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## The association of alcohol use and heavy drinking with subsequent handgun carrying among youth from rural areas

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### Abstract

**Purpose:** Alcohol use and handgun carrying are more prevalent among youth in rural than urban areas and their association may be stronger among rural adolescents. Alcohol use may be modifiable with implications for reducing handgun carrying and firearm-related harm. We examined the association between lagged alcohol use and subsequent handgun carrying in rural areas and examined variation in the association by developmental stages, hypothesizing that it would be stronger among adolescents than youth adults.

**Methods:** We used a longitudinal sample of 2,002 adolescents from age 12–26 growing up in 12 rural communities in 7 states with surveys collected from 2004–2019. We estimated the association of lagged past-month alcohol use on handgun carrying in the subsequent 12-months using population-average generalized estimating equations with logistic regression on multiply-imputed data.

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Author Contributions: AE, JPS, SO, EG, KD, MK, EW, and AR developed the study design; AE conducted all data analyses; AE had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis; AE and AR coordinated and managed the study; AE and JPS managed revisions; All authors conceived of the study, participated in its design and development, helped interpret results from data analyses, assisted in drafting the manuscript, and read and approved the final manuscript.

Declarations of Interest: None

**Findings:** During adolescence (ages 12–18), those who drank heavily had 1.43 times the odds (95% CI=[1.01,2.03]) of subsequent handgun carrying compared to those who did not drink alcohol, and those who consumed alcohol but did not drink heavily had 1.30 times the odds of subsequent handgun carrying compared to those who did not drink (95% CI=[0.98,1.71]). During young adulthood (ages 19–26), associations of alcohol use (OR=1.28;95% CI=[0.94,1.63]) and heavy drinking (OR=1.38;95% CI=[1.08,1.68]) were similar to adolescence.

**Conclusion:** Alcohol use and subsequent handgun carrying were positively associated during adolescence and young adulthood among individuals who grew up in rural areas, similar to findings in urban areas. Reducing alcohol use may be an important strategy to prevent handgun carrying and firearm-related harm among young people in rural areas.

In 2020, suicide and homicide were among leading causes of death among US individuals aged 12–26 years.<sup>1</sup> About 91% of homicides and 52% of suicides among this population involved a firearm.<sup>1</sup> Handgun carrying is associated with firearm-related harm, both interpersonal and self-directed.<sup>2,3</sup> Recent evidence suggests that rural adolescents may initiate handgun carrying earlier and carry with a higher frequency and duration than their urban counterparts and is associated with bullying, physical violence, and other risk factors for violence.<sup>4–6</sup> Preventing or delaying handgun carrying among rural adolescents may be an important strategy for preventing firearm-related harm.

Prior research suggests that alcohol use may be an antecedent of handgun carrying. Alcohol use has numerous acute and long-term pharmacological effects that may contribute to handgun carrying among adolescents and young adults.<sup>7–10</sup> Alcohol use disrupts brain function, impairs information processing, and narrows attention. It may contribute to handgun carrying through several pathways, including by reducing impulse control, which helps regulate behavior, intensifying overreactions to perceived threats, or reducing the accuracy of cognitive assessments of health risk behaviors. Given pharmacological influences on the adolescent brain, alcohol may precede handgun carrying. Further, problem behavior theory supports both adolescent alcohol use and handgun carrying as well as other behaviors (e.g., stealing, violence, property damage) as co-occurring behaviors that can be detrimental to both individual and community health and well-being.<sup>11</sup> Existing research, primarily from urban areas, identifies alcohol use as a known correlate of firearm-related harm, and an potentially important focus for firearm-related harm prevention that is more common among rural adolescents.<sup>12–14</sup> However, given the cultural importance and greater access to firearms in rural areas, the nature and strength of its relationship with alcohol use may be different than that in urban areas. Adolescents in rural areas are an important population to study because both handgun carrying and alcohol use among them are more common than those behaviors among urban adolescents. In 2020, the prevalences of alcohol use and handgun carrying in the last 12 months were 20.6% and 7.1%, respectively, among rural adolescents compared to 18.0% and 3.2% among urban adolescents aged 12–18.<sup>15</sup> Almost half of adults living in rural areas say they own a gun, compared to only 19% of adults living in urban areas,<sup>16</sup> and rural adolescents' ability to engage in both handgun carrying and alcohol consumption may be greater than their urban peers.

Adolescence and young adulthood are important developmental periods during which both alcohol use and handgun carrying behaviors may be established. Several studies of urban adolescents find a positive association between alcohol use and handgun carrying.<sup>17–27</sup> The association between alcohol use and firearm-related harm is generally stronger among adolescents than adults.<sup>14</sup> However, existing evidence is mostly based on urban populations and is largely cross-sectional, with only two studies of urban youth examining these associations longitudinally.<sup>19,21</sup> Few studies assess handgun carrying specifically despite its role in firearm-related harm. Moreover, the temporality of these associations has not been established. If alcohol use precedes handgun carrying, reducing alcohol use may have the capacity to reduce handgun carrying and firearm-related harm.

The goal of this study was to examine the association between lagged alcohol use and subsequent handgun carrying among adolescents and young adults who grew up in rural areas using a longitudinal sample after adjusting for important risk and protective factors that may influence these behaviors. We hypothesized that alcohol use would precede handgun carrying particularly among adolescents. We also hypothesized that associations would be larger with heavy drinking which would be consistent with a dose-response relationship. Lastly, because of illegality of both behaviors during adolescence and the pharmacological effects of alcohol on brain function particularly during adolescence, we hypothesized that the strength of the association between alcohol use and subsequent handgun carrying would be greater during adolescence than in young adulthood. Our study extends the literature, mostly from urban areas, by focusing on adolescents growing up in rural areas, examining developmental stage and types of alcohol use, and evaluating the temporality between alcohol use and handgun carrying, all vital to informing prevention. Our findings will provide important information on handgun carrying among rural adolescents and young adults, an important risk factor of firearm-related harm, and help inform rural health practice.

## METHODS

### Study Design

We analyzed data from 2,002 participants in the control arm of the Community Youth Development Study (CYDS) collected longitudinally from age 12 (Grade 6) to age 26 as part of a community-randomized trial of the Communities That Care (CTC) prevention system. All public school students in 12 participating communities from 7 states (Colorado, Illinois, Kansas, Maine, Oregon, Utah, Washington) in the 5<sup>th</sup> grade in 2003–2004 were eligible to participate, and parental consent and student assent were obtained for 77% of the eligible population.<sup>28–30</sup> These communities included one small rural town, seven large rural towns, and four urban-focused towns based on the ZIP code approximation of the Rural-Urban Commuting Area (RUCA) taxonomy and had an average population of 14,222 (range:2,034–33,870).<sup>31</sup> Participants in the experimental arm of the study were excluded from this study because the intervention has been shown to reduce both alcohol use and handgun carrying.<sup>32,33</sup> The sample included 962 females (48.1%) and 1,040 males (51.9%), and almost 40% of participants had at least one parent/guardian with a college education or more (n=794; 39.7%). This study used 10 waves of data collected from ages 12–26

(2004–2019). The amount of time between study waves varied; in adolescence participants were surveyed almost each year from age 12–18 [age 12 (Grade 6), 13 (Grade 7), 14 (Grade 8), 15 (Grade 9), 16 (Grade 10), and 18 (Grade 12)], and less often in young adulthood (age 19, 21, 23, 26). Retention was 86.4% or greater at each wave. The CYDS study protocol and the current study were approved by the University of Washington Institutional Review Board.

