Crash Types: Markers of Increased Risk of Alcohol-Involved Crashes Among Teen Drivers*

C. RAYMOND BINGHAM, PH.D.,[†] JEAN T. SHOPE, PH.D., M.S.P.H., JULIE E. PAROW, B.S.,[†]
AND TRIVELLORE E. RAGHUNATHAN, PH.D.[†]

University of Michigan Transportation Research Institute, 2901 Baxter Road, Ann Arbor, Michigan 48109-2150

ABSTRACT. Objective: Teens drink/drive less often than adults but are more likely to crash when they do drink/drive. This study identified alcohol-related crash types for which teen drivers were at greater risk compared with adults. **Method:** Michigan State Police crash records for drivers ages 16-19 (teens) and 45-65 years (adults) who experienced at least one crash from 1989 to 1996 were used to create alcohol crash types consisting of alcohol-related crashes that included specific combinations of other crash characteristics, such as drinking and driving at night (i.e., alcohol/nighttime). These data were combined with data from the 1990 and 1995 National Personal Travel Surveys and the 2001 National Household Travel Survey to estimate rates and rate ratios of alcohol-related crash types based on person-miles driven. **Results:** Teens were relatively less likely than adults to be involved in alcohol-related

crashes but were significantly more likely to be in alcohol-related crashes that included other crash characteristics. Teen males' crash risk was highest when drinking and driving with a passenger, at night, at night with a passenger, and at night on the weekend, and casualties were more likely to result from alcohol-related nighttime crashes. All the highest risk alcohol-related crash types for teen female drinking drivers involved casualties and were most likely to include speeding, passenger presence, and nighttime driving. **Conclusions:** The frequency with which passengers, nighttime or weekend driving, and speeding occurred in the highest risk alcohol-related crash types for teens suggests that these characteristics should be targeted by policies, programs, and enforcement to reduce teen alcohol-related crash rates. (*J. Stud. Alcohol Drugs* 70: 528-535, 2009)

OVERALL RATES OF DRIVING after using alcohol have been steadily decreasing in the United States for the past 2 decades, corresponding with a steadily declining trend in fatal alcohol-related motor vehicle crashes. This decreasing trend was also true of teen drivers (i.e., those ages 16-19 years) until the early to mid-1990s, when the rate of alcohol-related crashes for this age group leveled off and continued at about the same rate to the present (Shope and Bingham, 2008; National Highway Traffic Safety Administration, 2006a). Failure to make further reductions in alcohol-related crashes in this youngest age-group of drivers points to the need for a better understanding of alcohol-related driving and its association with crashes in this age-group so that policy and interventions can more effectively address this problem.

Alcohol-related crashes are less frequent among 16- to 19-year-olds than adult age-groups. Rates of alcohol-related

driving and crashes peak among drivers in their early 20s and then decline monotonically with increasing age, and it is not until around age 55 that rates of alcohol-related driving fall below levels seen among 16- to 19-year-olds. Although teens drink and drive less often than adults, when they do drink and drive, they are at considerably greater risk of crashing, and this is true at all blood alcohol concentrations (BACs; Gonzales et al., 2005; Mayhew et al., 1986; Voas et al., 1998; Williams, 2003; Zador et al., 2000). This elevated crash risk among teen drinking drivers may result from several factors. One may be inexperience and underdeveloped driving skills (Committee on Injury and Poison Prevention and Committee on Adolescence, 1996; Jonah, 1986; Ulmer et al., 1997). Another factor may be the consumption patterns of underage drinkers, who typically consume larger amounts of alcohol in a single sitting compared with adult drinkers (Substance Abuse and Mental Health Services Administration, 2003); hence, when they do drink and drive, they are likely to have higher BACs than adult drinking drivers.

Research has identified driving conditions other than drinking and driving that elevate the crash risk of teen drivers. Adult drivers experience either no change in risk or a small safety benefit from having passengers. In contrast, crash risk for teens is markedly elevated when driving with teen passengers, and that risk is significantly higher with each additional passenger (Aldridge et al., 1999; Chen et al., 2000; Doherty et al., 1998; Masten, 2004; Preusser et al., 1998; Simons-Morton et al., 2005; Williams et al., 2007).

Received: August 11, 2008. Revision: April 10, 2009.

*This research was supported with funding from the Centers for Disease Control and Prevention, National Center for Injury Prevention and Control (contract no. 200-2005-M-13172), and the National Institute on Alcohol Abuse and Alcoholism (RO1 AA09026).

[†]Correspondence may be sent to C. Raymond Bingham at the above address or via email at: rbingham@umich.edu. Julie E. Parow is with the School of Medicine, University of Michigan, Ann Arbor, MI. Trivellore E. Raghunathan is with the School of Public Health, University of Michigan, Ann Arbor, MI.

Nighttime driving is associated with increased crash risk for drivers generally, but teen drivers' risk of crashing at night is elevated relative to other age groups (Williams, 2003). Teen drivers are at the lowest risk of crashing when they are driving while supervised by an adult (Mayhew et al., 2003).

