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Developing and testing the predictive validity of household firearm storage measures: Insights from rural Alaska

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Abstract

Introduction.—Measuring change in firearm storage is paramount to evaluating if interventions influence storage. Yet, there is little empirical basis for how to measure this change. This methodology study compared three different firearm storage measures using data from the Family Safety Net trial (n=46), a randomized controlled trial among firearm-owning adults in a rural Alaska Native community to encourage unloaded and locked firearm storage.

Methods.—The team compared baseline and one-month follow-up measures of household firearm storage: (1) cumulative firearm accessibility, (2) average firearm accessibility, and (3) number of unlocked firearms. All measures included information about locking status; the cumulative and average firearm accessibility measures incorporated additional information about ammunition. Unadjusted and adjusted generalized estimating equations evaluated the associations of the storage measures with adult perceptions of youth firearm access. Receiver operating

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Patient and public involvement: A local steering committee guided the research in partnership with a tribal health organization, Maniilaq Association, who shaped the project from its inception.

characteristic (ROC) curves from unadjusted models compared the measures' abilities to predict adult perceptions of youth firearm access.

Results.—All household firearm storage measures were sensitive to change between baseline and one-month follow-up ($p < 0.05$). These measures demonstrated a similar and moderate ability to predict adult perceptions of youth access (AUC range: 0.68–0.76).

Conclusion.—The number of unlocked firearms is an easily interpretable outcome when evaluating the effect of firearm storage interventions on storage practices, and it performed similarly well in predicting adults' perceptions of youth firearm access as compared to more complex measures. Research that evaluates the ability of firearm storage measures to predict actual youth access will inform interventions to prevent youth firearm access.

Keywords

firearm injury; firearm storage; violence; suicide; Alaska Native

INTRODUCTION

Many rural households in Alaska Native communities have firearms, often for continuing cultural practices such as subsistence hunting.^{1,2} Yet, firearm-involved intentional and unintentional injuries and fatalities heavily burden American Indian and Alaska Native youth, often through historic trauma, structural racism, and poverty that disrupt intergenerational protective factors.^{3–5} An important strategy to reduce this health inequity in rural Alaska Native communities involves reducing unauthorized youth access to firearms.⁶

Practitioners, legislators, and researchers have developed recommendations, policies, and interventions to prevent or reduce youth access to firearms—often by encouraging or mandating adult owners store firearms locked and unloaded, with ammunition stored separately.^{7,8} These efforts align with research demonstrating that any household firearms stored loaded or unlocked pose a risk to youth safety.^{9,10} Yet, measuring change in household firearm storage remains a challenge.^{8,11} For example, it is unclear how to simultaneously consider the number of firearms in a household, their locked versus unlocked status, and where owners store ammunition.

To evaluate whether interventions or policies prevent unauthorized youth firearm access, the field needs household firearm storage measures that are both associated with youth firearm access and sensitive to change over time. In this methodology study, the team compared three different household firearm storage measures using data from the Family Safety Net trial, a randomized controlled trial among firearm-owning adults in a rural Alaska Native community.

METHODS

This study uses data from the Family Safety Net pilot study, a trial to test suicide lethal means reduction and firearm safety interventions among adults living in households with firearms in a rural Alaska Native community. Supplemental Methods 1 details the trial.

Briefly, the trial randomized participants into one of four arms that encouraged unloaded and locked firearm storage. Supplemental Figure 1 illustrates the analytic flow diagram, which collapsed all study arms into one analytic sample for the present analyses.

Setting and participants

The study took place in a remote Alaskan Native community. The research team, a regional leader, tribal leader and the tribal health and social services organization, Maniilaq Association, co-led recruitment. Recruitment strategies included flyers, word-of-mouth invitations, local radio announcements, and snowball sampling. Eligibility criteria for the study included: age 18 years or older, residing in Northwest Alaska at least five years, living in households with firearms, having people under age 29 spend time in their homes, and access to a cell phone capable of receiving text messages. Only one adult per household could participate in the study.

