FiGHTS: A Preliminary Screening Tool for Adolescent Firearms-Carrying

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See editorial, p. 808.

Study objective: Adolescent firearms-carrying is a risk factor for serious injury and death. Clinical screening tools for firearms-carrying have not yet been developed. We present the development of a preliminary screening test for adolescent firearms-carrying based on the growing body of knowledge of firearms-related risk factors.

Methods: A convenience sample of 15,000 high school students from the 1999 National Youth Risk Behavior Survey was analyzed for the purpose of model building. Known risk factors for firearms-carrying were candidates for 2 models predicting recent firearms-carrying. The "brief FiGHTS score" screening tool excluded terms related to sexual behavior, significant substance abuse, or criminal behavior (Fi=fighting, G=gender, H=hurt while fighting, T=threatened, S=smoker). An "extended FiGHTS score," which included 13 items, was developed for more precise estimates.

Results: The brief FiGHTS score had a sensitivity of 82%, a specificity of 71%, and an area under the receiver operating characteristic (ROC) curve of 0.84. The extended FiGHTS score had an area under the ROC curve of 0.90. Both models performed well in a validation data set of 55,000 students.

Conclusion: The brief and extended FiGHTS scores have high sensitivity and specificity for predicting firearms-carrying and may be appropriate for clinical testing.

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INTRODUCTION

Homicides and suicides resulted in approximately 55,000 deaths per year in the 1990s, with 70% attributable to firearms.[1] Recognizing these intentional injuries as a leading cause of death in adolescents, a number of national medical organizations have made policy statements favoring screening for gun carrying, referring patients to violence treatment, and increasing firearms research.[2-5] Primary care screening will miss adolescents, including a majority of male adolescents, who do not present for well-patient visits, demonstrating the importance of the emergency department (ED) in determining at-risk status for firearms.[6] Screening for other behaviors such as domestic violence, seat belt use, and drug and alcohol abuse is effective and results in improved patient

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Capsule Summary

What is already known on this topic

Firearms-carrying by adolescents is a major risk factor for injury and death, but physicians rarely screen for this behavior.

What question this study addressed

Responses to the 1999 National Youth Risk Behavior Survey were analyzed to develop a screening tool to identify youth at high risk for current or recent firearms-carrying.

What this study adds to our knowledge

Four simple screening questions and male sex may be used to generate a FiGHTS score (Fi=fighting, G=gender, H=hurt while fighting, T=threatened, S=smoker) that appears to be fairly sensitive and specific for identifying youth who carry firearms.

How this might change clinical practice

If the FiGHTS score is prospectively validated, it will be a useful addition to the growing list of screening questions that can be used to identify patients whose behavior or circumstances places them at increased risk of serious injury, disease, or death.

outcomes; therefore, the ED is a likely place for effective firearms interventions as well.[7-9]

Direct questioning of a patient about high-risk behavior as an initial screening test is reasonable but often insufficient. In the case of illegal activity, substance abuse, or sexual behaviors, studies have shown the sensitivity of direct questioning to be far inferior to that of formalized screening tests.[10] Additionally, direct questioning is not helpful in primary prevention strategies in which patients are at risk for an adverse behavior but have not yet engaged in it. Finally, direct questioning often fails to adequately risk-stratify patients for determining severity of disease and response to therapy compared with formalized screening tools.

For these reasons, it is essential to develop a screening tool to augment direct questioning for firearms-carrying. A partial list of known risk factors on which to build such a tool includes male sex,[11-14] smoking,[15] alcohol use,[12,15-17] drug use,[11,18] multiple sex partners,[16] poor academic performance,[15,16] being older than classmates,[19] television viewing,[20] criminal behavior,[14] feeling threatened,[21] fear,[17,21-23] and poor parental relations.[12,24] Although associations between these risk factors and firearms are widely accepted, neither an overall assessment of firearms-carrying risk nor a screening tool is currently available.