The research identifying conditions resulting in elevated crash risk for teen drivers has informed programmatic efforts to improve teen driver safety. Most notable is graduated driver licensing (GDL), which has been implemented broadly across the United States and in other nations. GDL programs vary by jurisdiction but have some combination of extended periods of supervised driving and restrictions on driving in conditions that present the greatest risk to teen drivers, such as at night and with passengers. However, although it has been shown that teen drinking drivers are generally more likely to crash than adult drinking drivers, little research has focused on which factors contribute most to this difference. It is likely that the risk of crashing for teen drinking drivers is elevated more when combined with some characteristics than with others. Such information would be useful in developing new and enhancing existing programs to reduce morbidity and mortality resulting from alcohol-related crashes involving teen drivers. The purpose of this study was to identify alcohol-related crash types for which teen drinking drivers are at excess risk compared with adults and to identify which crash characteristics contributed most to that difference in crash risk.

Method

Crash data and crash types

Michigan State Police crash records were obtained for each calendar year from 1989 to 1996 for all Michigan State Police-reported crashes. These data represented crashes

for drivers ages 16-19 (teens) ($n = 634,359$; 44% male) and 45-65 years (adults) ($n = 1,420,828$; 56% male) at the time of their crashes. All driver ages younger than 20 years were grouped for the majority of the analyses, because this age group is broadly recognized for its high risk of crash involvement. Drivers ages 45-65 were selected as the comparison, because this group has the lowest crash risk of any age-group, thereby providing a meaningful comparison to judge the degree of teen drivers' risk elevation. Using the Michigan State Police data, alcohol crash types were identified. Crashes rarely include just one characteristic, such as occurring at night. Instead, they generally include multiple characteristics, such as being alcohol involved, occurring at night, and occurring with passengers present. To specify crash risk better, crash types were formed based on their inclusion of the same characteristics, such as alcohol-involved crashes that occurred at night with passengers present (referred to in this article as alcohol/nighttime/passenger crashes). The crash characteristics used to identify crash types were selected using four criteria: (1) they represented drivers' behaviors well enough to identify likely causes of the crash (e.g., speeding), (2) they were known from prior research to be a threat to teens (e.g., driving with passengers), (3) they provided information about the surrounding context of the crash (e.g., bad weather conditions), and (4) they indicated crash outcome/severity (i.e., fatal and nonfatal injuries [casualties]). In addition, practical issues limited what crash types could be examined. For example, if crash types combined more than three characteristics, cell sizes started to be too small to obtain stable estimates; therefore, a limit was set at three characteristics per crash type. Table 1 lists and briefly describes the alcohol crash types examined in this study (see Bingham and Shope, 2007). This study received human subjects approval by the University of Michigan Institutional Review Board.

TABLE 1. Crash elements and alcohol crash types

Crash types	Description
Alcohol crash types	
Nighttime	At night
Nighttime/weekend	At night on the weekend
Nighttime/passenger	At night with at least one passenger
Nighttime/speeding	At night and involved speeding
Passenger	At least one passenger on board
Passenger/speeding	At least one passenger and involved speeding
Passenger/weekend	At least one passenger and occurred on the weekend
Speeding	Involved speeding
Speeding/weekend	Involved speeding and occurred on the weekend
Weekend	Occurred on the weekend
Alcohol casualty crash types	
Casualty	Involved at least one casualty in any vehicle involved
Casualty/nighttime	Casualty crash at night
Casualty/passenger	Casualty crash with at least one passenger
Casualty/speeding	Casualty crash that involved speeding
Casualty/weekend	Casualty crash and occurred on the weekend

Data analysis

Estimating person-miles driven (PMD). PMD was estimated using data from the 1990 and 1995 National Personal Travel Surveys and the 2001 National Household Travel Survey (Federal Highway Administration, 2001). For each of the three surveys, respondents of the age ranges included in this study were identified (i.e., 16-19 and 45-65 years of age) using data for the northern midwest region of the United States (i.e., Wisconsin, Illinois, Indiana, Ohio, and Michigan), and their data were weighted to provide representative estimates of annual miles driven by the population of drivers in the area examined. Two data sets were then formed from each of the three surveys. In the first, annual miles driven were summed by year of age, gender, and state to obtain total miles driven for each group. In the second, population sizes were calculated by summing the weighted sample sizes by year of age, gender, and state. The two data sets containing annual miles driven and population size for each survey were merged, and this process was repeated for each survey (the National Personal Travel Surveys, 1990, 1995, and the National Household Travel Survey, 2001). The resulting three data sets were appended into a single file and raw PMD were calculated by dividing the total annual miles driven for each year of age by gender by state group, by that group's population size. The three files containing raw PMD were appended into a single file. Final estimates of PMD were then calculated using a mixed model predicting raw PMD with all main effects and interactions of year of age, gender, state, and survey year as random effects, and weighting the model by the square root of the population size. The predicted values from this model provided estimates of PMD by year of age and gender for each survey and were used to calculate rates and rate ratios (RRs). Up to this point, the data for all five states had been included to yield more stable estimates of PMD. Those data were dropped from the data set, and only Michigan data were used to estimate crash rates and RRs for this study.

In the final step of data preparation, the change in PMD between surveys, from 1990 to 1995 and from 1995 to 2001, was divided by the number of intervening years and summed with the PMD for the previous year to obtain linear estimates of annual PMD over the interval examined in this study (i.e., 1989-1996).

