HHS Public Access

Author manuscript

J Behav Med. Author manuscript; available in PMC 2020 August 01.

Published in final edited form as:

J Behav Med. 2019 August ; 42(4): 635–645. doi:10.1007/s10865-019-00021-8.

Predictors of transitions in firearm assault behavior among drug-using youth presenting to an urban emergency department

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Abstract

Risk and protective factors for firearm assault (FA) have been established, but little is known about factor preceding transitions in FA behavior. We modeled covariate effects on individuals' transitions in FA behavior (Yes/No) using inhomogeneous, continuous-time, Markov Chains. 3287 assessments were made across five initial biannual follow-ups, and two additional biannual follow-ups (an average of 2.2 years later) from a follow-on study; 2687 pairs of transitions were observed (2414 No-FA → No-FA; 89 No-FA → FA; 121 FA → No-FA; 63 FA → FA). Non-firearm peer violence (HR = 2.31, 95% CI [1.28,4.21]), firearm victimization (HR = 2.57, 95% CI [1.31,5.04]), and marijuana ASSIST sum (HR = 1.27, 95% CI [1.05,1.54]) all preceded transitions into FA, but not transitions out of FA. Delinquent peer associations both hastened transitions into FA (HR = 1.19, 95% CI [1.00,1.40]) and slowed transitions out of FA (HR = 0.84, 95% CI:[0.72,1.00]), with analogous findings regarding attitudes favoring retaliation. Efforts to prevent FA initiation should

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Conflict of interest Jason E. Goldstick, Patrick M. Carter, Justin E. Heinze, Maureen A. Walton, Marc Zimmerman, and Rebecca M. Cunningham have no conflicts of interest to report.

Human and animal rights and Informed consent All procedures were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent (and parental consent with youth assent for participants under 18) was obtained from all individual participants included in the study.

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focus on those currently reporting firearm violence victimization, and on factors indicating an escalating delinquency trajectory (e.g. non-firearm violence, substance use), while programs focusing on peer influences and social norms may be effective at preventing FA regardless of current FA status.

Keywords

Firearms; Violence; Substance use; Emergency department; Transitions

Introduction

Firearm violence is a significant public health problem in the United States, particularly among youth. Specifically, firearm violence is the 2nd leading cause of death of children in the US, with rates 37 times higher than 12 comparable nations, an order of magnitude higher than the relative differences between countries on other leading causes of death (Cunningham et al., 2018). This epidemic disproportionately affects African American youth in the US, among which it is the leading cause of death (CDC, 2017). Recognizing the scope of this problem, and the opportunity clinicians have to be an integral part of addressing it, editors of the Journal of the American Medical Association (Bauchner et al., 2017) have made a public appeal to medical professionals to assist with the development and implementation of firearm violence prevention programs. In that editorial, the editors suggested a role of clinicians in encouraging safe storage, and in conducting screening for suicide risk and firearm violence risk. Determining factors that precede transitions—or changes—in firearm assault behaviors (FA) among youth is vital to the development of prevention programs. Research that includes both factors preceding transitions into FA are ones to consider for preventing FA initiation, and those preceding transitions out of FA may aid in disrupting a deleterious trajectory.

Prior researchers have identified correlates of FA and associated behaviors. In particular, substance use is a consistent and robust correlate of firearm violence (Carter et al., 2015; Darke, 2010; Harford et al., 2013; McGinty et al., 2016) and associated behaviors, such as firearm carrying (Steinman & Zimmerman, 2003; Wintemute, 2011) and a propensity for making threats about firearm violence (Casiano et al., 2008). In addition, substance use plays a role in the link between mental illess and violence perpetration; specifically, evidence suggests that mental health symptoms are correlated with violence perpetration primarily when there is co-occurring substance use (Elbogen & Johnson, 2009; Goldstick et al., 2018a). Other psychosocial risk factors, including prior violence (Goldstick et al., 2017a; Spano & Bolland, 2013), delinquent peer affiliations (Goldstick et al., 2017a; Lizotte et al., 2000), community violence exposure (Halliday-Boykins & Graham, 2001; Burgason et al., 2014), and attitudes toward retaliation (Carter et al., 2015) have all proven to be associated of firearm carriage and/or violence involvement. Yet, no prior researchers have focused on factors that precede transitions in FA. To clarify relationships and associations underlying youth FA, existing findings must be extended to show how substance use and psychosocial factors combine to modulate transitions in FA behaviors.

Some evidence suggests that risk factors for interpersonal violence may differ based on one's current level of violence involvement. For example, researchers have found that the initiation of partner violence was associated with employment status, while persistence of pre-existing partner violence was not (Jasinski, 2001; Lorber & O'leary, 2004). The fact that many researchers studying violence etiology focus specifically on violence persistence (Eke et al., 2011; Kosterman et al., 2001; Lorber & O'leary, 2004; Walton et al., 2002) or violence initiation (Foshee et al., 2010; Swahn & Donovan, 2004; Williams et al., 2007) reflects an acknowledgment that there are differences in the etiology between the two. Thus, factors facilitating transitions in FA may differ from generalized risk factors. Yet, FA researchers have not incorporated such nuance; specifically, no prior researchers have examined what factors precede FA transitions, and how factors preceding transitions *into* FA are differentiated from those preceding transitions *out* of FA.