Data Collection

Participants completed a questionnaire at baseline and one-month post-intervention. Participants could complete the questionnaire independently on a tablet or have a researcher read the questions aloud and input responses. The questionnaire took an average of 18 minutes to complete (range 5–45 minutes). Participants received \$20 for the baseline and \$30 for follow-up questionnaires. Supplemental Table 1 provides questionnaire item wording and response options.

Measures

Household firearm storage inventory.—The team collected information about firearm storage from participants in an inventory. Participants identified up to five firearms stored in their home. For each firearm, participants answered five questions about storage, which indicated if: 1) the firearm was locked with a cable or trigger lock; 2) the firearm was locked in a gun safe/cabinet; 3) the firearm was unloaded; 4) the firearm’s ammunition was stored away from the firearm; and 5) the firearm’s ammunition was locked in an ammo box. Response options included “yes,” “no,” and “not sure.” The team considered “not sure” responses as missing. The household firearm storage inventory informed three different household firearm storage measures: cumulative firearm accessibility, average firearm accessibility, and the number of unlocked firearms.

Less than five participants reported storing any firearms loaded, precluding analyses of a measure of loaded firearm storage, loaded *and* unlocked firearm storage, or loaded *or* unlocked firearm storage.

The team limited the inventory to five firearms based on community input to limit participant burden. Among the analytic sample, less than five respondents reported owning more than five firearms.

Cumulative firearm accessibility. The cumulative firearm accessibility from the household firearm storage inventory involved two steps. First, the team calculated a firearm accessibility score for each firearm (firearm accessibility score range, 4–8), with higher

scores reflecting more accessible firearms. Each firearm received two points for being stored unlocked (versus one point for locked), loaded (versus one point for unloaded), with ammunition (versus one point for away from ammunition), and with ammunition unlocked (versus one point for ammunition locked). The cumulative firearm accessibility score summed the individual firearm accessibility scores for all firearms within the home, with up to five household firearms (possible cumulative firearm accessibility range: 4–40). As such, households with more firearms had a higher upper bound for possible scores as compared to households with fewer firearms.

Average firearm accessibility.: The average firearm accessibility score was similar to the cumulative firearm accessibility, but the average firearm accessibility score averaged the scores for all firearms within the home (rather than summing), with up to five household firearms (possible average firearm accessibility range: 4–8). Due to this averaging, the number of household firearms did not influence the lower and upper bound for possible scores.

Number of unlocked firearms.: From the household firearm storage inventory, the team calculated the total number of firearms stored unlocked, for up to five firearms per participant.

Perceived youth firearm access.—Participants reported the ages of the other people who spent time in their home. For each age group of children and adolescents (e.g., under 7 years, 7–11 years, 12–17 years), participants indicated how long it would take these youth to access a household firearm and fire it. Response options included: 1) less than 15 minutes; 2) between 15 minutes and one hour; 3) they couldn't get access to a gun and fire it, and; 4) I don't know how long it would take. The team considered "I don't know how long it would take" responses as missing. For participants who indicated multiple age groups of children and adolescents who spent time in their homes, the team retained the response option with the shortest time to access and fire a firearm. The team dichotomized youth access into no access (i.e., they couldn't get access to a gun and fire it) versus access (i.e., access in less than 15 minutes or between 15 minutes and one hour).

Statistical Analyses

To evaluate sensitivity to change, the team examined differences at baseline and one month follow-up in the three household firearm storage measures using the Wilcoxon signed-rank test (for continuous measures) and McNemar's Chi-squared test with continuity correction (for categorical measures).

Generalized estimating equations evaluated the associations of the three household firearm storage measures with concurrent perceived youth firearm access. All models included an exchangeable correlation structure to account for within-person correlation. The team estimated both unadjusted and adjusted models that controlled for participant gender and age.

To compare household firearm storage measures' abilities to predict perceived youth firearm access, the team created receiver operating characteristic (ROC) curves from the unadjusted

mixed effects logistic regression models and calculated the corresponding area under the curve (AUC).¹² The team used the DeLong method to test for differences in the AUCs at $\alpha = 0.05$.¹³

The team used R version 4.3.1 for all statistical analyses, including the geepack¹⁴ package for generalized estimating equation models and the pROC package¹⁵ for ROC curves.