Implicit in the screening paradigm is that the disease being screened for has an effective intervention. Because 50% of firearms deaths are suicides, screening for firearms could play a valuable role in expediting appropriate referrals in the depressed and substance-abusing patients who, before their deaths, frequently interact with health professionals.[25] Psychiatric history alone is insufficient to select at-risk adolescents for screening, however, because many adolescent firearm suicides appear to be impulsive.[26] Additionally, there is evidence that many locally implemented programs decrease interpersonal violence.[27] For the violence researcher, the benefit of screening and adequate risk stratification might help clarify the most effective violence intervention strategies and the populations to which they apply. We propose a brief bedside clinical test, supported by an extended regression model, to developing a clinically useful screening test for firearms-carrying.

MATERIALS AND METHODS

The National Youth Risk Behavior Survey is a cross-sectional surveillance survey administered by the Centers for Disease Control and Prevention every 2 years and has been described in detail elsewhere.[6] Data from the 1999 survey were used for the following analysis. The sample was drawn from 52 communities selected from across the United States according to the degree of urbanization and racial factors to ensure a representative cross-section of the country. From within the 52 communities, 187 schools were selected at random. Within the schools, entire classrooms were sampled at random by subject, either English or History, in grades 9 to 12. Of the 187 schools randomly selected, 144 (77%) agreed to participate. At the school level, 86% of adolescents selected completed the surveys, with those not completing the survey representing mostly students absent on the day of the survey. Absenteeism rates of this magnitude are common.[28] The most common reason for school nonparticipation was competing time requirements from similar survey instruents.[29] A total of 15,349 completed questionnaires were returned.

The survey is a self-administered questionnaire designed to maximize anonymity and voluntary participation. Local parental permission procedures were followed before administration of the survey. The Human Investigations Review Committee certified the study protocol and analyses as exempt from full review according to 45 CFR §46.101(b)(4). SPSS statistical software (version 11.0; SPSS, Inc., Chicago, IL) was used for the analysis.

Risk factors associated with firearms-carrying that were included in the 1999 Youth Risk Behavior Survey were candidates for inclusion in the models. Two models with alternate intended uses were constructed. The first model, referred to as the brief FiGHTS (Fi=fighting, G=gender, H=hurt while fighting, T=threatened, S=smoker) score, is intended as a screening tool for a brief interview and includes only terms not related to sexual behavior, significant substance abuse, or criminal behavior. Candidate terms for inclusion in the model were (items in parentheses indicate possible responses to questions) sex (male/female), having fought within the past 12 months (yes/no), having been injured while fighting in the past 12 months (yes/no), having been threatened with a weapon at school in the past 30 days (yes/no), having been a regular smoker (yes/no), having had a checkup by a physician or nurse while not sick in the past 2 years (yes/no), being older than the class average for the student's grade (yes/no), having skipped school for fear of safety in past 30 days (yes/no), having felt sad or hopeless daily for more than 2 weeks in past year to the point of decreasing usual activities (yes/no), and residential status (rural, urban, suburban). The covariates were allowed to enter into a forward-stepwise binary logistic regression model according to their Wald coefficient. With the goal of parsimony in mind, it was predetermined that a maximum of 6 terms could be included.

A second model, called the extended FiGHTS score, was constructed from the development data set in which known or suspected risk factors for firearms-carrying were candidates for the model, including items on substance abuse and sexual and criminal behavior. Candidates for this model included (items in parentheses indicate possible responses to questions) sex (male/female), age (12 to 18 years), grade (9 to 12 or ungraded), number of times fought in the past 12 months (0 to 6, >6), times injured while fighting in the past 12 months (0, 1, 2 to 3, 4 to 5, 6 to 7, 8 to 9, 10 to 11, >11), times threatened with a weapon at school in the past 30 days (0, 1, 2 to 3, 4 to 5, >5), having been a regular smoker (yes/no), having had a checkup by a physician or nurse while not sick in the past 2 years (yes/no), being older than the class average for the student's grade (yes/no), times skipped school for fear of safety in the past 30 days (0, 1, 2 to 3, 4 to 5, >5), having felt sad or hopeless daily for more than 2 weeks in the past year to the point of decreasing usual activities (yes/no), number of days alcohol consumed in the past month (0, 1 to 2, 3 to 5, 6 to 9, 10 to 19, 20 to 29, all 30), lifetime uses of marijuana (0, 1 to 2, 3 to 9, 10 to 19, 20 to 39, 40 to 99, >99), ever used cocaine (yes/no), ever sniffed glue (yes/no), ever used heroin (yes/no), ever used methamphetamines (yes/no), ever injected drugs (yes/no), number of sexual partners in the past 3 months (never had sex, no partner in past 3 months, 1 to 5, >5), region of the United States (South, West, Midwest, North), and metropolitan area (rural, urban, suburban).