Understanding risk and protective factors for transitions in an emergency department (ED) or hospital-based cohort may be an important factor in taking advantage of the opportunity with which clinical staff are presented. Prior hospital-based violence prevention programs have primarily relied on the reason for their hospital visit—specifically, whether or not the patient arrived at the hospital due to a violent injury—as an indication that prevention services are warranted. Yet, that approach only considers secondary prevention. Recent work has identified potentially effective screening strategies for future firearm violence (Goldstick et al., 2017a) and intervention (Walton et al., 2010; Cunningham et al., 2012; Carter et al., 2016), involvement that is not restricted to youth presenting with a violent injury. Capitalizing on such strategies for firearm violence prevention requires understanding what drives changes in FA behavior and whether the etiology of future FA is modulated based on current FA involvement.

In this study, we used data from the Flint Youth Injury (FYI) study (Cunningham et al., 2015; Bohnert et al., 2015), a prospective study of drug-using youth presenting to an urban emergency department (ED), to characterize transitions in FA behavior across seven time points. Using inhomogeneous Markov Chain models, we estimated transition rates between FA (Yes/No), and how those rates were modulated by demographics, and validated measures of substance use, peer influences, community violence exposure, peer and intimate partner non-firearm violence, violence attitudes, and depression and anxiety symptoms. Within this unified framework, we tested whether covariate effects on the risk of future FA differed based on current FA involvement. Our hypothesis was that transitions into FA would be preceded by lesser delinquent behaviors, such as non-firearm violence and substance use, while transitions out of FA would be facilitated by lowered community violence exposure and fewer delinquent peer affiliations.

Methods

Study design and setting

The Flint Youth Injury (FYI) study is a two-part prospective cohort study that began with the recruitment of drug-using (predominantly marijuana) youth age 14–24 at the Hurley Medical Center in Flint, Michigan. The primary aim of the FYI study was to ascertain the medical

service needs of assault-injured (AI) and non-assault-injured comparison group (CG) youth presenting to the ED (see Bohnert et al., 2015).

Recruitment for the first part (FYI-1) of the FYI study occurred from 12/2009 to 09/2011, 7 days a week, 5am–2am. All AI youth arriving during recruitment shifts were screened. To guard against secular trends in recruitment of AI and CG youth, the next available CG arrival with the same age group (14–17, 18–20, 21–24) and sex as the last AI recruit was approached for screening. Youth responding positively to any past-6-month substance use were eligible for the study. Per study protocols, staff excluded those reporting sexual assault, suicidal ideation, and those that could not consent due to a medical or mental health condition. Staff attempted to recruit initially unstable patients if they stabilized within 72 h of admission. Eligible youth who enrolled in the longitudinal study (n = 599; 349 AI and 250 CG) were measured at baseline, 6-, 12-, 18-, and 24-months, and were remunerated $20, $30, $40, $45, and $50 for those assessments, respectively. The baseline sample was 58.3% African American, 58.8% male, and had an average age of 19.9 (SD = 2.4). At every follow-up, > 83.7% of participants were able to be assessed (Roche et al., 2018).

The FYI study continued into a second phase (FYI-2) to collect 2 more waves of data (Buu et al., 2017). FYI-2, in addition to continuing to measure substance use, violence, and related outcomes among recruited youth, comprised a randomized control trial comparing methods for daily data collection. Recruitment for FYI-2 proceeded by re-contacting FYI-1 participants who were over age 18 and had consented to being re-contacted at the conclusion of FYI-1; this recruitment occurred in two cohorts, the first taking place 3/2014–9/2014, and the second occurring 1/2015–1/2016. In total, 352 FYI-1 participants were enrolled for the second study, and were measured at baseline, 6-months post baseline, for which individuals were remunerated $20, and $30, respectively. Retention remained high at 6-month follow-up (n = 308; 87.5%). In both studies, informed consent was obtained (and assent, with parental consent, for minors) for all participants and an NIH certificate of confidentiality was obtained; IRBs at Hurley Medical Center and the University of Michigan approved all protocols.

Measures

The present inquiry focuses on surveys conducted at seven time points in FYI-1/FYI-2, and not the other measurements obtained (chart reviews, timeline-follow back, daily assessments in FYI-2). The survey length was reduced in FYI-2 and thus some measures were eliminated; we focus solely on measurements that were consistent and available across both phases of the longitudinal study. See the study supplemental materials (web link goes here) for wording of several key measures.