Public Involvement

A local steering committee guided the research in partnership with a tribal health organization, Maniilaq Association, who shaped the project from its inception. The University of Michigan Institutional Review Board (IRB) (HUM#00199229) and Maniilaq Association Board approved this study. All participants provided informed consent.

RESULTS

Table 1 provides descriptive statistics for the sample. The average age of the 46 participants was 43.7 years (SD=16.5 years, range=18–76 years). All participants identified as American Indian or Alaska Native, and most identified as male (n=29; 63%). Supplemental Table 2 details differences between participants who had complete and incomplete data.

On average, participants' cumulative firearm accessibility scores (baseline: $\bar{x} = 15.0$, SD=8.6; follow-up: $\bar{x} = 11.7$, SD=6.0; $p < 0.01$), average firearm accessibility scores (baseline: $\bar{x} = 5.47$, SD=0.76; follow-up: $\bar{x} = 4.27$, SD=0.49; $p < 0.01$), and number of unlocked firearms (baseline: $\bar{x} = 1.86$, SD=1.66; follow-up: $\bar{x} = 0.18$, SD=0.46; $p < 0.01$) decreased between baseline and follow-up, as did perceived youth firearm access (baseline: n=17 [47.2%]; follow-up: n=6 [18.1%]; $p = 0.03$; Table 1).

Table 2 provides results from the generalized estimating equation models. Higher cumulative firearm accessibility scores (OR=1.09, 95% CI=1.03–1.17; aOR=1.10, 95% CI=1.03–1.17), higher average firearm accessibility scores (OR=2.87, 95% CI=1.55–5.33; aOR=2.86, 95% CI=1.54–5.29), and higher counts of unlocked firearms (OR=1.99, 95% CI=1.24, 3.18; aOR= 1.99; 95% CI=1.24–3.19) were all associated with higher odds of perceived youth firearm access. All three household firearm storage measures performed similarly and moderately in predicting adult perceptions of youth firearm access (cumulative firearm accessibility: AUC=0.68, 95% CI=0.54–0.82; average firearm accessibility: AUC=0.74, 95% CI=0.62–0.86; number of unlocked firearms: AUC=0.76, 95% CI=0.64–0.88; Table 2; Figure 1).

DISCUSSION

The number of unlocked firearms in a home is an easily interpretable outcome when evaluating the effect of firearm storage interventions on storage practices. This measure was sensitive to change over time in the present sample of firearm owners in a rural Alaska Native community, and it performed similarly in predicting adults' perceptions of youth firearm access as compared to more complex measures that incorporated information about ammunition storage.

The findings suggest that ammunition storage state may not influence adults' perceptions of youth firearm access beyond locked/unlocked firearm storage. Yet, researchers have found that storing ammunition locked and separately from a firearm may reduce firearm injuries among children and adolescents.¹⁰ Following this evidence, the American Academy of Physicians,^{16–18} the American Academy of Child and Adolescent Psychiatry,¹⁹ the National Shooting Sports Foundation,²⁰ and the U.S. Concealed Carry Association,²¹ recommend storing ammunition locked and separately from firearms to keep youth safe. Although ammunition storage may not influence adults' perceptions of youth access to firearms, it may influence actual access. Alternatively, it may be that ammunition storage has little additional influence on youth safety in a house where at least one firearm already is stored unlocked.

Although a change in the number of unlocked firearms may indicate the effect of an intervention on influencing storage practices, we know less about this measures' association with actual youth firearm access. Notably, the present analyses relied on adult perceptions of youth firearm access; parents' perceptions of youth firearm access often underestimate what youth report.²² Future research that evaluates household firearm storage measures against youth perceptions of their own firearm access, and case-control designs that evaluate these measures against actual youth firearm access, would inform the predictive validity of household firearm storage measures and inform strategies to prevent youth firearm access.

