indicates the month just before the firearm injury. Pain, psychiatric, and substance use disorders are defined in the exhibit 1 notes.

care spending relative to controls, of which 95 percent was nominally paid by insurers and 5 percent through patient cost sharing. Taken together, these results illustrate the large clinical, psychosocial, and economic ripple effects of gun violence in America's youth through families and society.

Additional spending such as on services and supports for disability would further raise spending by patients, payers, and society. This may be disproportionately larger for child and adolescent survivors of firearm injury than for adults, given the plausibly longer life remaining. A recent estimate of the total economic toll of gun violence in the US reached \$557 billion per year (comparable to 2.6 percent of the gross domestic product), 88 percent of which derived from quality-of-life losses among victims and their families.<sup>32</sup>

Our findings illustrate the substantial health needs, particularly mental and behavioral health

needs, of children and adolescents who survive firearm injuries and similarly of the families of injury victims (both fatal and nonfatal). Such data can inform clinical practice—for example, by improving screening for mental health conditions not only in survivors of firearm injuries but also in their siblings and parents, and potentially other family members, friends, or classmates. One interpretation of the finding that mental health diagnoses and mental health services use did not increase among siblings of survivors is that these siblings were not negatively affected. However, another likely interpretation is that the effects of firearm violence on people close to those who are shot often go underrecognized and may only manifest in claims data as decreased engagement with their own health care, consistent with our findings of reduced office visits and other routine services. Thus, siblings might not be obtaining much-needed support in the aftermath of familial trauma. Im-



# These results illustrate the large clinical, psychosocial, and economic ripple effects of gun violence in America's youth.

proved health systems, rooted in trauma-informed approaches, may be essential to ensuring that those indirectly affected by firearm injuries are identified and able to access needed care. Novel educational programs could help ensure that clinicians have the training to have clinically and culturally competent discussions with patients and families about firearm injuries.<sup>49</sup>

These findings improve the evidence base by providing rigorous estimates of the health and health care consequences of firearm injuries among children and adolescents. Qualitatively, our results are similar to estimates from the general population,<sup>29</sup> but the applicability to child and adolescent injuries and the evidence on fatal

injuries are novel. Our findings also support prior or economic estimates.<sup>18-22</sup> By matching each exposed survivor or family member to up to five controls, using preinjury characteristics, these results likely better approximate causal inference relative to prior studies that lacked quasi-experimental designs.

However, we emphasize that our results might not generalize to the Medicaid population, which is the source of coverage for most children and adolescents outside of commercial coverage. The absence of enrollee race and ethnicity data, a common limitation in commercial claims, precluded analyses of treatment effect heterogeneity that addressed disparities.

## Conclusion

Child and adolescent survivors of firearm injuries experienced large increases in mental and behavioral health disorders, as well as health care spending, during 2007–21. Meanwhile, their family members also exhibited increased mental illness and use of mental health services, with reductions in some aspects of routine health care. When children and adolescents were killed by firearms, family members experienced even larger changes in mental health and mental health services use. These substantial indirect consequences of firearm injuries highlight their profound ripple effects through families and society. ■

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