Firearm assault (FA)

This analysis focuses on modeling transitions in self-reported FA, which was measured at each time point based on any affirmative response to four questions regarding frequency of firearm assault. Past 6-month intimate partner (“You used a gun on him/her”) and non-partner (“You used a gun on someone”) FA frequency were measured using the modified Conflict Tactics Scale (Straus et al., 1996). Frequency of past 6-month firearm assault via

threats (“You pulled a gun on someone”) was measured using an item adapted from the National Longitudinal Study of Adolescent Health (Sieving et al., 2001). Each question was measured on a six point scale (0: “Never”, 6: “20 + times”); a response of anything other than “Never” on any of the three questions was coded positive for firearm assault, and is treated as the FA “state” variable in sub-sequent analyses.

Covariates

Demographics (age, sex, race) were self-identified using validated instruments from prior studies (Handelsman et al., 2005; Sieving et al., 2001). Given that the sample was predominantly either African American or Caucasian, we dichotomized race to an indicator of African American race.

We measured violence exposure and attitudes with a variety of validated measurements of peer behaviors, community violence exposure, and personal beliefs about violence. Items from the modified Conflict Tactics Scale (Straus et al., 1996) measured non-firearm-related violence in analogous fashion to the FA outcome measure. For descriptive analyses, we stratified violence experience by moderate (e.g. slapping) and major (e.g. choking, burning) violence. We used an indicator of any past-6-month self-reported firearm violence victimization as a covariate, but not aggression, as it is endogenous to the outcome. A subscale from the “Children’s Perceptions of Environmental Violence” (Hill & Noblin, 1991) survey measured retaliatory attitudes as the average of seven items, with lower scores indicating attitudes more favorable to retaliation. A scale from the “Things I’ve Seen and Heard” Survey (Richters & Martinez, 1990) measured community violence exposure as the average of five items (e.g. “I have heard gunshots in my neighborhood”) measuring the frequency of community violence exposures. A scale from the Flint Adolescent Study (Zimmerman et al., 2002) measured delinquent peer behaviors (7 items) and positive peer behaviors (4 items), each calculated as the average of the corresponding items to produce scales of negative, and positive, peer behaviors, respectively.

We measured substance use behaviors and mental health symptoms using validated instruments. The NIDA modified Alcohol, Smoking, and Substance Involvement Screening Test (ASSIST) (Saunders et al., 1993) measured past 6-month drug use; due to cannabis being the primary substance used, the ASSIST sum was only used as a covariate for cannabis. We created a binary indicator of any other illicit drug misuse (ASSIST sum ≥ 4). The Alcohol Use Disorders Identification Test Consumption subscale (AUDIT-C) (Humeniuk et al., 2008) measured past 6 month alcohol consumption. The Brief Symptom Inventory (BSI) measured depression and anxiety symptoms, constructed as summary scores (averages) of twelve items (Piersma et al., 1994).

Statistical analysis

Our primary analytic goal was to characterize transitions in FA behaviors across the seven waves/time points, and to determine the contributions of covariates to those transitions. We began by calculating the number of transitions between states of “FA” and “No-FA” across consecutive time points and descriptively contrasting transitions dichotomies of next-step

transitions (i.e. contrasting FA → FA dyads with FA → no-FA dyads, and No-FA → FA dyads with No-FA → No-FA dyads) to look at unadjusted correlates of transitions in FA.

To obtain adjusted covariate effects on FA state, we used inhomogeneous Markov Chain models (Jackson, 2011). These models operate by parameterizing the transition intensity function, which is analogous to the hazard function in survival analysis models, as a function of covariates. Specifically, the transition intensity—i.e. the instantaneous transition rate—from state i to state j, q_{ij}, is modeled in terms of covariates at the pre-transition time-point, z, as

$$\log\left(q_{ij}\right) = \alpha_{ij} + \beta_{ij}z$$

The probability of a given transition can then be determined from covariate values and the time-lag by exponentiating the transition intensity times the time-lag. As such, differential follow-up periods are handled elegantly within this framework. For example, if the time gap between one participant's 1st and 2nd follow-up is 5.7 months, while it is 6.5 months for another, this framework eliminates the need to treat those two scenarios equivalently. Similarly, missed follow-ups are handled elegantly; for example, if an individual completes the 1st follow-up on 12/01/2010, misses the second follow-up, then completes the 3rd follow-up on 11/25/2011, that transition can be incorporated into the model as an 11.8 month transition, with no assumption about the intermediary state that was missed during the 2nd follow-up. We will report effects in terms of exponentiated regression coefficient estimates, which correspond to adjusted hazard ratio from state i to state j for a one-unit increase in the covariate. For example, if state i is "No FA" and j is "FA", then these hazard ratios will quantify the effect of each covariate on the likelihood of initiating FA, indicating targets for prevention.