Limitations

The study is subject to limitations. All firearms that participants reported as loaded were also unlocked, precluding the opportunity to evaluate how the loaded status of a firearm, alone, predicts adult perceptions of youth firearm access. Additionally, the storage inventory did not capture all firearms in the few households reporting more than five firearms. As this study relies on a small sample of Alaska Native community members living in rural Alaska, future research also is needed to validate the present findings and evaluate their generalizability to different geographies and populations. Many participants did not know their firearms' storage states, introducing a substantial amount of missing data. The present study also combined perceived youth access data for multiple age groups (under 7 years, 7–11 years, 12–17 years). Associations between household firearm storage and youth access, however, may vary between different age groups. Additionally, the evaluated household firearm storage measures did not account for temporary storage locations or the time spent in designated storage locations. Finally, analyses were unable to assess if the presence of a firearm (regardless of storage state) is associated with perceived youth access, as the study only included adults living in a home with firearms.

Conclusions

The number of unlocked firearms is an easily measured and interpretable outcome when evaluating the effect of interventions on storage practices. Research that evaluates the ability of firearm storage measures to predict actual youth access will inform interventions to prevent youth firearm access.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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What is already known on this topic.

Practitioners, legislators, and researchers have developed recommendations, policies, and interventions to prevent or reduce youth access to firearms—often by encouraging or mandating adult owners store firearms locked and unloaded, with ammunition stored separately. Measuring change in household firearm storage is fundamental to evaluating if such policies and interventions influence firearm storage practices.

What this study adds.

Using data from firearm-owning adults in a rural Alaska Native community, this study found three different household firearm storage measures that are sensitive to change over time and associated with adult perceptions of youth firearm access.

How might this study affect research, practice, or policy?

The number of unlocked firearms in a home is an easily interpretable outcome when evaluating the effect of firearm storage policies and interventions on storage practices. Future work to evaluate the ability of firearm storage measures to predict actual youth access is necessary to inform strategies that prevent youth firearm access.