A logistic regression model was developed according to an established method of predictive modeling that has been described in detail elsewhere.[30,31] Briefly, after the primary effects of the covariates were accounted for, interaction terms were considered according to a priori plausibility. All terms that met the significance criteria of P less than .05 were included in the final model. The candidate terms for the model were recoded to ordinal, binary, or categoric variables to select the form that best predicted the probability of firearms-carrying according to residual plots. For example, marijuana use was reduced from 7 levels of use to a binary term (used <20 times, used >20 times).

Approximately 10% of the surveys were incomplete with respect to all the risk factors of interest. For selecting the terms in the brief and extended FiGHTS scores, surveys with missing data were excluded. After selection of the risk factors of interest for the final models, incomplete surveys were reintroduced to the data set to estimate odds ratios (ORs) on all risk factors for which data were complete.

For evaluating reliability and generalizability of the models, a number of validation data sets were constructed. First, the 1999 National Youth Risk Behavior Survey was divided randomly into 2 groups before any analyses were undertaken. Two thirds of the subjects composed a "development" data set on which a large number of potential models were tested. The remaining one third of cases were analyzed only after the final models had been developed as a check of internal validity and reliability. Additional validation data sets were derived from variations of the 1999 National Youth Risk Behavior Survey administered to US students every other year since 1991.[6] Although the surveys vary slightly by year, several were similar enough to allow testing of the FiGHTS scores. Finally, the 1998 National Alternative High School Youth Risk Behavior Survey, a survey similar to the 1999 National Youth Risk Behavior Survey given to failing students at risk for school dropout, was also adapted as a validation data set.[6] Of the 6 candidate data sets, 4 collected sufficient information to validate the brief FiGHTS score

(the 1998 National Alternative Youth Risk Behavior Survey [n=8,918], the 1997 National Youth Risk Behavior Survey [n=16,262], the 1995 National Youth Risk Behavior Survey [n=10,904], and the 1993 National Youth Risk Behavior Survey [n=16,296]). Only 2 candidate data sets, the National Alternative Youth Risk Behavior Survey and the 1997 National Youth Risk Behavior Survey, collected sufficient information to validate the extended FiGHTS after adjustment for missing terms (1997 National Youth Risk Behavior Survey missing region of the United States and both lacking "having had a checkup by MD in past 2 years").

RESULTS

Each of the 15 characteristics, including race, sex, metropolitan status, and 12 other risk factors, was significantly associated with firearms-carrying in the crude analysis (Table 1). Excluding intravenous drug use, all risk factors were found in at least 5% of subjects. More than 98% of students offered a response to the questions of interest, with the exception of recent sexual activity and alcohol use (6% and 4% missing, respectively). In a fully adjusted model, smoking, being injured while fighting, and a positive depression screen lost statistical significance as predictors for recent firearms-carrying. Residence in Southern or Midwestern states compared with Northeastern and Western states remained independently associated with firearms-carrying, as did rural residence compared with urban and suburban. The clustered nature of the data was considered, and hierarchical models that did not alter the selection of items to be used for the FiGHTS scores were evaluated (results not shown).