We built the Markov Chain model in two steps. First, we selected demographic variables and additional covariates based on unadjusted associations, additionally ensuring constructs of interest in the project (e.g. alcohol use) were included. Noting the relatively small number of transitions from the "FA" state, we sought a process that would borrow information across initial states ("FA" and "No-FA") unless there was strong evidence that such pooling would be misleading. With that in mind, we individually tested whether each variable's effect on future FA differed depending on the current FA state. Specifically, if No-FA is labeled state "0" and FA is labeled as state "1", we tested whether $\beta_{01} = -\beta_{10}$; that is, whether the No-FA → FA transition rate was equivalent to the inverse of the transition rate from FA → No-FA, which amounts to a test of whether the likelihood of being in the FA state differs depending on the current state. For transparency, we reported the results of those tests, in addition to displaying how different the corresponding hazard ratios are without the equality constraint (Table 2). Second, we constructed a final model, with covariate effects constrained to be state-invariant, except those that were found to have significant state-dependence in the first step. This process allowed us to borrow information across transitions to estimate the hazard ratios, aggregating across transitions coming from both Non-FA and FA, partially circumventing the limited sample size among the latter.

Results

Descriptive analysis

Across all follow-ups, we found 211 person/time points where individuals self-reported FA, and those reports came from 123 unique individuals. FA was more commonly reported in the earlier waves, with 9.8% of individuals self-reporting past 6 month FA at baseline, 8.4% at the 1st follow-up, 7.8% at the 2nd follow-up, and rates of 4.3–4.5% in the 3rd–5th follow-ups. At the final follow-up, 2.9% reported FA. We analyzed 2687 consecutive measurements that could be paired within-individual; 2414 (89.8%) of those were No-FA → No-FA pairs, 89 (3.3%) were No-FA → FA pairs, 121 (4.5%) were FA → No-FA pairs, and 63 (2.3%) were FA → FA pairs.

Table 1 shows descriptive contrasts between No-FA individuals who do versus do not transition into FA at the next follow-up, as well as FA individuals who do versus do not transition into No-FA. In terms of demographics, males were more likely to transition into FA from No-FA. Violence exposure, both in terms of aggression and victimization, intimate partner and non-partner violence, and largely across violence severity levels, was associated with transitions from No-FA into FA. In many cases, violence rates (e.g. intimate partner aggression, both major and moderate) were elevated among those who maintained FA, as opposed to those who transitioned from FA into No-FA, but those contrasts were not statistically significant. Depression/anxiety symptoms were not associated with either set of transitions. Negative peer influences and community violence exposure both preceded No-FA → FA transitions, and suggested possible associations with FA maintenance ($p < 0.1$), although again the latter comparisons were not significant. Attitudes favoring retaliation preceded future FA among those not currently endorsing FA; a similar pattern was seen among those currently endorsing FA, but the effect was not significant ($p = 0.06$). Marijuana use preceded No-FA → FA transitions. Elevated rates of alcohol use among those ending up in FA states (both from No-FA and FA) were not significant.

Markov chain models

The variables selected for the adjusted model included demographics, community violence exposure, negative peer influence, retaliatory attitudes, marijuana use, and alcohol use. From among the non-firearm aggression measures we chose an indicator of any intimate partner aggression and an indicator of any non-partner aggression; we made this choice based on substantive differences in the etiologies of those two violence modalities, and visual differences in their relative effect sizes seen in Table 1, particularly with regard to transitions out of No-FA. In addition, the sub-categories of those two aggression categories showed substantial overlap. From among the victimization measures, we chose the most proximate and severe category—firearm victimization, also noting substantial overlap between the non-firearm victimization categories and the firearm victimization categories.

Table 2 shows tests of state-dependence for each covariate selected for the main model. Both non-partner non-firearm aggression ($p = 0.04$), and firearm violence victimization ($p < 0.001$) showed state-dependence, only increasing the risk of future FA among those currently in the No-FA state; among those currently in the FA state, neither variable

modulated their transition rates. Similarly, marijuana use showed state dependence (p = 0.03), only operating as a risk factor for future FA among those currently in the No-FA state. The association between future FA and race also differed based on current FA state (p = 0.04); black youth were more likely to transition into FA from Non-FA, but didn't show an equivalent propensity to stay in the FA state. No other variables tested displayed state dependence.

Table 3 shows the final fitted Markov Chain model, with covariate effects displayed as hazard ratios. The Pearson test, with a test statistic based on a weighted sum of Pearson χ^2 statistics, (Jackson, 2011) supplied no evidence of lack-of-fit (p = 0.27); this is consistent with Fig. 1, which shows the model-predicted prevalence of FA over time, showing no substantial discordance between observed and expected rates. Male and black youth transitioned from No-FA to FA at 55% and 93% faster rates, respectively, than their counterparts. Male youth analogously had 35% slower transition rates out of FA than females. Black youth transitioned out of FA at a 61% faster rate than white youth, but this difference was not statistically significant (p = 0.08). Youth reporting non-partner aggression that did not involve a firearm transitioned into FA from No-FA at over twice the rate of those who did not. Similarly, those with no current FA who reported firearm violence victimization transitioned into FA at more than 2.5 × the rate of those not reporting firearm violence victimization. Greater marijuana use frequency among those with no current FA increased the rate of transition into FA. In contrast, none of non-partner non-firearm violence, firearm violence victimization, or marijuana affected transition probabilities among those currently in the FA state. Youth reporting non-firearm intimate partner violence had 21% faster rates of transition into FA, and 17% slower rates out of FA, than their counterparts, but those effects were not statistically significant. Negative friend associations and attitudes favoring retaliation both increased the transition rate into FA, and slowed the rate of transition out of FA; that is, those factors operate as risk factors for future FA regardless of current FA status.