Estimating rates and rate ratios. A Poisson regression model was used to estimate the rates and RRs for each crash type, separately. The numerator of the Poisson distribution was the number of occurrences of crashes, the denominator was annual PMD, and the offset was the log of PMD. Therefore, a loglinear model was tested. In the regression model for the logarithm of the rates, the primary predictor variable was age group (1 = teen, 0 = adult). Denoting this dummy variable as x , the regression model to predict the expected number of occurrences (on the log scale) is

$$\log \mu = \lambda_0 + \lambda_1 x + \log(PMD).$$

The parameters were estimated using the maximum likelihood approach. The rates for adults and teens are estimated by substituting the estimated parameters in the expressions $\exp(\lambda_0)$ and $\exp(\lambda_0 + \lambda_1)$, respectively. These two rates were multiplied by 100,000 to express the rates as per 100,000 PMD. The relative risk or RR was calculated as $\exp(\lambda_1)$, the ratio of the two estimated rates given above. Because the rates and RRs were estimated using a regression model and not calculated directly, the RRs from this study are not a simple ratio of teen to adult crash rates. The accuracy of these estimates is dependent on how well three assumptions are met: (1) Michigan State Police crash data provided accurate depictions of the characteristics of the crashes, (2) Michigan State Police crash data for teenage and adult drivers were equally represented in the Michigan State Police records, and (3) estimates of miles driven provided by the National Personal Travel Surveys and National Household Travel Survey provided accurate population estimates for Michigan.

Results

Sample description

Alcohol was involved in 4.6% of all crashes, overall, with 4.5% of all crashes involving teen drivers and 4.7% of all crashes involving adult drivers being alcohol related. By age group and gender, 5.5% and 3.0% of all crashes were alcohol related for teenage male and female drivers, respectively. For adults, these figures were 6.2% (males) and 2.6% (females).

Frequencies and percentages of teen and adult male and female drivers who were involved in each of the alcohol-related crash types included in this study are listed in Table 2. Consistently, teen and adult males were involved in a higher percentage of alcohol-related crashes of all types examined in this study than women. Alcohol/nighttime crashes were the most prevalent for both teenage males and females, and alcohol/casualty (i.e., fatal and nonfatal injuries combined) was the most prevalent type for adult males and females. The least common alcohol-related crash types were alcohol/speeding/weekend for teen and adult males and teenage females, and alcohol/speeding/weekend and alcohol/passenger/speeding for adult females.

Overall crash rates of teens were compared with those of adults separately for 16-, 17-, 18-, and 19-year-old drivers. The RRs for overall crashes by year of age compared with adults were 5.07, 2.86, 2.25, and 1.57, respectively, for men, and 3.67, 2.29, 1.27, and 1.15, respectively, for women. This pattern is the same as that observed in the literature for all crashes, with each successive year of age being associated with a substantial decline in crash risk (Mayhew et al., 2003).

TABLE 2. Frequencies and percentages of the Michigan population ages 16-20 and 45-65 who experienced a crash type at least once between 1989 and 1996

Crash types	Men				Women			
	Teens		Adults		Teens		Adults	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Alcohol crash types								
Nighttime	14,875	1.01	13,154	0.89	4,892	0.33	3,547	0.24
Nighttime/weekend	6,985	0.47	5,499	0.37	2,311	0.16	1,476	0.10
Nighttime/passenger	8,072	0.55	2,914	0.20	2,927	0.20	1,014	0.07
Nighttime/speeding	3,862	0.26	1,576	0.11	637	0.04	270	0.02
Passenger	10,906	0.74	7,307	0.50	4,323	0.29	2,442	0.17
Passenger/speeding	2,587	0.18	467	0.03	455	0.03	97	0.01
Passenger/weekend	5,067	0.34	3,243	0.22	2,098	0.14	151	0.07
Speeding	4,760	0.32	3,061	0.21	784	0.05	494	0.03
Speeding/weekend	2,078	0.14	1,251	0.09	352	0.02	186	0.01
Weekend	9,205	0.63	12,560	0.85	3,463	0.24	3,463	0.24
Alcohol casualty crash types								
Casualty	9,827	0.67	14,940	1.02	4,088	0.28	4,588	0.31
Casualty/nighttime	7,229	0.49	6,482	0.44	2,727	0.19	1,854	0.13
Casualty/passenger	5,490	0.37	3,892	0.26	2,377	0.16	1,375	0.09
Casualty/speeding	2,416	0.16	1,562	0.11	467	0.03	262	0.02
Casualty/weekend	4,449	0.30	6,056	0.41	1,799	0.12	1,787	0.12

Notes: Numbers of each crash type should be interpreted as a subset of the broader crash type. For example, of the 14,875 alcohol crashes occurring at night for men, 6,985 occurred on the weekend, 8,072 included a passenger, and so forth.

Alcohol crashes: Men

Table 3 shows the rates and RR values for alcohol-related crashes involving teen and adult male drivers. Overall, alcohol-related crash involvement by male teen drivers was relatively low compared with involvement by male adult drivers, with the RR for alcohol-related crashes being 2.13, which was statistically significantly less than the RR for all crashes (2.41). The alcohol crash type with the highest rate for teen males was alcohol/nighttime, followed by alcohol/passenger, alcohol/weekend, alcohol/nighttime/passenger, alcohol/casualty/nighttime, and alcohol/nighttime/weekend. Alcohol crash types showing the largest differences between teen and adult males included alcohol/passenger/speeding (RR = 18.16), alcohol/nighttime/passenger (RR = 9.08), alcohol/nighttime/weekend (RR = 8.03), alcohol/speeding/weekend (RR = 5.44), alcohol/passenger/weekend (RR = 5.12), and alcohol/speeding (RR = 5.10). All these alcohol-related crash types were statistically significantly larger than the RR for all alcohol-involved crashes (RR = 2.13), indicating that these are crash type RRs for which teens are at considerable excess crash risk relative to adult drivers. The smallest difference in alcohol-related crash rates was observed for the alcohol/weekend crash type (RR = 2.40).