## Outcome

**Handgun carrying.**—At each data collection point, participants were asked how many times in the past year they carried a handgun. Ordinal response options ranged from never to 40 or more times. We dichotomized responses such that 0 indicated a participant reported never carrying in that study wave and 1 indicated a participant reported carrying a handgun at least once. We dichotomized responses for parsimony and interpretability and because we were primarily interested in the occurrence of handgun carrying, not the frequency.

## Exposure

At each wave participants were asked on how many occasions they had beer, wine, or hard liquor during the past thirty days, with response options ranging from 0 to 40 or more occasions. Participants were also asked how many times they had five or more alcohol drinks in a row in the past two weeks (i.e., heavy drinking) with response options from None to 10 or more times. The primary measure of interest was a three-level categorical variable about past 30-day alcohol use, based on information from responses about alcohol use and heavy drinking: 1) no alcohol use – participant did not report consuming alcohol during the past 30-days; 2) alcohol use without heavy drinking – participant reported consuming alcohol in the past 30-days but did not report heavy drinking in the past 2-weeks; and 3) heavy drinking – participant reported consuming alcohol in the past 30-days and reported heavy drinking in the past 2-weeks. We also generated a dichotomous variable measuring any past 30-day alcohol use, coded as 1 if a participant reported consuming beer, wine, or hard liquor on one or more occasions and 0 if they did not report consuming these alcoholic beverages (no alcohol use).

## Developmental period

To assess differences in associations during adolescence and young adulthood, we created a binary indicator variable to distinguish two developmental periods (adolescence [Grades 6–12 (ages 12–18)]; young adulthood [Ages 19 to 26]) where a zero indicated adolescence and a one indicated young adulthood.

## Covariates

To minimize the possibility of bias due to the omission of factors associated with both alcohol use and handgun carrying, we included a number of potential confounding variables, selected a priori, measuring demographic characteristics and risk and protective factors in multiple domains (community, family, individual, peer). Individual-level demographic characteristics included age at grade 6 interview and gender. Individual/peer-level risk and protective factors included a rebelliousness scale, sensation-seeking scale, attendance

at religious services, alcohol use among close friends, and handgun carrying among close friends. Family-level risk and protective factors included parental/guardian maximum education, family history of severe alcohol or drug problem, and family conflict. Community demographic characteristics included percentage of students eligible for free and reduced price lunch and total student population. Community-level risk and protective factors included perceptions about community norms favorable towards problem behaviors, community disorganization, and community attachment. Scale values, a measure of underlying risk/protection for various factors, were created using several questions with Likert scale response options for each scale. The number of questions used for each scale ranged from 3–5 and the Likert response options for each question ranged from a 4- to 6-point scale. For each risk/protective factor, scales were calculated by creating a common ordering for risk and protective factor item questions when response options differed and then calculating the average score across items.<sup>32,34</sup> Cronbach's alphas for each scale ranged from 0.78–0.97. Most covariates were time-varying (rebelliousness, sensation-seeking, attendance at religious services, friend alcohol use, friend handgun carrying, family conflict, community norms, community disorganization, and community attachment).

### Statistical Analysis

We estimated the association between lagged alcohol use and handgun carrying in the subsequent study wave using population-average generalized estimating equations with logistic regression. Our primary specification used the three-level alcohol use exposure (no alcohol use, alcohol use without heavy drinking, heavy drinking) interacted with developmental stage (adolescence versus young adulthood). All regressions were adjusted for individual-level demographic characteristics, individual/peer-level risk and protective factors, family-level risk and protective factors, community demographic characteristics, and community-level risk and protective factors. Standard errors were adjusted for individual-level serial correlation by clustering at the individual-level. To address missing data (Tables A1 and A2), all analyses were conducted on twenty multiply imputed datasets, imputed using multivariate imputation by chained equations (MICE) in Stata (Table A3). Association estimates were pooled across imputed datasets using Rubin's rules.<sup>35</sup> In all model specifications, handgun carrying in the current study wave was a function of time-constant demographic characteristics of participants and the community as well as alcohol use and time-varying covariates from the prior study wave (i.e., alcohol use and time-varying covariates were measured at the same time, both lagged by one wave in relation to handgun carrying). Because of the lagged structure, the outcome data range from age 13–26, and exposure data range from age 12–23.

### Sensitivity analyses

We conducted sensitivity analyses to assess the robustness of our findings. To explore whether our findings were influenced by persistence within individuals in handgun carrying behavior across time, we conducted a sensitivity analysis including lagged handgun carrying as a covariate. We conducted another sensitivity analysis including a series of binary indicators for each community (community-level fixed effects) to account for time-constant differences in communities in the study that may be associated with handgun carrying and alcohol use. We also conducted a sensitivity analyses to better situate our findings with the

existing literature from urban areas. Studies in urban areas have primarily focused on any alcohol use without considering intensity (i.e., no alcohol use, alcohol use without heavy drinking, heavy drinking), so we estimated another regression where a binary measure of alcohol use (any alcohol use) was compared to no alcohol use interacted with developmental stage. Finally, because depression may be an additional confounder, we included lagged depression as a covariate, measured with a 4-item scale from ages 12–18 years and with the patient health questionnaire-9 (PHQ-9) from ages 19–26 years.<sup>36</sup>

## RESULTS

The proportion of participants who reported alcohol use without heavy drinking grew from 5.0% at age 12 to 23.4% at age 26 (Figure 1). The proportion of participants who reported alcohol use with heavy drinking grew steadily from age 12 to 18 (from 1.9% to 16.3%), more rapidly from age 18 to 21 (from 16.3% to 33.4%), and levelled off afterwards (around 30%). The proportion of participants who reported handgun carrying at each study wave increased slightly between ages 12 and 26 from 3.3% to 9.2%. Over the study period (2004–2019), handgun carrying between ages 13 and 26 was more common among those who reported alcohol use (n=70;19.8%) or heavy drinking (n=421;32.4%) at least once between ages 12 and 23 compared to those who did not report using alcohol (n=59;17.6%) between ages 12 and 23 (Table 1).