Discussion

The current work adds to our understanding of FA behavior among youth by estimating the heretofore unknown frequency, and factors preceding, transitions in FA in this high-risk population. Our results indicate that firearm transitions are relatively common, and that some components of the etiology of FA initiation differ from that of FA sustainment, suggesting that FA prevention strategies may need to be tailored to current FA involvement status. On adjusted analysis, several factors were specific to preceding transitions into FA, including non-partner non-firearm aggression, firearm violence victimization, and marijuana use. Psychosocial factors, such as delinquent peer influences, and attitudes favoring retaliation, were both associated with transitions into FA, and inhibitive of transitions out of FA. Black youth and male youth were at higher risk of transitioning into FA, and males were at greater risk of sustaining FA. Our results are broadly consistent with our initial hypothesis that FA initiation would be preceded by lesser delinquency.

Social norms were important risk factors for future FA in this population. We found that that delinquent peer affiliations both facilitate transitions into FA, and slow transitions out of FA,

suggesting social influences as an important universal FA prevention component. This is consistent with prior research indicating the importance of peer influences among youth (Steinberg & Monahan, 2007), particularly with regard to delinquent behavior, such as substance use (Goldstick et al., 2017b), fighting (Mrug et al., 2014), bullying (Paluck et al., 2016), and even firearm violence specifically (Goldstick et al., 2017a). Social influences and normative perceptions may also impact attitudes toward violence and, in particular, attitudes toward retaliation, which were also found to be important risk factors for future FA in our analysis, both in terms of facilitating transitions in FA, and inhibiting transitions out of FA. Youth often have exaggerated perceptions of the norms surrounding delinquent behaviors such as substance use, (Borsari & Carey, 2001; Suls & Green, 2003) and firearm carrying (Hemenway et al., 2011), and norms are modifiable through intervention, (Paluck et al., 2016; Prince & Carey, 2010; Suls & Green, 2003), including attitudes toward firearm violence (Milam et al., 2016). Thus, normative resetting may be a promising route for universal prevention, particularly, when combined with other individual-focused evidenced-based violence prevention strategies, such as motivational interviewing, mentoring, and/or collaborative care models (e.g. Walton et al., 2010; Cunningham et al., 2012; Carter et al., 2016); however, the efficacy of such approaches on FA remains to be determined.

Prior aggression was an important risk factor for transitions into FA in this population, giving evidence to our hypothesis that FA may arise as an escalation from lesser delinquency. In particular, non-partner aggression not involving a firearm more than doubled the rate of FA development. Our findings are consistent with prior studies indicating that earlier onset of delinquency increased the risk of serious violence involvement later (Tolan et al., 2000), and with behavioral theories on the escalation of violence (Tremblay et al., 2006). This escalation hypothesis is also consistent with the fact that non-firearm violence was not associated with FA sustainment; i.e. once an individual is already involved with firearm violence, lesser violence is no longer an important risk factor.

The finding that firearm violence victimization dramatically increased the transition rate into FA suggests a complimentary hypothesis that individuals engage in FA out of a fear of victimization. This is consistent with prior literature that demonstrates that primary motives for firearm carriage/possession include a perceived need for protection or self-defense (Steinman & Zimmerman, 2003; Lizotte et al., 2000; Carter et al., 2013). Yet, the fact that firearm violence victimization was not a risk factor for FA sustainment suggests the habituation of violence inherent to residing in the FA state may render firearm violence victimization less important as a risk factor. In this regard, the efficacy of promising individual-level approaches (e.g. Walton et al., 2010) as well as multi-component community-level approaches such as vacant lot clean-up (e.g. Heinze et al., 2018) should be evaluated for efficacy on prevention of FA.

Substance use was also a key factor in the etiology of FA in this population, giving further evidence of the escalation hypothesis. This finding is consistent with a large body of work consistently showing associations between substance use and violence perpetration (Goldstick et al., 2015, 2018b; Carter et al., 2017; Walton et al., 2009). Our findings were specific to marijuana use, the substance of choice among this study population, perhaps owing to the low rates of other illicit drug misuse, and the comparatively low rates of alcohol

use among this population, particularly given that this is a primarily marijuana-using sample. The fact that substance use only was associated with transitions into FA, and not sustainment of FA, gives further evidence of the hypothesis that FA may arise as an escalation of lesser delinquencies and that, once FA has been initiated, those lesser delinquencies are no longer associated with FA. This result suggests that interventions to reduce youth substance use as well as violence involvement may be productive for interrupting a delinquency trajectory heading toward FA. For example, promising evidenced-based programs could be tested for efficacy on FA (Walton et al., 2010; Cunningham et al., 2012; Carter et al., 2016).