According to sensitivity and specificity, 5 terms were selected for the brief FiGHTS score: fighting within the past year, male sex, being injured while fighting within the past year, having been threatened with a weapon at school within the past 30 days, and being a regular smoker (Table 2). We elected to omit a sixth term because it added only marginally to the sensitivity and specificity yet made the test 20% longer. All subjects were assigned a FiGHTS score by giving 1 point for each of the 5 characteristics that they possessed. For example, a male smoker who did not fight, was not injured, and was not threatened was given a score of 2.

The output of the brief FiGHTS score is shown in Table 3, along with associated test characteristics. The 30% of adolescents with a FiGHTS score of 2 or higher represent 82% of gun carriers. Comparison of subjects at each level of FiGHTS score and above with those with lower scores reveals that higher values are consistently associated with increased odds of gun carrying. Comparison of each level of FiGHTS score with a score of 0 demonstrates an exponentially increasing association with gun carrying (results not shown). Comparison of subjects with a score of 2 or higher with subjects with a score of 0 to 1 maximizes the sum of sensitivity (82%) and specificity (78%), a point that we will arbitrarily refer to as the optimal FiGHTS score for the sake of comparison across data sets. Despite the magnitude of the OR and a receiver operator characteristic (ROC, a plot of sensitivity versus 1 – specificity) curve with an area of .84 (Table 4), the positive predictive values of a positive test (having a high FiGHTS score) are only low to moderate because of the low prevalence of gun-carrying in the study population (5%). The negative predictive value of the test is consistently higher than 90% in all test and validation data sets, showing that the FiGHTS score effectively classifies the majority of students at low risk for firearms-carrying.

The extended FiGHTS score incorporated all significant terms from the fully adjusted model shown in Table 1 and includes an interaction term for sex and intravenous drug use. The Hosmer-Lemeshow goodness-of-fit statistic was 10.467 (P=.38), indicating an overall good fit of the model. Figure 1 presents the full regression ORs in a form that allows calculation of an individual subject's predicted probability for firearms-carrying. Students are given points for each of the 10 risk factors in the table, and a total score is calculated. For example, a male student (20 points) who fought 5 times (19 points), has not been treated by a physician (3 points), and is older than average for his class (2 points) would score 44 points. Once calculated, the score is converted into a probability of firearms-carrying by using the log linear chart in Figure 2. Because firearms-carrying varies by geography, the conversion tables in Figure 2 allow for region-specific probabilities. Continuing the previous example, the student with a score of 44 would have approximately a 3% probability of recent firearms-carrying in the urban Northeast, 6% in the urban South, and 9% in the rural Midwest.

Both the brief and extended FiGHTS scores performed well in validation testing, as shown by similar areas under the ROC in all data sets (Table 4). Applying the FiGHTS score in these independent data sets reproduces almost exactly the results seen in the development process, lending credence to the test's repro-

ducibility. The optimal sensitivity, specificity, and positive and negative predictive values are also stable across studies and over time, occurring at the same threshold for positive and negative tests in 5 of 6 data sets. The FiGHTS scores 0 to 1 define the range for a negative test, maximizing the sum of sensitivity plus specificity in all surveys, except the National Alternative Youth Risk Behavior Survey, in which a score of 0 to 2 defines that point. Although FiGHTS administered in the National Alternative Youth Risk Behavior Survey setting demon-

Table 1.
Prevalence of risk factors for adolescent gun-carrying (N=10,111).