### Differences in the association between alcohol use, heavy drinking, and handgun carrying in adolescence and young adulthood

We found that those who drank heavily during adolescence had 1.43 times the odds (95% CI=[1.01,2.03]) of handgun carrying in the following 12-months compared to those who did not drink alcohol, after adjusting for covariates (Figure 2, Table 2). Alcohol use without heavy drinking during adolescence was associated with an increase in estimated odds of handgun carrying (Odds ratio[OR]=1.30, 95% CI=[0.98,1.71]) compared to those who did not drink alcohol. The associations of alcohol use without heavy drinking (OR=1.28; 95% CI=[0.94,1.63]) and with heavy drinking (OR=1.38; 95% CI=[1.08,1.68]) with subsequent handgun carrying were similar during young adulthood.

### Sensitivity analyses

Findings from sensitivity analyses adjusting for lagged handgun carrying, community-level fixed effects, and lagged depression were similar to results from the primary specification. After adjusting for lagged handgun carrying, those who drank heavily during adolescence and young adulthood had 1.40 (95% CI=[0.98,2.00]) and 1.39 (95% CI=[1.07,1.70]) times the odds of handgun carrying in the subsequent wave, respectively, compared to those who did not drink alcohol. Those who consumed alcohol without heavy drinking during adolescence and young adulthood had 1.31 (95% CI=[0.99,1.74]) and 1.32 (95% CI=[0.96,1.68]) times the odds of subsequent handgun carrying, respectively, compared to those who did not drink alcohol. Our findings were also very similar to the main specification when we adjusted for community fixed effects (in adolescence: alcohol use without heavy drinking OR=1.29 [95% CI=0.98,1.71], heavy drinking OR=1.43 [95% CI=1.01,2.02]; in young adulthood: alcohol use without heavy drinking OR=1.29 [95% CI=0.95,1.64], heavy

drinking OR=1.38 [95%CI=1.07,1.68]) and when controlling for depression (in adolescence: alcohol use without heavy drinking OR=1.27 [95%CI=0.95,1.71], heavy drinking OR=1.38 [95%CI=0.97,1.97]; in young adulthood: alcohol use without heavy drinking OR=1.30 [95%CI=0.96,1.63], heavy drinking OR=1.42 [95%CI=1.09,1.75]). In sensitivity analyses using a binary measure of alcohol use (any alcohol use compared to no alcohol use), those who used alcohol in the past 30-days had 1.35 greater odds (95%CI=[1.14,1.59]) of handgun carrying in the following 12-months compared to those who did not use alcohol (Figure 2, Table 2).

## DISCUSSION

This study contributed to our understanding of the association between alcohol use and handgun carrying in two important ways. First, this study established an association between alcohol use and subsequent handgun carrying among adolescents and young adults who grew up in rural areas. Second, our findings extended the existing literature showing that alcohol use may precede subsequent handgun carrying. Third, we expanded on the existing literature by exploring these associations longitudinally using data from the last two decades, during which youth handgun carrying and firearm-related harm have increased in rural areas.<sup>37,38</sup> Overall, we found that any alcohol use was associated with higher odds of subsequent handgun carrying and the odds were greater with heavy drinking. The associations did not meaningfully differ during adolescence vs. young adulthood, when both alcohol use and handgun carrying are typically legal. Given the relatively high baseline handgun carrying prevalence among rural youth and young adults, our findings suggest meaningful increases in handgun carrying associated with alcohol use. For example, given a 7% baseline handgun carrying prevalence among rural youth,<sup>15</sup> a 43% increase related to heavy drinking could increase rural adolescent handgun carrying prevalence to 10%. Therefore, reducing alcohol use, especially heavy drinking, among young people may be an important strategy for preventing handgun carrying and firearm-related harm particularly in rural areas.

Some existing alcohol use prevention programs have been shown to reduce alcohol use and alcohol-related consequences.<sup>39–42</sup> Our findings indicate that these prevention programs may have the additional benefit of reducing subsequent handgun carrying and risk for firearm-related harm in rural areas. Given prior findings on early initiation of handgun carrying among rural adolescents around age 12,<sup>4</sup> effective school-based and family-focused prevention programs focusing on children younger than 10 years (e.g., Raising Healthy Children, Seattle Social Development Project) and adolescents ages 10–15 (e.g., keeping it REAL, Project Northland, Guiding Good Choices, Strengthening Families 10–14) may help prevent subsequent handgun carrying among adolescents in rural areas through reductions in alcohol use because they are appropriately timed.<sup>43</sup> Some of these programs (Guiding Good Choices and Strengthening Families) were specifically tested in rural contexts, while other may need to be adapted before use. However, existing evidence-based community-level programs and interventions aiming to improve healthy development have been tested in and are suitable for rural areas. These include the Communities that Care prevention system, which has been shown to reduce alcohol use, violent behaviors, and handgun carrying, particularly among adolescents.<sup>32,33</sup>

Our findings also inform practice for both rural health care providers and public health practitioners. Both alcohol use and handgun carrying are health risk behaviors that can be reduced to prevent firearm-related harm. Clinicians can engage in safety promotion and counseling about these health risk behaviors.<sup>44–47</sup> Access to firearms is a key contributor to firearm-related harm.<sup>48</sup> Many rural health care providers indicate that conversations about firearm storage and safety can be difficult in rural contexts. Clinicians can engage with patients and families to focus on prevention and safety strategies that can prevent both alcohol and handgun access in homes with children and adolescents. Clinicians can encourage families to participate in family-based prevention programs that focus on concepts like communication and family bonds that can reduce risk factors and increase protective factors and could be applied to both alcohol and firearm access.<sup>49–52</sup> Though a promising strategy, more work is needed to create and tailor health communication strategies in clinical settings to align with rural culture and not stigmatize these health risk behaviors. Existing evidence suggests that firearm-related harm prevention strategies need to address these cultural factors.<sup>53,54</sup>

There are some limitations of our findings. First, the CYDS study from which our data are drawn did not obtain information on firearm-related harm (e.g., non-fatal firearm injuries, firearm-related suicide attempts), so we are unable to directly measure associations between alcohol use, handgun carrying, and firearm-related harm. Understanding how the association between alcohol use and handgun carrying may contribute to firearm-related harm among rural adolescents and young adults is an important area of future study. Moreover, the time frame queried for alcohol use, heavy drinking, and handgun carrying varied from 30 days to 2 weeks to 12 months, respectively. Therefore, we can only establish that the same people used alcohol and subsequently carried a handgun. Despite this, recent use (past 30-day) may have greater validity in identifying those who drink during adolescence, an advantage of our current approach. In addition, there was a varying amount of time between study waves that was longer during young adulthood. Importantly, responses to questions about alcohol use and handgun carrying could be subject to social desirability bias. “Handgun carrying” was also not explicitly defined in the survey question, and it is possible that respondents had slightly different definitions of this term. Future research should examine how youth and young adults, including those in rural areas, conceptualize and define such firearm-related terms. Lastly, more work is needed to establish the causal pathways by which alcohol use increases engagement in handgun carrying. Mediation analyses may shed more light on mechanisms (e.g., culture, social context, mental health) contributing to the established associations between alcohol use and handgun carrying.