We found some demographic correlates of FA transitions. Our finding adds to the knowledge that males are at higher risk for firearm aggression (Carter et al., 2015) by adding the nuance that males are both more likely to transition into FA and, once there, are slower to transition out. This indicates males are optimal firearm violence intervention candidates, whether it is for primary or secondary prevention. In adjusted analysis, we found that black youth transitioned into FA at greater rates. Racial specificity in the epidemiology of FA highlights the need for culturally tailored interventions, which have been shown to be more effective in the context of other behavioral interventions (Nierkens et al., 2013).

We note some limitations of our work. First, our study was limited to a single city which may limit our generalizability, but this is the first attempt to apply these methods to study FA transitions. Our results suggest it may be a fruitful direction for future research that applies this method with data from different contexts and populations. Second, the lack of temporal specificity on the timing of the FA involvement (other than past-6-month) limits our statistical analysis, which could be strengthened by knowledge of the exact timing of the behavioral transition. Relatedly, we have no way of knowing lifetime FA history prior to participation in our the study, but earlier FA would only mask the results we found, so it may be safe to conclude that our results might actually be stronger if we started with participants who had no FA history prior to out initial data collection. Third, only about 60% of the original cohort was recruited for the follow-on FYI-2 study comprising the final two time points for our analysis. This attrition may have biased our results, but we found no clear imbalances among those who were recruited into the second study beyond the fact that females were more likely to enroll. Fourth, our sample was comprised of drug using youth (> 95% marijuana), which was about half of youth presenting to the emergency department (Bohnert et al., 2015); thus, replication with general samples of youth is required. Finally, due to more limited measures in the follow-on study, we were unable to examine potentially important factors measured only in the first study (e.g., PTSD or substance use disorder diagnosis). Our results, nevertheless, do indicate that even non-clinical levels of substance use may be associated with FA, suggesting that perhaps diagnosable disorder may present even greater risk for FA transition.

Conclusion

These limitations notwithstanding, our study is the first to examine transitions in firearm assault behavior among youth and their temporal antecedents. Our results provide a basis for distinguishing between primary and secondary firearm assault prevention programs, as well as what factors would work across conditions. Firearm assault initiation is preceded by

lesser violence involvement, such as non-firearm peer violence, substance use, and firearm victimization experience. In addition, peer influences and social norms/beliefs have effects on future firearm assault that are not specific to those who have already initiated. Thus, programs focused on preventing the initiation of firearm violence should include content related to peer influences and normative resetting, while programs focused on preventing ongoing firearm violence should, in addition to the aforementioned, incorporate components designed to interrupt an escalating delinquency trajectory (e.g., mentoring); and seek to engage individuals with firearm victimization history (e.g., assault-injured youth).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Funding

This work was funded by R03 AA025449 (PI: Goldstick), R01 DA024646 (PI: Cunningham), R01 DA035183 (PI: Cunningham), and R24HD087149 (PI: Cunningham).

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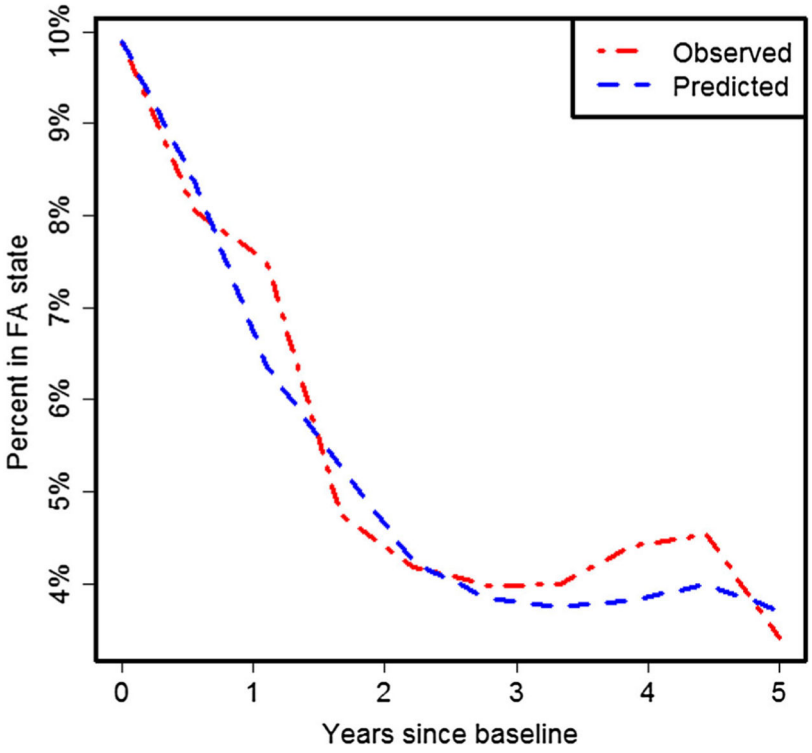