Risk Factor	Did Not Carry Gun	Carried Gun	Missing	Crude OR (95% CI)	Adjusted OR (95% CI)*
Total	9,568	543	122†		
Sex			49		
Female	5,117	60		—	—
Male	4,407	478		9.3 (7.1–12.1)	7.3 (5.2–10.1)
Residential area			105		
Suburban	3,175	167		—	—
Urban	5,103	272		1.0 (0.8–1.2)	1.0 (0.8–1.34)
Rural	1,189	100		1.6 (1.2–2.1)	1.75 (1.3–2.4)
Region			0		
West	1,898	71		—	—
Northeast	1,287	68		1.4 (1.0–2.0)	1.1 (0.8–1.8)
Midwest	1,554	94		1.6 (1.2–2.2)	1.7 (1.2–2.5)
South	4,829	310		1.7 (1.3–2.2)	2.0 (1.5–2.7)
Smoking status			125		
Nonsmoker	7,801	309		—	—
Regular smoker	1,653	223		3.4 (2.8–4.1)	0.9 (0.7–1.1)
Fighting status in past year			134		
None	6,396	118		—	—
B1	3,062	401		7.1 (5.8–8.8)	2.7 (2.2–3.5)
Threatened with weapon at school			7		
No	8,947	373		—	—
Yes	616	168		6.5 (5.4–8.0)	2.1 (1.7–2.9)
Injured while fighting in past year			44		
No	9,245	430		—	—
Yes	286	106		8.0 (6.2–10.2)	1.7 (0.9–2.4)
Has been treated by physician in past 2 y			199		
No	2,961	221		1.6 (1.3–1.9)	1.4 (1.1–1.7)
Yes	6,425	305		—	—
Older than average age for class			42		
No	8,806	464		—	—
Yes	724	75		2.0 (1.5–2.5)	1.4 (1.00–2.0)
Positive depression screen			14		
No	6,689	330		—	—
Yes	2,866	212		1.5 (1.3–1.8)	1.1 (0.9–1.5)
Skipped school out of fear for safety			4		
No	8,966	451		—	—
Yes	599	91		3.0 (2.4–3.8)	1.3 (1.0–1.9)
Alcohol use in past 30 days			421		
No	4,987	105		—	—
Yes	4,211	387		4.4 (3.5–5.4)	1.7 (1.4–2.3)
Lifetime marijuana use >20 times			168		
No	7,716	226		—	—
Yes	1,706	295		5.9 (4.9–7.1)	1.9 (1.5–2.4)
Ever injected drugs			44		
No	9,445	460		—	—
Yes	84	78		20.1 (14.5–27.7)	2.5 (1.6–3.8)
Sexual partner in past 3 mo			619		
No	5,654	128		—	—
Yes	3,335	375		5.0 (4.0–6.1)	1.9 (1.4–2.5)

CI, Confidence interval.
*Adjusted for all other covariates in the model.
†Missing gun status.

strates slightly different properties from those of the National Youth Risk Behavior Survey population, overall the ROC, sensitivity, specificity, and positive and negative predictive values are well within the acceptable range.

In addition to prediction of relative risk of recent firearms-carrying, the extended FiGHTS score predicts absolute risk. For the 1999 National Youth Risk Behavior Survey, the extended FiGHTS score's predictions agree closely with observed rates of firearms-carrying across all levels of probability and all subgroups. Although the extended FiGHTS score predicts relative risk in the National Alternative Youth Risk Behavior Survey and the 1997 National Youth Risk Behavior Survey well with high sensitivity and specificity, it consistently underpredicts the absolute risk of firearms-carrying in these validation data sets (results not shown).

Table 2.
*Brief FiGHTS score questionnaire.**

Key Word	Question
Fighting	During the past 12 months, have you been in a physical fight?
Gender	Male?
Hurt	During the past 12 months, have you been in a physical fight in which you were injured and had to be treated by a doctor or nurse?
Threatened	During the past 12 months, have you been threatened or injured with a weapon such as a knife or gun on school property?
Smoker	Have you ever smoked cigarettes regularly, that is, at least 1 cigarette every day for 30 days?

*One point given for each positive response in the questionnaire.

DISCUSSION

The National Youth Risk Behavior Survey, a large, nationally representative survey of adolescents with

Table 3.
Adolescent gun-carrying by FiGHTS score.