## CONCLUSIONS

Alcohol use, particularly heavy drinking, was moderately associated with higher odds of subsequent handgun carrying in adolescence and young adulthood in this sample of rural youth, adjusting for a host of potential confounding factors. Strategies to reduce and delay alcohol use may be useful for the prevention of handgun carrying and firearm-related harm. Given early initiation of handgun carrying among rural adolescents, prevention programs should focus on elementary aged children and adolescents. Tested and effective school-based and family-focused alcohol prevention programs and community-based prevention systems



like Communities that Care could be implemented in rural areas to help reduce both alcohol-related consequences and firearm-related harm.

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## APPENDIX

**Table A1.**

Number and % of missing exposure and outcome responses at each study wave

Variable	Missing at least one (handgun carrying, alcohol use, or heavy drinking)		Handgun carrying		Alcohol use		Heavy drinking	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Wave 1 (Grade 6, Age 12)	60	3.0%	33	1.7%	46	2.3%	37	1.9%
Wave 2 (Grade 7, Age 13)	141	7.0%	105	5.2%	117	5.8%	104	5.2%
Wave 3 (Grade 8, Age 14)	131	6.5%	103	5.1%	113	5.6%	106	5.3%
Wave 4 (Grade 9, Age 15)	140	7.0%	117	5.9%	127	6.3%	127	6.3%
Wave 5 (Grade 10, Age 16)	171	8.5%	145	7.2%	154	7.7%	157	7.8%
Wave 6 (Grade 12, Age 18)	217	10.8%	207	10.3%	212	10.6%	212	10.6%
Wave 7 (Age 19)	221	11.0%	214	10.7%	219	10.9%	221	11.0%
Wave 8 (Age 21)	227	11.3%	214	10.7%	224	11.2%	222	11.1%
Wave 9 (Age 23)	286	14.3%	280	14.0%	282	14.1%	284	14.2%
Wave 10 (Age 26)	303	15.1%	298	14.9%	301	15.0%	302	15.1%

There were 1,143 CYDS participants (57.1% of the sample) with complete exposure (alcohol use) and outcome (handgun carrying) data for all study waves. 469 participants (23.4%) were missing either the exposure or outcome in 1–2 study waves. The remaining 390 participants (19.5%) were missing either the exposure or outcome in 3 or more study waves.

**Table A2.**

Missing data for study participants from Age 12–26

Variable	Purpose	Type	Missing <i>n</i>	(%)	Reason missing	Domain
Handgun carrying	Outcome	Time-varying	1,716	8.6	Non-response	Individual
Alcohol use (past 30-day)	Exposure	Time-varying	1,795	9.0	Non-response	Individual
Heavy drinking (past 2 weeks)	Exposure	Time-varying	1,772	8.9	Non-response	Individual
Age at Grade 6 interview	Confounder	Time-invariant	140	0.7	Non-response	Individual
Male gender	Confounder	Time-invariant	–			Individual
Rebelliousness (scale)	Confounder	Time-varying	6,682	33.4	Planned	Individual
Sensation seeking (scale)	Confounder	Time-varying	15,222	76.0	Planned	Individual
Friends alcohol use	Confounder	Time-varying	7,532	37.6	Planned	Peer

Variable	Purpose	Type	Missing n	(%)	Reason missing	Domain
Friends handgun carrying	Confounder	Time-varying	8,933	44.6	Planned	Peer
Parental/guardian maximum education	Confounder	Time-invariant	930	4.6	Non-response	Family
Family history of substance use problem	Confounder	Time-invariant	10	0.05	Non-response	Family
Family conflict (scale)	Confounder	Time-varying	1,997	10.0	Non-response	Family
Attendance at religious services	Confounder	Time-varying	4,220	21.1	Planned	Family
% free and reduced lunch	Confounder	Time-invariant	–			Community
Total student population	Confounder	Time-invariant	–			Community
Community norms favorable toward anti-social behavior (scale)	Confounder	Time-varying	8,372	41.8	Planned	Community
Community disorganization (scale)	Confounder	Time-varying	5,222	26.1	Planned	Community
Community attachment (scale)	Confounder	Time-varying	2,643	13.2	Planned	Community

**Note.** There were 2,002 participants and ten waves of available data for each individual resulting in 22,022 observations. Planned refers to missingness that was a part of the Community Youth Development Study study design. Specifically, a planned missing-data three-form design, with items distributed evenly across forms and forms distributed randomly to participants was used to minimize survey burden.<sup>1</sup>

**Table A3.**

Variables used in multivariate imputation by chained equations (MICE)

Variable	Purpose	Type	Domain
Handgun carrying	Outcome	Time-varying	Individual
Alcohol use (past 30-day)	Exposure	Time-varying	Individual
Heavy drinking (past 2 weeks)	Exposure	Time-varying	Individual
Age at Grade 6 interview	Confounder	Time-invariant	Individual
Gender	Confounder	Time-invariant	Individual
Rebelliousness (scale)	Confounder	Time-varying	Individual
Sensation seeking (scale)	Confounder	Time-varying	Individual
Friends alcohol use	Confounder	Time-varying	Peer
Friends handgun carrying	Confounder	Time-varying	Peer
Parental/guardian maximum education	Confounder	Time-invariant	Family
Family history of substance use problem	Confounder	Time-invariant	Family
Family conflict (scale)	Confounder	Time-varying	Family
Attendance at religious services	Confounder	Time-varying	Family
% free and reduced lunch	Confounder	Time-invariant	Community
Total student population	Confounder	Time-invariant	Community
Community norms favorable toward anti-social behavior (scale)	Confounder	Time-varying	Community
Community disorganization (scale)	Confounder	Time-varying	Community
Community attachment (scale)	Confounder	Time-varying	Community
Caught by parents (handguns)	Improve prediction	Time-varying	Family
Caught by parents (alcohol)	Improve prediction	Time-varying	Family

Variable	Purpose	Type	Domain
Cool to drink alcohol	Improve prediction	Time-varying	Individual
Cool to carry handgun	Improve prediction	Time-varying	Individual

## References

1. Hawkins JD, Brown EC, Oesterle S, Arthur MW, Abbott RD, Catalano RF. Early effects of Communities That Care on targeted risks and initiation of delinquent behavior and substance use. *Journal of Adolescent Health*. 2008;43:15–22.