Fig. 1.
Observed percent in the FA state versus the percent predicted by the Markov Chain model

Table 1

Descriptive contrasts between different FA transition types among the FYI sample

	No FA → No FA	No FA → FA	OR(95%CI)	FA → No FA	FA → FA	OR (95%CI)
Number	2414	89		121	63	
Baseline demographics						
Male	1277 (52.9%)	64 (71.9%)	**2.28 (1.43, 3.64)**	91 (75.2%)	52 (82.5%)	1.56 (0.72, 3.37)
Age	21.4 (2.8)	21.0 (2.5)	0.95 (0.88, 1.03)	20.7 (2.4)	20.5 (2.6)	0.96 (0.85, 1.09)
Black	1465 (60.7%)	61 (68.5%)	1.41 (0.90, 2.22)	88 (72.7%)	42 (66.7%)	0.75 (0.39, 1.45)
Aggression						
Any Partner aggression	749 (31.0%)	41 (46.1%)	**1.90 (1.24, 2.91)**	80 (66.1%)	49 (77.8%)	1.79 (0.89, 3.62)
Minor aggression	692 (28.7%)	38 (42.7%)	**1.85 (1.21, 2.85)**	77 (63.6%)	47 (74.6%)	1.68 (0.85, 3.31)
Major aggression	459 (19.0%)	31 (34.8%)	**2.28 (1.45, 3.56)**	60 (49.6%)	40 (63.5%)	1.77 (0.95, 3.30)
Any peer aggression	768 (31.8%)	53 (59.6%)	**3.16 (2.05, 4.86)**	90 (74.4%)	51 (81.0%)	1.46 (0.69, 3.10)
Minor aggression	631 (26.1%)	46 (51.7%)	**3.02 (1.98, 4.63)**	78 (64.5%)	42 (66.7%)	1.10 (0.58, 2.10)
Major aggression	608 (25.2%)	43 (48.3%)	**2.78 (1.81, 4.25)**	83 (68.6%)	50 (79.3%)	1.76 (0.86, 3.62)
Any major aggression	808 (33.5%)	47 (55.8%)	**2.22 (1.45, 3.40)**	95 (78.5%)	52 (82.5%)	1.29 (0.59, 2.83)
Any minor aggression	951 (39.4%)	55 (61.8%)	**2.49 (1.61, 3.85)**	95 (78.5%)	51 (81.0%)	1.16 (0.54, 2.50)
Any aggression	1077 (44.6%)	61 (68.5%)	**2.70 (1.72, 4.26)**	102 (84.3%)	55 (87.3%)	1.28 (0.53, 3.11)
Victimization						
Any partner victimization	902 (37.4%)	48 (53.9%)	**1.96 (1.28, 3.00)**	88 (72.7%)	53 (84.1%)	1.99 (0.91, 4.36)
Minor victimization	866 (35.9%)	48 (53.9%)	**2.09 (1.37, 3.20)**	81 (66.9%)	50 (79.4%)	1.90 (0.93, 3.90)
Major victimization	627 (26.0%)	34 (38.2%)	**1.76 (1.14, 2.73)**	66 (54.5%)	41 (65.1%)	1.55 (0.83, 2.91)
Any peer victimization	747 (30.9%)	39 (43.8%)	**1.74 (1.14, 2.67)**	76 (62.8%)	43 (68.3%)	1.27 (0.67, 2.43)
Minor victimization	635 (26.3%)	32 (36.0%)	**1.57 (1.01, 2.45)**	71 (58.7%)	36 (57.1%)	0.94 (0.51, 1.74)
Major victimization	555 (23.0%)	28 (31.5%)	1.54 (0.97, 2.43)	66 (54.5%)	39 (61.9%)	1.35 (0.73, 2.52)
Any major victimization	861 (35.7%)	45 (50.6%)	**1.84 (1.21, 2.82)**	85 (70.2%)	51 (81.0%)	1.80 (0.86, 3.77)
Any minor victimization	1065 (44.1%)	52 (58.4%)	**1.78 (1.16, 2.73)**	99 (81.8%)	53 (84.1%)	1.18 (0.52, 2.67)
Any victimization	1146 (47.5%)	57 (64.0%)	**1.97 (1.27, 3.06)**	102 (84.3%)	57 (90.5%)	1.77 (0.67, 4.68)
Any firearm victimization	265 (10.9%)[a]	27 (30.3%)	**3.53 (2.21, 5.65)**	61 (50.4%)	31 (49.2%)	0.95 (0.52, 1.75)
Psychosocial						
Anxiety/dep (BSI)	0.58 (0.83)	0.62 (0.66)	1.07 (0.82, 1.40)	0.78 (0.79)	0.98 (1.00)	1.30 (0.92, 1.84)