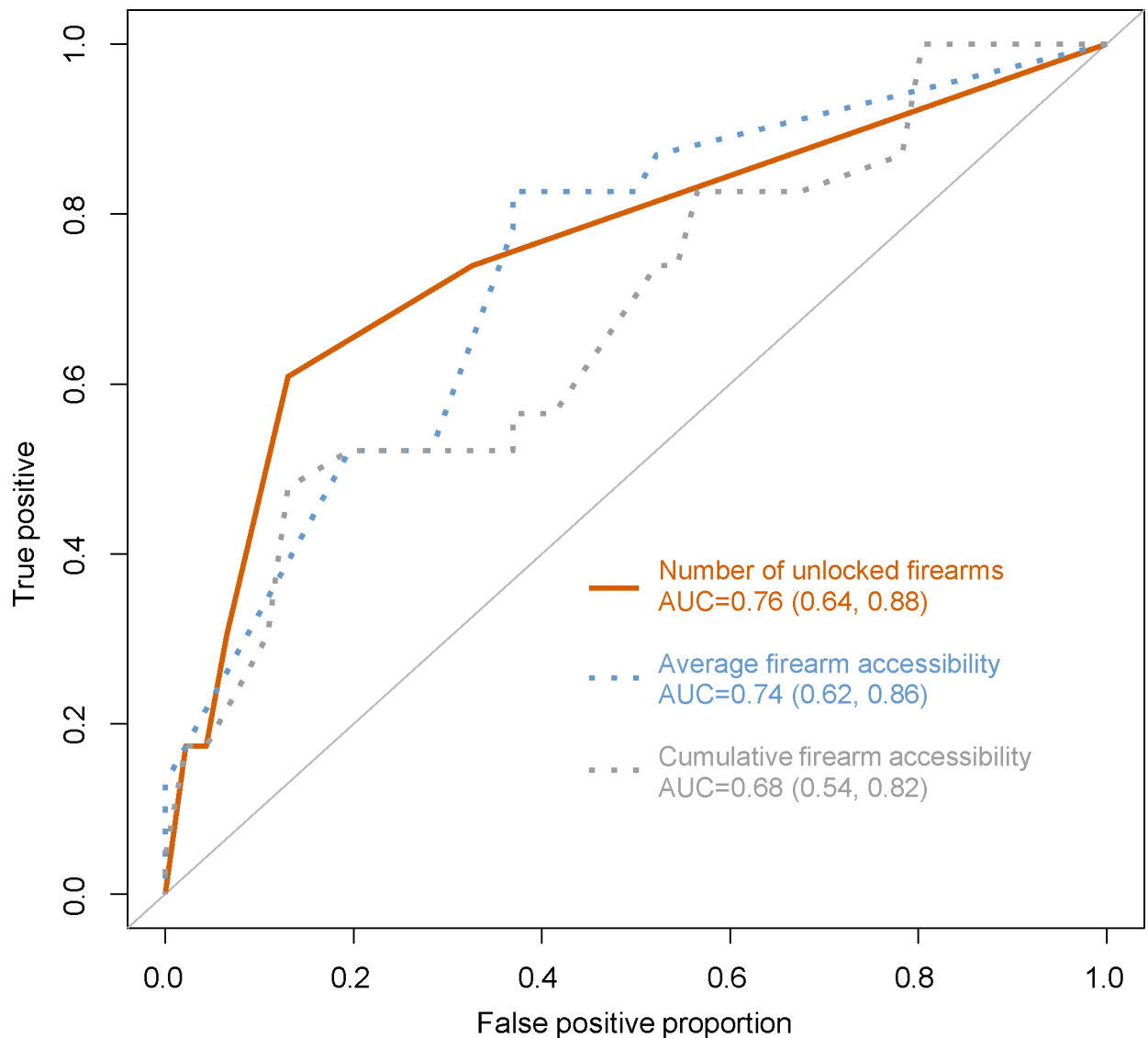


Figure 1.

Receiver operating characteristic curve (ROC) and area under the curve (AUC) for predicting perceived youth firearm access^a based on (1) number of unlocked firearms, (2) average firearm accessibility^b, and (3) cumulative firearm accessibility^c, among participants (n=46; 69 participant-assessments) from the Family Safety Net Study in rural Alaska 2023.

Notes. Predictions based on generalized estimating equation results for the associations of three different firearm storage variables with perceived youth firearm access.

a. Perceived youth firearm access is a dichotomous indicator that reflects if participants think that children or adolescents (aged 0–17 years) could access the firearms in their home.

b. Average firearm accessibility (range 4–8) reflects average accessibility to unlocked and loaded firearms and ammunition, developed in two steps: 1) each firearm in the home (up to 5 firearms) received two points for being stored unlocked (versus one point for locked), loaded (versus one point for unloaded), with ammunition (versus one point for away from

ammunition), and with ammunition unlocked (versus one point for ammunition locked); 2) the team averaged the firearm accessibility scores for all firearms in the home.

c. Cumulative firearm accessibility (range 4–40) reflects cumulative accessibility to unlocked and loaded firearms and ammunition, developed in two steps: 1) each firearm in the home (up to 5 firearms) received two points for being stored unlocked (versus one point for locked), loaded (versus one point for unloaded), with ammunition (versus one point for away from ammunition), and with ammunition unlocked (versus one point for ammunition locked); 2) the team summed firearm accessibility scores for all firearms in the home.

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Table 1.

Demographic characteristics, firearm storage, and perceived youth firearm access among the analytic sample from the Family Safety Net Study in rural Alaska ($n=46$) at baseline and one-month follow-up, 2023.

	Mean (standard deviation) or n (%)			
	Full sample $n=46$	Baseline $n=36$	Follow-up $n=33$	Test for difference $n=23$
<u>Demographic characteristics</u>				
Age, in years	43.7 (16.5)	--	--	--
Gender		--	--	--
Male	29 (63.0%)			
Female	17 (37.0%)			
Race		--	--	--
American Indian or Alaska Native	46 (100%)			
Ethnicity		--	--	--
Hispanic	<i>suppressed</i>			
Non-Hispanic	<i>suppressed</i>			
Relationship to youth ^a		--	--	--
Parent/grandparent	23 (50.0%)			
Aunt/uncle/other adult family member	12 (26.1%)			
Brother/sister/cousin	11 (23.9%)			
Friend	6 (13.0%)			
Other	<i>suppressed</i>			
Age group of youth visiting the home ^a				
Under 7 years	-	22 (61.1%)	22 (66.7%)	
7–11 years	-	22 (61.1%)	22 (66.7%)	
2–17 years	-	29 (80.6%)	28 (84.8%)	
<u>Firearm storage</u>				
Cumulative firearm accessibility ^b	--	15.0 (8.6)	11.7 (6.0)	$V=231, p<0.01$
Average firearm accessibility ^c	--	5.47 (0.76)	4.27 (0.49)	$V=210, p<0.01$
Number of unlocked firearms	--	1.86 (1.66)	0.18 (0.46)	$V=136, p<0.01$
<u>Perceived youth firearm access</u>				
Perceived youth firearm access ^d	--	17 (47.2%)	6 (18.1%)	$\chi^2(1, N=23) = 5.00, p=0.03$