## REFERENCES

1. Centers for Disease Control and Prevention. Fatal Injury reports, national, regional and state, 1981–2020. Accessed October 13, 2022. <https://wisqars.cdc.gov/fatal-reports>
2. Ash P, Kellerman A. Reducing gun carrying by youth. *Arch Pediatr Adolesc Med*. 2001;155(3):330–331. [PubMed: 11231796]
3. Bushman B, Calvert S, Dredze M, Al E. Youth Violence: What We Know and What We Need to Know. *American Psychology*. 2016;71(1):17–39.
4. Ellyson AM, Gause EL, Oesterle S, et al. Trajectories of Handgun Carrying in Rural Communities from Early Adolescence to Young Adulthood. *JAMA Netw Open*. 2022;5(4):e225127. doi:10.1001/jamanetworkopen.2022.5127
5. Ellyson AM, Gause E, Lyons VH, et al. Bullying and physical violence and their association with handgun carrying among youth growing up in rural areas. *Prev Med (Baltim)*. 2023;167:107416. doi:10.1016/j.ypmed.2022.107416
6. Dalve K, Ellyson AM, Gause EL, et al. School Handgun Carrying Among Youth Growing Up in Rural Communities. *Journal of Adolescent Health*. 2023;72(4):636–639. doi:10.1016/j.jadohealth.2022.10.033
7. National Institute on Alcohol Abuse and Alcoholism. Alcohol Alert: Alcohol, Violence, and Aggression. NIAAA Publications Distribution Center. 1997;38.
8. Gustafson R. Alcohol and Aggression. *J Offender Rehabil*. 1994;21(3–4):41–80. doi:10.1300/J076v21n03\_04
9. Miczek KA, DeBold JF, van Erp AMM, Tornatzky W. Alcohol, GABAA-Benzodiazepine Receptor Complex, and Aggression. In: *Recent Developments in Alcoholism*. Springer US; 2002:139–171. doi:10.1007/0-306-47141-8\_9
10. Cook P, Moore M. Economic perspectives on reducing alcohol-related violence. In: *NIAAA Research Monograph No. 24, ed. Alcohol and Interpersonal Violence: Fostering Multidisciplinary Perspectives*. NIH Pub No. 93–3496. National Institute on Alcohol Abuse and Alcoholism; 1993:193–212.
11. Jessor R. Problem-Behavior Theory, Psychosocial Development, and Adolescent Problem Drinking. *Addiction*. 1987;82(4):331–342. doi:10.1111/j.1360-0443.1987.tb01490.x
12. Lambert D, Gale JA, Hartley D. Substance Abuse by Youth and Young Adults in Rural America. *The Journal of Rural Health*. 2008;24(3):221–228. doi:10.1111/j.1748-0361.2008.00162.x [PubMed: 18643798]
13. Friesen EL, Bailey J, Hyett S, et al. Hazardous alcohol use and alcohol-related harm in rural and remote communities: a scoping review. *Lancet Public Health*. 2022;7(2):e177–e187. doi:10.1016/S2468-2667(21)00159-6 [PubMed: 34774200]
14. Branas CC, Han S, Wiebe DJ. Alcohol Use and Firearm Violence. *Epidemiol Rev*. 2016;38(1):32–45. doi:10.1093/epirev/mxv010 [PubMed: 26811427]
15. Substance Abuse and Mental Services Administration. National Survey on Drug Use and Health (NSDUH), 2020 Detailed Tables. Published online 2021. Accessed April 18, 2022. <https://datafiles.samhsa.gov/>

16. Igielnic R. Rural and urban gun owners have different experiences, views on gun policy. Published 2017. Accessed October 23, 2022. <https://www.pewresearch.org/short-reads/2017/07/10/rural-and-urban-gun-owners-have-different-experiences-views-on-gun-policy/#:~:text=While%2021%25%20of%20urban%20gun,by%2047%25%20of%20urban%20owners.>
17. Orpinas P, Basen-Engquist K, Grunbaum J, Parcel G. The co-morbidity of violence-related behaviors with health-risk behaviors in a population of high school students. *Journal of Adolescent Health*. 1995;16:216–225.
18. Hemenway D, Prothrow-Stith D, Bergstein J, Ander R, Kennedy B. Gun carrying among adolescents. *Law Contemp Probl*. 1996;59:39–53.
19. Simon T, Richardson J, Dent C, Chou C, Flay B. Prospective psychosocial, interpersonal, and behavioral predictors of handgun carrying among adolescents. *American Public Health Association*. 1998;88:960–963.
20. DuRant R, Krowchuk D, Kreiter S, Sinai S, Woods C. Weapon carrying on school property among middle school students. *Arch Pediatr Adolesc Med*. 1999;153:21–26. [PubMed: 9894995]
21. Markowitz S. The Role of Alcohol and Drug Consumption in Determining Physical Fights and Weapon Carrying by Teenagers. *East Econ J*. 2001;27(4):409–432.
22. Williams S, Mulhall P, Reis J, de Ville J. Adolescents carrying handguns and taking them to school: Psychosocial correlates among public school students in Illinois. *J Adolesc*. 2002;25:551–567. [PubMed: 12234560]
23. Peleg-Oren N, Saint-Jean G, Cardenas GA, Tammara H, Pierre C. Drinking Alcohol before Age 13 and Negative Outcomes in Late Adolescence. *Alcohol Clin Exp Res*. 2009;33(11):1966–1972. doi:10.1111/J.1530-0277.2009.01035.X [PubMed: 19719795]
24. Cunningham RM, Resko SM, Harrison SR, et al. Screening adolescents in the emergency department for weapon carriage. *Academic Emergency Medicine*. 2010;17:168176.
25. Hemenway D, Vrinotis M, Johnson R, Miller M, Azrael D. Gun carrying by high school students in Boston, MA: does overestimation of peer gun carrying matter? *J Adolesc*. 2011;34:997–1003. [PubMed: 21146203]
26. Ruggles K, Rajan S. Gun possession among American youth: A discovery-based approach to understand gun violence. *PLoS One*. 2014;9:e111893.
27. Vaughn M, Nelson E, Salas-Wright C, Al. E. Handgun carrying among White youth increasing in the United States: New evidence from the National Survey on Drug Use and Health 2002–2013. *Prev Med (Baltim)*. 2016;88:127–133.
28. Hawkins J, Catalano R, Arthur M, et al. Testing communities that care: the rationale, design and behavioral baseline equivalence of the community youth development study. *Prevention Science*. 2008;9:178–190. [PubMed: 18516681]
29. Hawkins J, Oesterle S, Brown E, Abbott R, Catalano R. Youth Problem Behaviors 8 years After Implementing the Communities that Care Prevention System. *JAMA Pediatr*. 2014;168:122–129. [PubMed: 24322060]
30. Brown E, Graham J, Hawkins J, et al. Design and analysis of the Community Youth Development Study longitudinal cohort sample. *Eval Rev*. 2009;33(4):311–334. [PubMed: 19509119]
31. Rowhani-Rahbar A, Oesterle S, Skinner ML. Initiation Age, Cumulative Prevalence, and Longitudinal Patterns of Handgun Carrying Among Rural Adolescents: A Multistate Study. *Journal of Adolescent Health*. 2020;66(4):416–422. doi:10.1016/j.jadohealth.2019.11.313
32. Oesterle S, Kuklinski MR, Hawkins JD, Skinner ML, Guttmanova K, Rhew IC. Long-Term Effects of the Communities That Care Trial on Substance Use, Antisocial Behavior, and Violence Through Age 21 Years. *Am J Public Health*. 2018;108(5):659–665. doi:10.2105/AJPH.2018.304320 [PubMed: 29565666]
33. Rowhani-Rahbar A, Oesterle S, Gause EL, et al. Effect of the Communities That Care Prevention System on Adolescent Handgun Carrying. *JAMA Netw Open*. 2023;6(4):e236699. doi:10.1001/jamanetworkopen.2023.6699
34. Pandika D, Bailey JA, Oesterle S, Kuklinski MR. Young adult opioid misuse indicates a general tendency toward substance use and is strongly predicted by general substance use risk. *Drug Alcohol Depend*. 2022;235:109442. doi:10.1016/j.drugalcdep.2022.109442
35. Rubin D. *Multiple Imputation for Nonresponse in Surveys*. John Wiley & Sons; 1987.