	No FA → No FA	No FA → FA	OR(95%CI)	FA → No FA	FA → FA	OR (95%CI)
Friend (−) influence	1.89 (0.63)	2.19 (0.73)	**1.85 (1.39, 2.45)**	2.49 (0.80)	2.71 (0.80)	1.41 (0.96, 2.08)
Friend (+) influence	2.12 (0.73)[a]	2.03 (0.72)	0.84 (0.62, 1.14)	2.03 (0.73)	1.93 (0.58)	0.81 (0.51, 1.29)
Community violence	1.33 (0.89)	1.68 (0.93)	**1.54 (1.22, 1.95)**	2.01 (0.92)	2.24 (0.80)	1.36 (0.95, 1.94)
Retaliatory attitudes	2.71 (0.53)	2.44 (0.57)	**0.39 (0.26, 0.57)**	2.36 (0.58)	2.19 (0.55)	0.59 (0.34, 1.02)
Substance use						
Marijuana use (ASSIST)	1.49 (1.36)	2.30 (1.49)	**1.44 (1.26, 1.64)**	2.62 (1.50)	2.79 (1.35)	1.09 (0.88, 1.34)
Alcohol use (AUDIT-C)	1.80 (2.60)	2.25 (3.18)	1.06 (0.98, 1.14)	2.83 (3.20)	3.06 (3.18)	1.02 (0.93, 1.12)
Illicit drug misuse	132 (5.5%)	4 (4.5%)	0.81 (0.29, 2.25)	15 (12.4%)	8 (12.7%)	1.03 (0.41, 2.57)

Aggression/Victimization do not include firearm-involved violence, unless specifically noted

Odds ratios reflect the odds of FA, given the current state so, on the left side, the OR is the relative odds of FA at the next assessment among those not currently reporting FA; on the right side, the OR is the relative odds of FA among those currently FA

[a]One missing value

Bold: $p < 0.05$ for the corresponding odds ratio

Table 2

Unadjusted covariate state-dependence tests among variables in the final model

	HR (No FA → FA)	HR (FA → No FA)	*p*
Age	0.95 (0.87, 1.05)	1.01 (0.93, 1.10)	0.63
Male	2.07 (1.18, 3.63)	0.84 (0.62, 1.38)	0.25
Black	1.70 (1.01, 2.87)	1.43 (0.91, 2.27)	**0.04**
Non-firearm non-partner aggression	3.01 (1.78, 5.09)	0.88 (0.54, 1.43)	**0.04**
Non-firearm partner aggression	1.68 (1.02, 2.78)	0.73 (0.47, 1.13)	0.64
Gun violence victimization	3.86 (2.25, 6.64)	1.17 (0.76, 1.80)	< **0.001**
Community violence	1.37 (1.04, 1.82)	0.83 (0.65, 1.06)	0.58
Friend negative influence	1.68 (1.21, 2.32)	0.83 (0.63, 1.09)	0.22
Retaliatory attitudes	0.89 (0.84, 0.95)	1.04 (0.99, 1.09)	0.14
Marijuana use	1.41 (1.20, 1.65)	0.96 (0.83, 1.13)	**0.03**
Alcohol use	1.35 (0.79, 2.31)	0.85 (0.54, 1.31)	0.75

p value corresponds to a test of whether the HR from No-FA (column 2) differs from the inverse of the HR from FA (column 3), which would indicate that risk factors for future firearm violence differ based on current FA status. If the *p*-value indicates significance, then we do not constrain the effects to be equivalent in the adjusted models

Bold values are statistically significant at $p = 0.05$

Table 3

Adjusted Markov Chain transition model for transitions between FA states

	HR (No FA → FA)	HR (FA → No FA)
Age[a]	1.00 (0.96, 1.05)	1.00 (0.95, 1.04)
Male[a]	**1.55** (**1.20**, **1.99**)	**0.65** (**0.50**, **0.83**)
Black	**1.93** (**1.06**, **3.52**)	1.61 (0.93, 2.76)
Non-firearm non-partner aggression	**2.40** (**1.32**, **4.34**)	1.23 (0.69, 2.19)
Non-firearm partner aggression[a]	1.21 (0.94, 1.55)	0.83 (0.65, 1.06)
Gun violence victimization	**2.61** (**1.33**, **5.12**)	1.59 (0.90, 2.79)
Community violence[a]	0.99 (0.86, 1.13)	1.01 (0.88, 1.16)
Friend negative influence[a]	**1.19** (**1.01**, **1.40**)	**0.84** (**0.71**, **0.99**)
Retaliatory attitudes[a]	**0.95** (**0.92**, **0.98**)	**1.05** (**1.02**, **1.08**)
Marijuana use	**1.27** (**1.05**, **1.55**)	1.02 (0.84, 1.25)
Alcohol use[a]	0.99 (0.96, 1.03)	1.01 (0.97, 1.05)

Bold indicates $p < 0.05$

[a]Effects are constrained across states so that the HR for transitions out of No-FA is equal to the inverse of the HR out of FA, corresponding to forcing risk factors for FA to have equivalent effects regardless of whether the transition is from No-FA or FA. The choice to enforce this constraint was based on prior tests displayed in Table 2 and described in the text