Notes. The table suppresses data where cell counts are non-zero and <5 and data that enable inferring exact non-zero cell counts <5 . Tests for differences based on the Wilcoxon signed-rank test (continuous variables) and McNemar's Chi-squared test (categorical variables) with continuity correction.

^a. Non-mutually exclusive categories; percentages do not add to 100%.

^b. Cumulative firearm accessibility (range 4–40) reflects cumulative accessibility to unlocked and loaded firearms and ammunition, developed in two steps: 1) each firearm in the home (up to 5 firearms) received two points for being stored unlocked (versus one point for locked), loaded (versus one point for unloaded), with ammunition (versus one point for away from ammunition), and with ammunition unlocked (versus one point for ammunition locked); 2) the team summed firearm accessibility scores for all firearms in the home.

^c. Average firearm accessibility (range 4–8) reflects average accessibility to unlocked and loaded firearms and ammunition, developed in two steps: 1) each firearm in the home (up to 5 firearms) received two points for being stored unlocked (versus one point for locked), loaded (versus one point

for unloaded), with ammunition (versus one point for away from ammunition), and with ammunition unlocked (versus one point for ammunition locked); 2) the team averaged the firearm accessibility scores for all firearms in the home.

d. Perceived youth firearm access is a dichotomous indicator that reflects if participants think that children or adolescents (aged 0–17 years) could access the firearms in their home.

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Table 2.

Comparison of the accuracy of household firearm storage measures for predicting perceived youth firearm access^a among participants (n=46 participants; 69 participant- assessments) from the Family Safety Net Study in rural Alaska 2023.

Household firearm storage measure	OR (95% CI)	aOR (95% CI)	AUC (95% CI)	AUC comparisons <i>p</i> -value
1. Cumulative firearm accessibility ^b	1.09 (1.03, 1.17)	1.10 (1.03, 1.17)	0.68 (0.54, 0.82)	0.50 vs 2 0.30 vs 3
2. Average firearm accessibility ^c	2.87 (1.55, 5.33)	2.86 (1.54, 5.29)	0.74 (0.62, 0.86)	0.50 vs 1 0.70 vs 3
3. Number of unlocked firearms	1.99 (1.24, 3.18)	1.99 (1.24, 3.19)	0.76 (0.64, 0.88)	0.30 vs 1 0.70 vs 2

Notes. Results are from generalized estimating equation models using adult perceptions of youth firearm access as the outcome. *p*-values are from the comparison of AUCs using the DeLong method. AUCs are from the unadjusted models. **Bold** indicates significance at $\alpha = 0.05$. Adjusted odds ratio control for age (in years) and male gender.

Abbreviations: aOR, adjusted odds ratio; AUC, area under the receiver operating characteristic curve; CI, confidence interval; OR, odds ratio.

^a Perceived youth firearm access is a dichotomous indicator that reflects if participants think that children or adolescents (aged 0–17 years) could access the firearms in their home.

^b Cumulative firearm accessibility (range 4–40) reflects cumulative accessibility to unlocked and loaded firearms and ammunition, developed in two steps: 1) each firearm in the home (up to 5 firearms) received two points for being stored unlocked (versus one point for locked), loaded (versus one point for unloaded), with ammunition (versus one point for away from ammunition), and with ammunition unlocked (versus one point for ammunition locked); 2) the team summed firearm accessibility scores for all firearms in the home.

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