36. Rhew IC, Monahan KC, Oesterle S, Hawkins JD. THE COMMUNITIES THAT CARE BRIEF DEPRESSION SCALE: PSYCHOMETRIC PROPERTIES AND CRITERION VALIDITY. *J Community Psychol.* 2016;44(3):391–398. doi:10.1002/jcop.21766 [PubMed: 27872502]
37. Carey N, Coley RL. Prevalence of Adolescent Handgun Carriage: 2002–2019. *Pediatrics.* 2022;149(5). doi:10.1542/PEDS.2021-054472
38. Schleimer JP, Gause E, Dalve K, Ellyson AM, Rowhani-Rahbar A. Rural-urban variation in the association of adolescent violence and handgun carrying in the United States, 2002–2019. *JAMA Netw Open.* 2023;6(3):e231153.
39. Lemstra M, Bennett N, Nannapaneni U, et al. A systematic review of school-based marijuana and alcohol prevention programs targeting adolescents aged 10–15. *Addiction Research & Theory.* 2010;18(1):84–96. doi:10.3109/16066350802673224
40. Strøm HK, Adolfsen F, Fossum S, Kaiser S, Martinussen M. Effectiveness of school-based preventive interventions on adolescent alcohol use: a meta-analysis of randomized controlled trials. *Subst Abuse Treat Prev Policy.* 2014;9(48). doi:10.1186/1747-597X-9-48
41. Hennessy EA, Tanner-Smith EE. Effectiveness of Brief School-Based Interventions for Adolescents: A Meta-analysis of Alcohol Use Prevention Programs. *Prevention Science.* 2015;16(3):463–474. doi:10.1007/s11121-014-0512-0 [PubMed: 25294110]
42. Harrop E, Catalano RF. Evidence-Based Prevention for Adolescent Substance Use. *Child Adolesc Psychiatr Clin N Am.* 2016;25(3):387–410. doi:10.1016/j.chc.2016.03.001 [PubMed: 27338963]
43. Stigler MH, Neusel E, Perry CL. School-based programs to prevent and reduce alcohol use among youth. *Alcohol research & health.* 2011;34(2):157–162. [PubMed: 22330213]
44. Pallin R, Spitzer SA, Ranney ML, Betz ME, Wintemute GJ. Preventing Firearm-Related Death and Injury. *Ann Intern Med.* 2019;170(11):ITC81–ITC96. doi:10.7326/AITC201906040 [PubMed: 31158880]
45. Barclay C, Viswanathan M, Ratner S, Tompkins J, Jonas DE. Implementing Evidence-Based Screening and Counseling for Unhealthy Alcohol Use with Epic-Based Electronic Health Record Tools. *The Joint Commission Journal on Quality and Patient Safety.* 2019;45(8):566–574. doi:10.1016/j.jcjq.2019.05.009 [PubMed: 31378277]
46. O'Connor EA, Perdue LA, Senger CA, et al. Screening and Behavioral Counseling Interventions to Reduce Unhealthy Alcohol Use in Adolescents and Adults. *JAMA.* 2018;320(18):1910. doi:10.1001/jama.2018.12086 [PubMed: 30422198]
47. Bradley KA, Kivlahan DR, Williams EC. Brief Approaches to Alcohol Screening: Practical Alternatives for Primary Care. *J Gen Intern Med.* 2009;24(7):881–883. doi:10.1007/s11606-009-1014-9 [PubMed: 19495888]
48. Grossman DC, Miller BA, Riedy C, et al. Gun Storage Practices and Risk of Youth Suicide and Unintentional Firearm Injuries. *JAMA.* 2005;293(6):707. doi:10.1001/jama.293.6.707 [PubMed: 15701912]
49. Webster-Stratton C, Taylor T. Nipping early risk factors in the bud: Preventing substance abuse, delinquency, and violence in adolescence through interventions targeted at young children (0 to 8 Years). *Prevention Science.* 2001;2(3):165–192. doi:10.1023/A:1011510923900 [PubMed: 11678292]
50. Ary D v., Duncan TE, Biglan A, Metzler CW, Noell JW, Smolkowski K. Development of adolescent problem behavior. *J Abnorm Child Psychol.* 1999;27(2):141–150. doi:10.1023/A:1021963531607 [PubMed: 10400060]
51. Kumpfer KL, Alvarado R. Family-strengthening approaches for the prevention of youth problem behaviors. *American Psychologist.* 2003;58(6–7):457–465. doi:10.1037/0003-066X.58.6-7.457 [PubMed: 12971192]
52. Catalano RF, Fagan AA, Gavin LE, et al. Worldwide application of prevention science in adolescent health. *The Lancet.* 2012;379(9826):1653–1664. doi:10.1016/S0140-6736(12)60238-4
53. Pruitt LD, Sung JC, Walker KA. What is “safety”? Lethal means counseling as a cross-cultural communication. *Military Psychology.* 2022;34(3):352–365. doi:10.1080/08995605.2022.2040939 [PubMed: 38536318]