To identify alcohol-related crash types that have the highest priority for policies and programs targeting teen drivers, alcohol-involved crash rates and RRs must be considered jointly. Crash types with high rates but low RRs have implications for efforts addressing driver safety generally but not for policies and programs addressing teen drivers specifically, because, as indicated by the low RR values, both teens and adults have equally high rates of such crashes. These

crash types are best addressed using methods that address the entire driving population. Crash types for which teen crash rates are moderate to high and for which the RRs are medium to large are of particular interest where teen driver safety is involved, because the rate is high and the difference between teens and adults, as indicated by the RR, is large. Policies, programs, and interventions that target these crash types are likely to be more effective if they target teen drivers specifically.

The crash types that had moderate to high rates and RRs

TABLE 3. Rate ratios, 95% confidence intervals, and rates for alcohol crashes involving teen and adult male drivers

Crash types	Rate ratio	95% CI		Rate ^a	
		Lower	Upper	Teens	Adults
Overall	2.41	2.40	2.42	14.92	6.19
Overall alcohol	2.13	2.10	2.16	0.81	0.38
Alcohol crash types					
Passenger/speeding	18.16	16.45	20.04	0.10	0.01
Nighttime/passenger	9.08	8.70	9.47	0.32	0.04
Nighttime/weekend	8.03	7.57	8.52	0.28	0.07
Speeding/weekend	5.44	5.08	5.84	0.08	0.02
Passenger/weekend	5.12	4.90	5.35	0.20	0.04
Speeding	5.10	4.87	5.33	0.19	0.04
Passenger	4.89	4.75	5.04	0.44	0.09
Nighttime/speeding	4.16	4.02	4.31	0.15	0.02
Nighttime	3.71	3.62	3.79	0.59	0.16
Weekend	2.40	2.34	2.47	0.37	0.15
Alcohol casualty crash types					
Casualty	2.16	2.10	2.21	0.39	0.18
Casualty/speeding	5.07	4.76	5.40	0.10	0.02
Casualty/passenger	4.62	4.44	4.82	0.22	0.05
Casualty/nighttime	3.66	3.53	3.78	0.29	0.08
Casualty/weekend	2.41	2.32	2.50	0.18	0.07

Notes: CI = confidence interval. ^aRates are based on 100,000 person-miles driven.

for teenage male drivers included alcohol/nighttime/passenger (RR = 9.08; rate = 0.32), alcohol/nighttime/weekend (RR = 8.03; rate = 0.28), alcohol/passenger (RR = 4.89; rate = 0.44), alcohol/nighttime (RR = 3.71; rate = 0.59), and alcohol/casualty/nighttime (RR = 3.66; rate = 0.29).

The contributions of speeding, passengers, nighttime, and weekend crash elements to crash risk are evident by comparing the RRs in Table 3. When combined with alcohol, each of the four factors significantly increased the likelihood that a crash would result in a casualty. The RR for all casualty crashes (RR = 2.16, 95% confidence interval [CI] = 2.10-2.21) was significantly less than the RRs for the alcohol crash types that included these additional elements. Speeding (RR = 5.07, 95% CI = 4.76-5.40) and passengers (RR = 4.62, 95% CI = 4.44-4.82) were associated with the greatest increases in the likelihood of a casualty crash for male teen drivers. Alcohol/casualty/nighttime was the only alcohol-related casualty crash type that demonstrated moderate to high levels of both the rate (0.29) and RR (3.66) (Table 3).

Alcohol crashes: Women

Table 4 contains rates of alcohol crash types for female teens and adults and RRs comparing the crash rates of teen and adult female drivers. Like teenage and adult males, alcohol-related crash involvement by female teen drivers was relatively low compared with involvement by female adult drivers, with the RR for alcohol-related crashes being 1.97. The alcohol crash types with the highest likelihoods of occurrence for teen versus adult female drivers were alcohol/passenger/speeding (RR = 10.87), alcohol/nighttime/speeding (RR = 5.47), alcohol/passenger/weekend (RR = 4.62),

alcohol/speeding/weekend (RR = 4.38), alcohol/passenger (RR = 4.10), and alcohol/nighttime/passenger (RR = 4.01). When examining both the rate and RR, the alcohol crash types with moderate to high levels of both measures of risk were alcohol/passenger (RR = 4.10; rate = 0.38) and alcohol/nighttime (RR = 3.20; rate = 0.43) crash types.

When compared with all alcohol-related casualty crashes (RR = 2.06), a casualty was more likely to result from an alcohol-related crash for teen female drivers if speeding, passengers, nighttime driving, or weekend driving were involved. The highest RRs involving these crash characteristics resulted for alcohol/casualty/speeding (RR = 4.13) and alcohol/casualty/passenger (RR = 4.01) crash types. The highest combined rate and RR was for alcohol/casualty/nighttime crashes (RR = 3.41; rate = 0.24) (Table 4). As with men, speeding, passengers, nighttime, and weekend crash elements combined with alcohol to significantly increase crash risk.