FiGHTS Score, (N=10,111)	Did Not Carry Gun in Past 30 d	Carried Gun in Past 30 d	OR* (95% CI)	Sensitivity	Specificity	Positive/ Negative Predictive Value	Likelihood Ratio
Total	9,568	543					
0	3,217	8	—	—	—	—	0.04
1	3,662	89	33 (16–67)	0.99	0.34	0.08/0.99	0.43
2	1,878	197	11 (9–14)	0.82	0.71	0.14/0.99	0.185
3	655	145	9 (7.6–11)	0.46	0.92	0.23/0.97	3.90
4	139	62	14 (11–19)	0.19	0.98	0.40/0.96	7.86
5	17	42	47 (27–83)	0.08	0.99	0.71/0.95	43.53

*OR compared with all subjects with lower FiGHTS score.

Table 4.
Discrimination properties of the full and brief FiGHTS scores.

	Area Under the ROC					
Data Set	Brief FiGHTS Score	Extended FiGHTS Score	Optimal Sensitivity, %*	Optimal Specificity, %*	Positive Predictive Value, %*	Negative Predictive Value, %*
1999 Development National Youth Risk Behavior Survey	0.84	0.90	82	71	14	99
1999 Validation National Youth Risk Behavior Survey	0.83	0.88	83	71	15	99
1998 National Alternative Youth Risk Behavior Survey	0.77	0.83	66	77	33	93
1997 National Youth Risk Behavior Survey	0.82	0.87	82	69	15	98
1995 National Youth Risk Behavior Survey	0.81	—	77	73	20	97
1993 National Youth Risk Behavior Survey	0.80	—	88	73	27	97

*Brief FiGHTS score only. "Optimal" refers to the FiGHTS score threshold for a positive test that maximizes the sum of sensitivity plus specificity. FiGHTS score 0 to 1 denotes the optimal negative test score in all data sets except the National Alternative Youth Risk Behavior Survey, in which 0 to 2 denotes a negative test.

high response rate and frequent administration, was used to develop a screening tool for adolescent firearms-carrying. This tool, the FiGHTS score, is robust over time and generalizable to suburban, rural, and urban communities across the United States. The FiGHTS score performs well at risk-stratifying adolescents, low scores in particular providing the clinician with confidence in identifying the majority of subjects who did not carry firearms.

We provide 2 instruments that are adaptable, depending on the needs of the user. The brief FiGHTS score is simple, noninvasive, and rapid, yet provides objective data for referral to social services, psychiatry, primary care, or violence prevention follow-up. For the clinician desiring a coarse stratification such as low, medium, or high risk of gun-carrying, the brief test is sufficient.

We provide evidence for the test's performance and reproducibility according to our arbitrary optimal positive test cut point. In clinical practice, the optimal point on the ROC curve depends on the test's intended use and includes technical considerations such as sensitivity and specificity and the clinical consideration of false positives and false negatives. Screening should also include consideration of pretest probability in that the clinician should approach high- and low-risk populations differently.

The extended FiGHTS score generates an absolute predicted probability of recent firearms-carrying that can also be viewed as a continuous risk scale from 0 to 100. The full regression model outperforms the brief model in terms of improved ROC but does so at a time cost of a longer test with more complicated data inter-

Figure 1.

*Scoring sheet for the extended FiGHTS score. The points assigned are derived from the € coefficients of the regression equation presented in the following paragraph. To make the calculations simpler, the € coefficients were multiplied by 10 and rounded to 1 significant digit. The inputs for the regression correspond directly to levels of risk. For example, if a student fought 3–4 times in the past year, the component of fighting risk=0.480×2. The 2 refers to second level of risk for a student fighting 3–4 times, not having fought 2 times. The alcohol term is categorical. Extended FiGHTS score regression: ln(odds firearms-carrying)=–7.89+(0.480) fought in school+(0.291) threatened at school+(0.131) skipped school out of fear for safety+(0.378) alcohol 1 to 2 times in past month+(0.462) alcohol 3 to 5 times in past month+(0.801) alcohol 6 to 30 times in past month+(1.601) alcohol daily in past month+(0.307) number of sexual partners in the past 3 months+(0.462) lifetime uses of marijuana >20+(1.966) male sex+(0.225) older than the class average+(0.294) no checkup by physician+(0.422) male IV drug use+(2.293) female IV drug use+(0.559) rural+(0.490) South/Midwest. *Assign 3 points if patient has had sexual partner in remote past but none in past 3 months.*