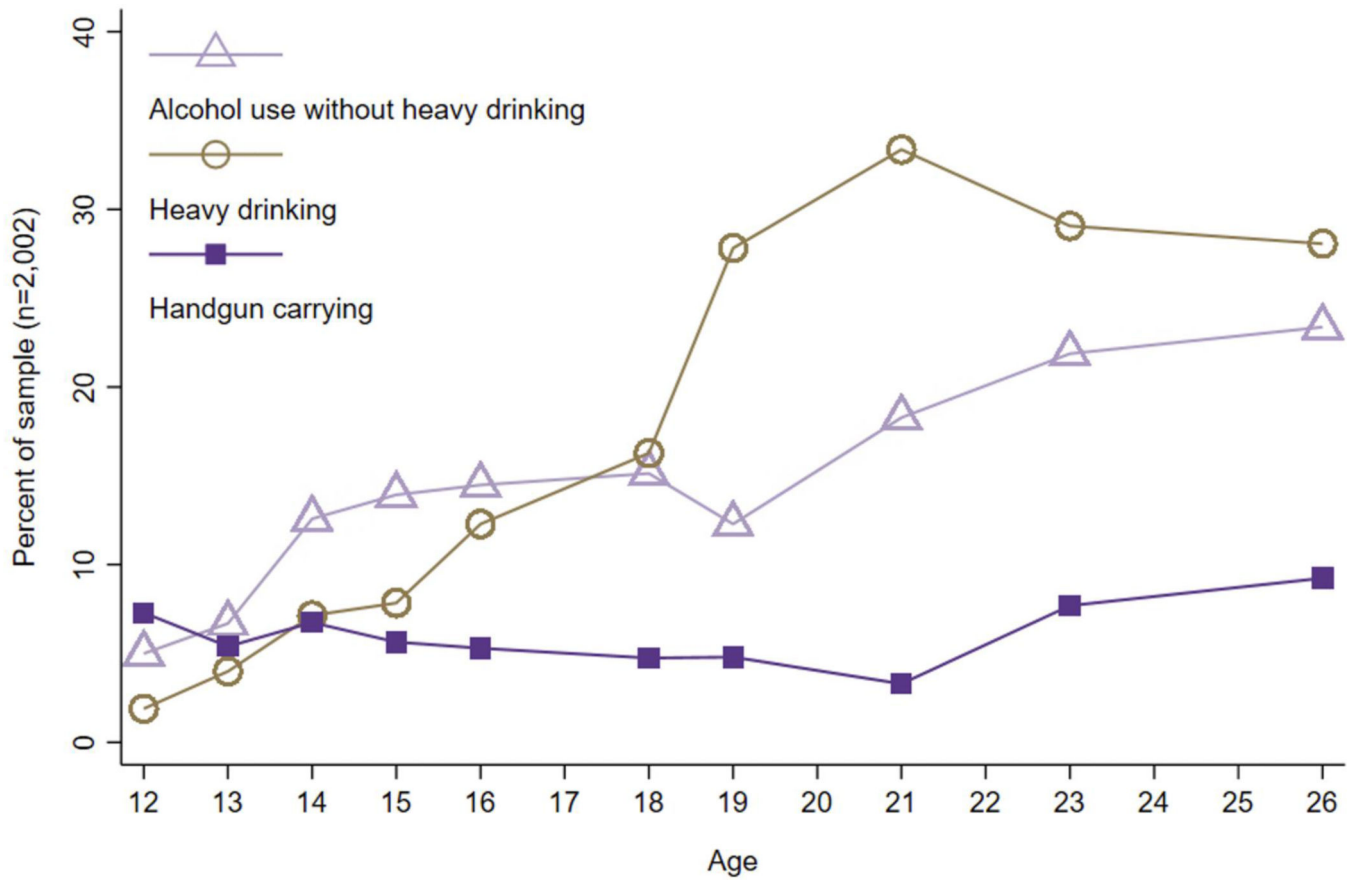
54. Marino E, Wolsko C, Keys SG, Al E. A culture gap in the United States: Implications for policy on limiting access to firearms for suicidal persons. *Journal of Public Health Politics*. 2016;37:110–121.

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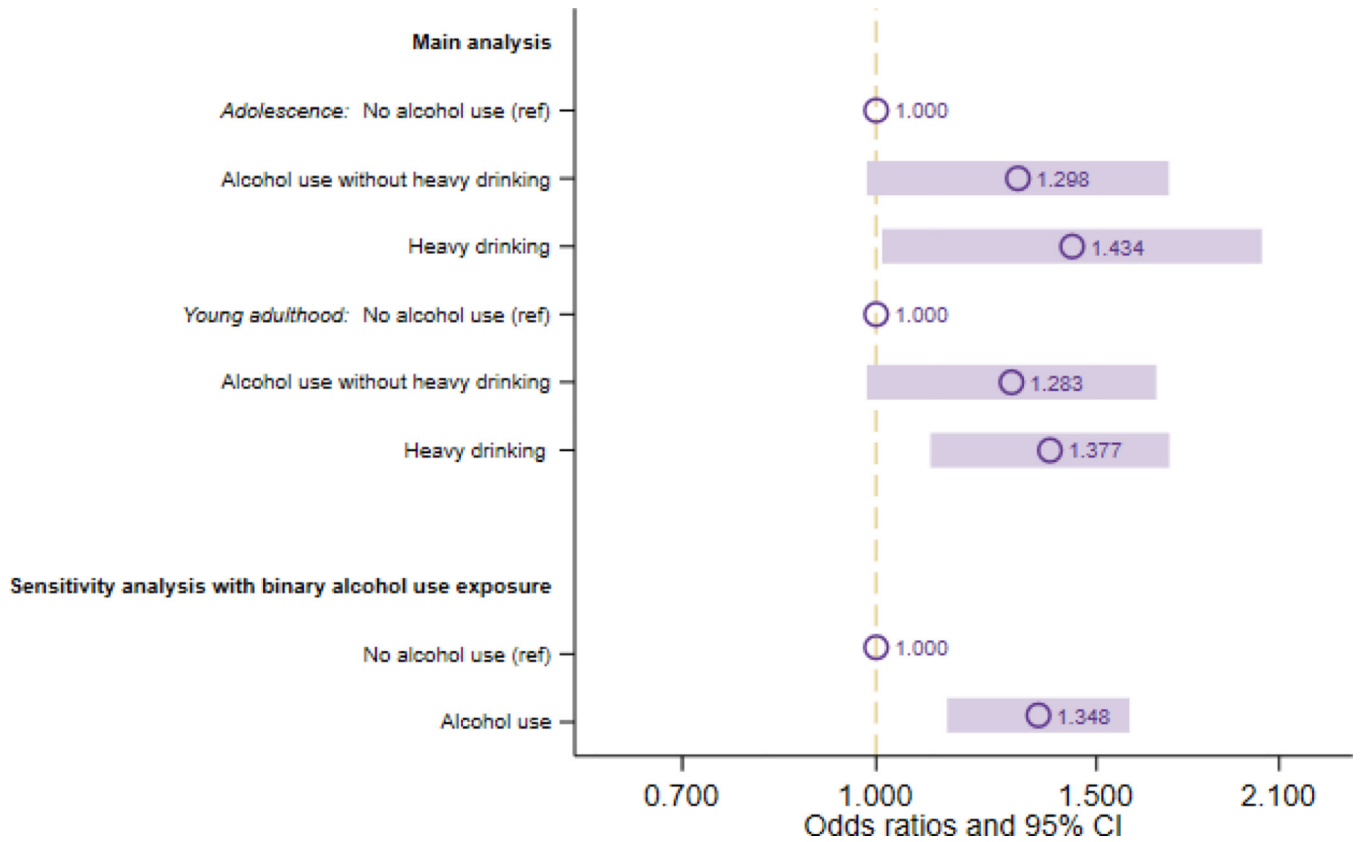
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**Figure 1.** Proportion of CYDS participants reporting alcohol use without heavy drinking, heavy drinking, and handgun carrying at each wave  
 Note. Each age on the x-axis represents handgun carrying reported in that study wave about the prior 12 months, alcohol use in that study wave about the prior 30 days, and heavy drinking in that study wave in the past 2 weeks. Ages without scatter points represent years where a survey was not administered.