Discussion

The purpose of this study was to identify factors that increase the likelihood that a teen drinking driver will have an alcohol-related crash. The results are consistent with past research as follows. The lower RRs found for alcohol-related crashes compared with all crashes indicated that teens are less likely to be involved in alcohol-related than in other types of crashes. Male drivers were at greater risk of crash involvement than women (National Highway Traffic Safety Administration, 2006a), and when they did drink and drive, teens were more likely than adults to experience an alcohol-related crash (Gonzales et al., 2005; Mayhew et al., 1986; Voas et al., 1998; Williams, 2003; Zador et al., 2000). Finally, for both men and women, speeding and passengers contributed most to an increased likelihood that an alcohol-involved crash would result in a casualty (Chen et al., 2000; Doherty et al., 1998; National Highway Traffic Safety Administration, 2006b).

The results of this study also quantify the differences between teens and adults, showing that when all alcohol-related crashes are considered together, teens experienced a two times greater risk of crashing than adults. When alcohol is coupled with other conditions, the risk of being involved in an alcohol-related crash was as much as 18 times greater for male teen drivers and 11 times greater for female teen drivers compared with adults. The increases in crash risk observed in this study when drinking and driving is combined with other hazardous driving conditions emphasize the importance of preventing teens from driving after they have been drinking; justifies the efforts and resources used to reduce the incidence of teen drinking and driving; and is a demonstration of the need for continued research, program development, and evaluation to further reduce drinking and driving by teens. It is equally important—given the frequency with which teens ride as passengers of teen drivers, the

TABLE 4. Rate ratios, 95% confidence intervals, and rates for alcohol crashes involving teen and adult female drivers

Crash types	Rate ratio	95% CI		Rate ^a	
		Lower	Upper	Teens	Adults
Overall	1.75	1.74	1.76	22.49	12.84
Overall alcohol	1.97	1.91	2.03	0.67	0.38
Alcohol crash types					
Passenger/speeding	10.87	8.73	13.53	0.04	0.00
Nighttime/speeding	5.47	4.74	6.30	0.06	0.01
Passenger/weekend	4.62	4.29	4.98	0.19	0.04
Speeding/weekend	4.38	3.67	5.24	0.03	0.01
Passenger	4.10	3.90	4.31	0.38	0.09
Nighttime/passenger	4.01	6.23	7.18	0.26	0.04
Speeding	3.68	3.29	4.11	0.07	0.02
Nighttime/weekend	3.63	3.40	3.87	0.20	0.06
Nighttime	3.20	3.06	3.34	0.43	0.14
Weekend	2.40	2.34	2.47	0.30	0.13
Alcohol casualty crash types					
Casualty	2.06	1.98	2.15	0.36	0.18
Casualty/speeding	4.13	3.55	4.80	0.16	0.07
Casualty/passenger	4.01	3.75	4.28	0.04	0.01
Casualty/nighttime	3.41	3.21	3.61	0.24	0.07
Casualty/weekend	2.33	2.18	2.49	0.21	0.05

Notes: CI = confidence interval. ^aRates are based on 100,000 person-miles driven.

tendency for teen drivers to have multiple teenage passengers at the same time (Williams et al., 2007), and the association observed in this study between driving with passengers and greater crash risk—to continue current efforts and to explore new approaches to prevent teens from riding with peers who have been drinking.

Several intervention and prevention approaches have been used to reduce drinking and driving, with varying levels of success. Some interventions have their effect indirectly by preventing or reducing underage drinking. Traditionally, adolescent alcohol interventions have been provided through school programs that attempted to prevent alcohol use by providing information and using teaching strategies to change attitudes and beliefs about alcohol use. Environmental strategies have been increasingly used to reduce adolescent alcohol use through policy, regulation, and enforcement. Effective strategies that have taken this approach include increasing the minimum drinking age, greater taxation on alcoholic beverages, and price increases (Grube and Nygaard, 2001; Holder et al., 1997; Komro and Toomey, 2002). Changes in minimum drinking age laws have been shown not only to influence underage drinking, by either increasing or decreasing the availability to even younger underage individuals, but also to result in substantial changes in rates of alcohol-involved motor vehicle crashes (Kypri et al., 2006; Voas et al., 2003). Interventions to reduce sales to underage individuals at bars and restaurants have also shown some effectiveness (Toomey et al., 2001).

Approaches that prevent drinking and driving directly have also been used. Alcohol interlocks, although not used specifically to target underage drinking drivers, have shown effectiveness with older populations of drivers and may represent a useful approach with underage offenders (Beirness and Marques, 2004; Bjerre et al., 2007; Bjerre and Thorsson, 2008; Coben and Larkin, 1999; Voas et al., 1999). Changes in policies and legislation resulting in lower minimum per se BAC levels have also proven effective in deterring drinking and driving in the general population (Schults et al., 2001) as well as among underage drivers. Evaluations of zero tolerance laws for underage drivers have repeatedly shown effectiveness (Zwerling and Jones, 1999); they are perhaps among the most effective approaches for this age group of drivers (Grube and Nygaard, 2001; Shults et al., 2001). None of these approaches have been implemented on a wide basis with teenage drivers as the specific target audience.