					Total
Times fought in past year	1	2–3	3–4	>4	
	5	10	14	19	
Times threatened at school in past 30 days	1	2–3	4–5	>5	
	3	6	9	12	
Times skipped school out of fear for safety	1	2–3	4–5	>5	
	1	3	4	5	
Number of days consumed alcohol in past month	1–2	3–5	6–30	Every day	
	4	5	8	16	
Number of sex partners in past 3 months*	0	1	2	>2	
	3	6	9	12	

Lifetime marijuana use >20 times	5
Male	20
Has not seen MD in past 2 years	3
Older than school class average	2
Male IV drug user	4
Female IV drug user	23

pretation. Although the brief FiGHTS score asks no questions about sexual or illegal behaviors, the extended FiGHTS score can be quite explicit in these areas, a fact that may influence the subject and the clinician. The clinician should review the test characteristics of the extended and the brief FiGHTS scores to determine whether the marginal benefit in performance outweighs the difficulties in administering the test.

The advantage of a single summary statistic such as the extended FiGHTS score should be considered further, however, particularly for the researcher. To control for confounding in studies of behaviors like firearms-carrying, sample sizes often need to be large. Even with large sample sizes, violence interventions can be difficult to compare, and effective interventions may go unnoticed in a group composed of wide-ranging underlying risks.[32] For example, an intervention may be helpful for intermediate-risk subjects but go unnoticed when many low-risk individuals are included in the study. A summary score, which captures much of the baseline risk in a single term, would increase the power of the study to show true differences by reducing the number of covariates in the model.

The extended FiGHTS score predicted the probability of recent firearms-carrying well in the development and the validation data sets for the 1999 National Youth Risk Behavior Survey. However, the extended score underpredicted the probability of firearms-carrying in the 1997 National Youth Risk Behavior Survey and the 1998 National Alternative Youth Risk Behavior Survey. The underprediction is due in part to incompleteness in the 1997 and 1998 data sets with respect to the information needed to assign a subject's full risk of weapons-carrying (region of the United States and last physician visit were not recorded). Because weapons-carrying is a complicated behavior to model, it is likely that different populations will have varying underlying social, political, economic, and geographic motivations to engage in the behavior.[33,34] Although it may prove difficult to encompass the entire range of these factors into a single model, systematic underprediction or overprediction is technically simple to correct through recalibration.

A main concern of the National Youth Risk Behavior Survey data is that it excludes subjects who do not attend school or who were absent when the survey was administered. By including the Alternative High School Youth Risk Behavior Survey responses in the validation process, we offer insight into the generalizability of the FiGHTS scores to students outside the mainstream education system, such as failing students and those expelled for illegal activity. The ROC statistic is somewhat smaller in the National Alternative Youth Risk Behavior Survey validation data set but still well within the acceptable range. We suspect that subjects with high absentee rates, such as nonresponders to the National Youth Risk Behavior Survey, likely have test sensitivity and specificity intermediate between that reported for the National Youth Risk Behavior Survey and the National Alternative Youth Risk Behavior Survey.