**Figure 2.** Estimated associations (adjusted odds ratios) and 95% confidence intervals (bars) of lagged alcohol use and subsequent handgun carrying among youth from rural areas  
 Note. All associations were estimated using population-averaged general estimating equations with logistic regression. All regressions were adjusted for individual-level demographic characteristics (age at grade 0 interview, gender), individual-peer-level risk and protective factors (rebelliousness scale, sensation-seeking scale, close friend alcohol use, close friend handgun carrying) family-level risk and protective factors [parental/guardian maximum education, attendance at religious services, family history of severe alcohol or drug problem, family conflict scale), community demographic characteristics (percent of students on free and reduced price lunch, total student population) and community-level risk and protective factors (community norms favorable towards problem behaviors scale, community disorganization scale, community attachment scale). Time-varying covariates were lagged. Standard errors were clustered at the individual-level.



**Table 1.**

Differences in handgun carrying and other characteristics by alcohol use from Age 12–23

	Never reported any alcohol use (Age 12–23) (n = 336)		Reported alcohol use but never reported heavy drinking (Age 12–23) (n = 354)		Reported heavy drinking (Age 12–23) (n = 1,298)	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Reported handgun carrying at least once (Age 13–26)	59	17.6	70	19.8	421	32.4
Covariates	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Male	184	54.8	155	43.8	693	53.4
Parental/guardian education college or more	153	45.5	141	39.8	498	38.4
Family history of substance use problem	185	55.1	240	67.8	1,029	79.3
Close friends (1 or more) who used alcohol	19	5.6	39	11.0	265	20.4
Close friends (1 or more) who carried a handgun	9	2.7	12	3.4	102	7.9
Attendance at religious services	197	58.6	176	49.7	636	49.0
	<i>mean</i>	<i>SD</i>	<i>mean</i>	<i>SD</i>	<i>mean</i>	<i>SD</i>
Age at first interview	12.1	0.4	12.0	0.4	12.1	0.4
% students in community eligible for free/reduced lunch	38.5	12.1	41.2	13.1	42.0	13.0
Total student population in thousands	5.0	2.8	3.5	2.3	3.6	2.4
Rebelliousness	1.4	0.6	1.6	0.6	1.7	0.7
Sensation seeking	1.8	1.1	2.0	1.2	2.5	1.4
Family conflict	1.8	0.7	1.9	0.8	2.0	0.8
Community norms	1.7	0.8	1.8	0.8	2.0	0.9
Community disorganization	1.4	0.5	1.5	0.5	1.5	0.6
Community attachment	3.3	0.8	3.2	0.9	3.2	0.9

**Note.** All descriptive statistics are *n* and % unless otherwise explicitly noted next to the variable name. Time-varying covariates are reported at the first available data collection point (age 12 for rebelliousness, close friend alcohol use, family conflict, attendance at religious services, community norms, community disorganization, and community attachment, and age 13 for sensation seeking and close friend handgun carrying). There were 14 participants who never provided a response to both questions about alcohol use and heavy drinking.

**Table 2.**

Estimated associations of lagged alcohol use and subsequent handgun carrying among youth from rural areas

Outcome: Subsequent handgun carrying		Main analysis		Sensitivity analysis with binary alcohol exposure	
Variable	Odds ratio	95% CI	Odds ratio	95% CI	95% CI
<b>Alcohol use, heavy drinking at different developmental stages</b>					
<i>During adolescence</i>					
<i>None (ref)</i>					
<i>Alcohol use without heavy drinking</i>	1.298	[0.983, 1.714]			
<i>Heavy drinking</i>	1.434	[1.011, 2.034]			
<i>During young adulthood</i>					
<i>None (ref)</i>					
<i>Alcohol use without heavy drinking</i>	1.283	[0.941, 1.629]			
<i>Heavy drinking</i>	1.377	[1.075, 1.681]			
<b>Any alcohol use</b>					
<i>No alcohol use (ref)</i>			1.348		[1.139, 1.594]
<i>Any alcohol use</i>			1.068		[0.855, 1.334]
<i>Age at Grade 6 interview</i>			4.104		[3.296, 5.112]
<i>Male gender</i>			1.039		[0.857, 1.260]
<i>Parental/guardian maximum education</i>			1.085		[0.955, 1.233]
<i>Rebelliousness</i>			0.971		[0.824, 1.145]
<i>Attendance at religious services</i>			1.001		[0.993, 1.009]
<i>% students on free and reduced lunch</i>			1.034		[0.995, 1.075]
<i>Total student population</i>			1.051		[0.974, 1.134]
<i>Sensation seeking</i>			0.914		[0.744, 1.123]
<i>Friend alcohol use</i>			1.798		[1.439, 2.247]
<i>Friend handgun carrying</i>			1.354		[1.075, 1.706]
<i>Family history of substance use problem</i>			0.970		[0.883, 1.066]
<i>Family conflict</i>			1.148		[1.041, 1.266]
<i>Community norms favorable toward anti-social behavior</i>			1.069		[0.947, 1.206]
<i>Community disorganization</i>			1.032		[1.005, 1.059]
<i>Community attachment</i>			1.032		[1.005, 1.060]

**Note.** All associations were estimated using population-averaged general estimating equations with logistic regression. All exposures and all time-varying covariates (rebelliousness, sensation seeking, friends alcohol use, friends handgun carrying, family conflict scale, attendance at religious services, community norms scale, community disorganization scale, and community attachment scale) were lagged. Standard errors were clustered at the individual-level.

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