The results of this study also suggest that the application of other existing, evidence-based approaches should be expanded to further reduce drinking and driving among underage drivers. One approach is GDL (Grube and Nygaard, 2001). Some form of GDL has been implemented in all U.S. states and the District of Columbia, with the exceptions of Arkansas and North Dakota (Insurance Institute for Highway Safety, 2009), but the systems vary broadly in strength, and GDL did not exist in Michigan during the time when the

crashes included in this study occurred. GDL is a program designed to delay full licensure, provide more time for supervised practice driving, and restrict driving privileges while teens are learning to drive independently so that the exposure of newly licensed independent drivers to higher risk driving conditions is limited (Insurance Institute for Highway Safety, 2009). Restrictions on driving privileges that are commonly imposed by GDL programs include nighttime and passenger restrictions. Another common provision of GDL programs is a stipulation that driving records remain clean in order for teens to advance to the next licensure level. The results of this study show that nighttime driving and driving with passengers are elements of alcohol-involved crash types with the highest risk to teens. A third element that is not currently included in any GDL program is restricted driving on weekends. Finally, although traffic offenses prevent teens in GDL programs from advancing to the next level of licensure, none of the programs have special stipulations for alcohol-involved driving offenses. The results of this study indicate that GDL's positive effect in reducing teen crash risk, generally, and alcohol-involved crash risk, specifically, could be enhanced by two changes to GDL program policies. The first change would be to impose restrictions on weekend driving at night and with passengers (where passenger restrictions do not already exist), so that these three common elements of increased alcohol-involved crash risk among teens are restricted by GDL. The second change would be to add contingencies to GDL that are specific to driving with a BAC of .02 g/dl or greater (i.e., zero tolerance) or speeding. For example, offenses for exceeding the speed limit by more than 10 miles per hour could result in teens being limited to supervised driving for 1 year following conviction, and alcohol-related offenses could mandate supervised driving for 2 years following conviction. These two enhancements to GDL would potentially reduce teen drivers' exposure to the alcohol-involved crash types that present the highest crash risk to teens.

Another genre of program and intervention that is showing promise, and that might be applied more vigorously to underage drinking driving, is parent-directed interventions. Simple motivational strategies can increase parents' use of driving agreements with their teens and encourage parents to impose greater restrictions on early teen driving (Simons-Morton, 2007; Simons-Morton and Hartos, 2003; Williams et al., 2006). Research has repeatedly shown an association between parental supervision and driver safety outcomes. Teen drivers' intentions to violate driving rules are less when parental supervision is greater (Desrichard et al., 2007). Also, greater parental monitoring during adolescence has been shown to predict safer young adult driving outcomes, including less high-risk driving behavior and fewer traffic offenses and crashes (Bingham and Shope, 2004a,b; Bingham et al., 2005, 2006). The addition of preventing drinking and driving as one of the specific objectives of parent-directed

interventions may hold promise as a means of reducing teen crash risk, not only in the early stages of driving but also potentially for years to come (Beck et al., 2005; Williams et al., 2006).

The Checkpoints program is one parent-directed intervention that has yielded promising results in several evaluations. The Checkpoints program provides parents with a motivational message and a structured approach guiding parents and teens in the development of a written driving agreement. The agreement includes the identification of driving privileges and rules, and the establishment of consequences for breaking the agreement. Evaluations of the Checkpoints program indicate that it results in more parents and teens establishing written agreements, greater limit setting on teen driving privileges, lower rates of risky teen driving, and fewer traffic violations by teen drivers. In addition, Checkpoints has resulted in higher levels of monitoring of teen driving by parents, more discussion of driving rules between parents and teens, and greater risk perception (Hartos et al., 2004; Simons-Morton et al., 2006a,b). Research on the Checkpoints program also indicates that it is more effective in states with GDL programs than in states without, suggesting that Checkpoints is a good partner program with GDL (Hartos et al., 2005). Drinking and driving has been included to a limited degree in the Checkpoints program but could receive more emphasis and specific evaluation for its effectiveness in reducing teen drinking and driving.

The apparent synergy between GDL and the Checkpoints program suggests that multicomponent approaches to intervention that combine several intervention modes and methods into a single intervention effort may be more likely to be effective than the application of single programs. Multicomponent approaches could be used to target teen drinking and driving at several levels of teens' environments simultaneously, thus increasing exposure to the intervention message and increasing the likelihood that it will have an effect. For example, such an approach might strengthen restrictions on alcohol sales to underage patrons, impose zero tolerance limits on teen drivers, implement enhanced GDL programs with stronger restrictions, and provide the Checkpoints program to parents when their teenage children are beginning to drive. Such a program would simultaneously reduce teens' access to alcohol (e.g., through rules and parental monitoring), provide GDL programming that increases limits on teen drivers' exposure to higher risk driving conditions, and help parents place safe driving restrictions on their teens and monitor their teens' driving.