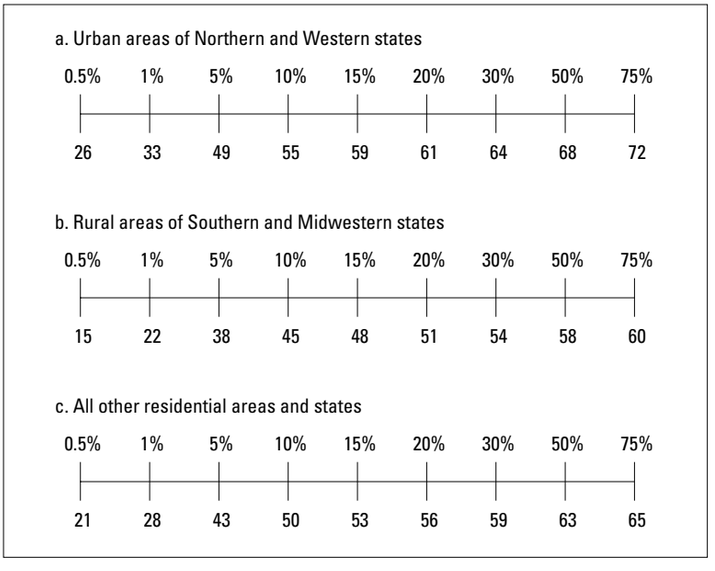

Figure 2.
Predicted probability of gun-carrying by FiGHTS score, residential area, and state.

The FiGHTS score relies on the groundbreaking work of researchers of the past 15 years to suggest the elements of a screening tool, yet final understanding of the associations and causal factors behind firearms violence is far from complete.[35,36] An investigation into independent risk factors is not the goal of this study, however. This study is designed to combine groups of associations to estimate the likelihood of firearms-carrying for screening purposes. Previous screening tools are limited in that they are not specific for firearms-carrying, study only small populations, or rely on expert opinion without any empiric testing.[37-40] Although the root causes of firearms-carrying may not be fully known, we do know that risk-taking and violence behaviors are highly correlated and tend to fall into groups such as substance abuse, fighting, and sexual behaviors.[41] In this study, we offer convincing evidence that measuring such associated behaviors is sufficient to formulate a screening tool even when the primary causes remain unknown.

Other risk factors not available in our data could have been considered for inclusion in the model. However, because risk-taking behaviors correlate strongly with one another, it is less likely that any single term, even a causative factor for violence, could greatly improve the ROC of 0.83 to 0.90 seen in the extended FiGHTS score (an ROC of 1.0 correlates to a sensitivity and specificity of 100%). By example, we tested the effect of singly removing all terms from the full model and witnessed only a marginal effect on ROC (results not shown). By similar argument, we suspect that dramatic improvements in the brief FiGHTS score would be difficult to obtain by item substitution. Nonetheless, we strongly suggest that future versions of the FiGHTS score evaluate those risk factors not available in our development data.

The methods of predictive modeling are parallel to the more common techniques of logistic regression modeling; however, an important distinction should be made.Unlike logistic regression models, the predictive model does not attempt to interpret the independent contributions of each risk factor. The overall predicted probability (in this case, of firearms-carrying) based on the collections of risk factors is the output of the model, not the relative contributions of separate components. Residual confounding, collinearity, and other factors therefore make our understanding of the individual regression coefficients shown in Figure 1 ambiguous. By extension, the weighted components of the extended FiGHTS score should not simply be thought of as proportional to the independent contributions of risk.

Although the brief and extended FiGHTS scores are promising tools, there are inherent weaknesses. First, like most research in this field, the models of firearms-carrying are based on the use of cross-sectional and self-reported data. Cross-sectional data raise the concern that the causal direction of any association is impossible to disentangle. Ideally, a model might identify at-risk adolescents before they carry firearms; however, the direction of causality is less important when only an estimate of ongoing firearms-carrying is of interest. A second major concern is that the FiGHTS models are based on questions answered during the administration of an anonymous survey, and these responses might differ in a clinical interview. The brief FiGHTS score includes questions that would likely be acceptable in most clinical encounters, although the extended FiGHTS score's administration might need to be carefully targeted. The extended score could likely be administered anonymously in a research setting to describe a population's baseline firearms risk.

Methodologic standards have been proposed for the systematic review of clinical prediction tools such as we propose in this study.[42] The FiGHTS scores comply well with these standards, and we suggest that the FiGHTS scores are ready for further clinical and research exploration. Despite some limitations, the current analysis clearly breaks new ground. We show that predictions of relative and absolute risk of firearms-carrying are possible through nonthreatening questioning. Although our findings may overestimate the field performance of the test, the models provide an estimate of the range of sensitivities and specificities that are possible in a screening tool. Finally, we offer objective data about the items that should be collected for any future prospectively tested screening tools for firearms-carrying.

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