Future research in this area should examine more recent data from a period after GDL implementation. Common components of GDL programs are based on research indicating that driving at night or with passengers represents a greater risk for teens than adults. In addition, it is possible that GDL programs have influenced other risk factors in teen crash occurrence, such as speeding, because of the require-

ment that teens maintain a clean driving record to advance through the system. Risk between teenage and young adult drivers might also be compared to determine how crash risk changes over time and what types of crashes decrease more rapidly or slowly with each year of age and/or licensure. Finally, the method employed in this study could also be used to compare the effects of GDL programs in different states that differ significantly in the conditions and restrictions they impose on novice teen drivers.

There are several limitations to the research presented here that should be addressed in future studies examining teen crash types. First, although this study was based on data from a large population, it included only data from Michigan and examined teen crashes during a period that predated the implementation of GDL in Michigan. Research using data from other populations and samples allowing pre- and post-GDL comparisons would expand and refine the information available from this study. Second, although the methods used in this study were effective in identifying alcohol-involved crash risk associated with constellations of crash characteristics, the results did not provide information about the circumstances and processes that link those characteristics or the mechanisms through which the characteristics studied contribute to the increased crash risk. Research using distinct designs and methods examining these issues is needed. Despite these weaknesses, this study provided unique information related to the characteristics of alcohol-related crashes for which teens experience the greatest risk using a novel and useful approach to measure driving exposure. Future research should further study and develop this and other measurement techniques that provide a clearer picture of how driving outcomes relate to individual exposure to driving.

References

- ALDRIDGE, B., HIMMLER, M., AULTMAN-HALL, L., AND STAMATIADIS, N. Impact of Passengers on Young Driver Safety, Transportation Research Record No. 1693, Washington, DC: Transportation Research Board, 1999.
- BECK, K.H., HARTOS, J.L., AND SIMONS-MORTON, B.G. Parent-teen disagreement of parent-imposed restrictions on teen driving after one month of licensure: Is discordance related to risky teen driving? *Prev. Sci.* **61**: 177-185, 2005.
- BEIRNESS, D.J. AND MARQUES, P.R. Alcohol ignition interlock programs. *Traffic Injury Prev.* **5**: 299-308, 2004.
- BINGHAM, C.R. AND SHOPE, J.T. Adolescent developmental antecedents of risky driving among young adults. *J. Stud. Alcohol* **65**: 84-94, 2004a.
- BINGHAM, C.R. AND SHOPE, J.T. Adolescent problem behavior and problem driving in young adulthood. *J. Adolesc. Res.* **19**: 205-223, 2004b.
- BINGHAM, C.R. AND SHOPE, J.T. Casualty crash types for which teens are at excess risk. *Annual Proc. Assoc. Adv. Automot. Med.* **51**: 509-523, 2007.
- BINGHAM, C.R., SHOPE, J.T., AND RAGHUNATHAN, T.E. Patterns of traffic offenses from adolescent licensure into early young adulthood. *J. Adolesc. Hlth* **39**: 35-42, 2006.

- BINGHAM, C.R., SHOPE, J.T., AND TANG, X. Drinking behavior from high school to young adulthood: Difference by college education. *Alcsm Clin. Exp. Res.* **29**: 2170-2180, 2005.
- BIERRE, B., KOSTELA, J., AND SELÉN, J. Positive health-care effects of an alcohol ignition interlock programme among driving while impaired (DWI) offenders. *Addiction* **102**: 1771-1781, 2007.
- BIERRE, B. AND THORSSON, U. Is an alcohol ignition interlock programme a useful tool for changing the alcohol and driving habits of drink-drivers? *Accid. Anal. Prev.* **40**: 267-273, 2008.
- CHEN, L.H., BAKER, S.P., BRAVER, E.R., AND LI, G. Carrying passengers as a risk factor for crashes fatal to 16- and 17-year-old drivers. *JAMA* **283**: 1578-1582, 2000.
- COBEN, J.H. AND LARKIN, G.L. Effectiveness of ignition interlock devices in reducing drunk driving recidivism. *Amer. J. Prev. Med.* **16** (1 Suppl.): 81-87, 1999.
- COMMITTEE ON INJURY AND POISON PREVENTION AND COMMITTEE ON ADOLESCENCE. The teenage driver. *Pediatrics* **98**: 987-990, 1996.
- DESIRICHARD, O., ROCHÉ, S., AND BÉGUE, L. The theory of planned behavior as mediator of the effect of parental supervision: A study of intentions to violate driving rules in a representative sample of adolescents. *J. Safety Res.* **38**: 447-452, 2007.
- DOHERTY, S.T., ANDREY, J.C., AND MACGREGOR, C. The situational risks of young drivers: The influence of passengers, time of day and day of week on accident rates. *Accid. Anal. Prev.* **30**: 45-52, 1998.
- FEDERAL HIGHWAY ADMINISTRATION. National Household Travel Survey. Washington, DC, 2001.
- GONZALES, M.M., DICKINSON, L.M., DIGUISEPPI, C., AND LOWENSTEIN, S.R. Student drivers: A study of fatal motor vehicle crashes involving 16-year-old drivers. *Ann. Emer. Med.* **45**: 140-146, 2005.
- GRUBE, J.W. AND NYGAARD, P. Adolescent drinking and alcohol policy. *Contemp. Drug Probl.* **28**: 87-131, 2001.
- HARTOS, J.L., BECK, K.H., AND SIMONS-MORTON, B.G. Parents' intended limits on adolescents approaching unsupervised driving. *J. Adolesc. Res.* **19**: 591-606, 2004.
- HARTOS, J.L., SIMONS-MORTON, B.G., BECK, K.H., AND LEAF, W.A. Parent-imposed limits on high-risk adolescent driving: Are they stricter with graduated driver licensing? *Accid. Anal. Prev.* **37**: 557-562, 2005.
- HOLDER, H.D., SALTZ, R.F., GRUBE, J.W., VOAS, R.B., GRUENEWALD, P.J., AND TRENO, A.J. A community prevention trial to reduce alcohol-involved accidental injury and death: Overview. *Addiction* **92** (6 Suppl. No. 2): S155-S171, 1997.
- INSURANCE INSTITUTE FOR HIGHWAY SAFETY. Licensing Systems for Young Drivers, Arlington, VA: Insurance Institute for Highway Safety, April, 2009 (available at: <http://www.iihs.org/laws/graduatedLicenseIntro.aspx>).
- JONAH, B.A. Accident risk and risk-taking behaviour among young drivers. *Accid. Anal. Prev.* **18**: 255-271, 1986.
- KOMRO, K.A. AND TOOMEY, T.L. Strategies to prevent underage drinking. *Alcohol Res. Hlth* **26**: 5-14, 2002.
- KYPRI, K., VOAS, R.B., LANGLEY, J.D., STEPHENSON, S.C.R., BEGG, D.J., TIPPETTS, A.S., AND DAVIE, G.S. Minimum purchasing age for alcohol and traffic crash injuries among 15- to 19-year-olds in New Zealand. *Amer. J. Publ. Hlth* **96**: 126-131, 2006.
- MASTEN, S.V. Teenage Driver Risks and Interventions, Report No. CAL-DMV-RSS-04-207, Sacramento, CA: Research and Development Branch, California Department of Motor Vehicles, 2004.
- MAYHEW, D.R., DONELSON, A.C., BEIRNESS, D.J., AND SIMPSON, H.M. Youth alcohol and relative risk of crash involvement. *Accid. Anal. Prev.* **18**: 273-287, 1986.
- MAYHEW, D.R., SIMPSON, H.M., AND PAK, A. Changes in collision rates among novice drivers during the first months of driving. *Accid. Anal. Prev.* **35**: 683-691, 2003.
- NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION. Traffic Safety Facts, 2005 Data: Alcohol, Report No. DOT HS 810 616, Washington: Department of Transportation, 2006a.
- NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION. Traffic Safety Facts, 2005 Data: Speeding, Report No. DOT HS 810 629, Washington: Department of Transportation, 2006b.
- PREUSSER, D.F., FERGUSON, S.A., AND WILLIAMS, A.F. The effect of teenage passengers on fatal crash risk of teenage drivers. *Accid. Anal. Prev.* **30**: 217-222, 1998.
- SHOPE, J.T. AND BINGHAM, C.R. Teen driving: Motor-vehicle crashes and factors that contribute. *Amer. J. Prev. Med.* **35** (3 Suppl.): S261-S271, 2008.
- SHULTS, R.A., ELDER, R.W., SLEET, D.A., NICHOLS, J.L., ALAO, M.O., CARANDE-KULIS, V.G., ZAZA, S., SOSIN, D.M., THOMPSON, R.S., AND THE TASK FORCE ON COMMUNITY PREVENTIVE SERVICES. Reviews of evidence regarding interventions to reduce alcohol-impaired driving. *Amer. J. Prev. Med.* **21** (4 Suppl.): 66-88, 2001.
- SIMONS-MORTON, B. Parent involvement in novice teen driving: Rationale, evidence of effects, and potential for enhancing graduated driver licensing effectiveness. *J. Safety Res.* **38**: 193-202, 2007.
- SIMONS-MORTON, B.G. AND HARTOS, J.L. How well do parents manage young driver crash risks? *J. Safety Res.* **34**: 91-97, 2003.
- SIMONS-MORTON, B.G., HARTOS, J.L., LEAF, W.A., AND PREUSSER, D.F. The effect on teen driving outcomes of the Checkpoints Program in a state-wide trial. *Accid. Anal. Prev.* **38**: 907-912, 2006a.
- SIMONS-MORTON, B.G., HARTOS, J.L., LEAF, W.A., AND PREUSSER, D.F. The effects of the Checkpoints Program on parent-imposed driving limits and crash outcomes among Connecticut novice teen drivers at 6-months post-licensure. *J. Safety Res.* **37**: 9-15, 2006b.
- SIMONS-MORTON, B., LERNER, N., AND SINGER, J. The observed effects of teenage passengers on the risky driving behavior of teenage drivers. *Accid. Anal. Prev.* **37**: 973-982, 2005.
- SUBSTANCE ABUSE AND MENTAL HEALTH SERVICES ADMINISTRATION (Office of Applied Studies). Quantity and Frequency of Alcohol Use, National Survey on Drug Use and Health, The NSDUH Report, December 12, 2003, Rockville, MD: Substance Abuse and Mental Health Services Administration, 2003 (available at: www.oas.samhsa.gov/2k3/AlcQF/AlcQF.htm).
- TOOMEY, T.L., WAGENAAR, A.C., GEHAN, J.P., KILIAN, G., MURRAY, D.M., AND PERRY, C.L. Project ARM: Alcohol Risk Management to Prevent Sales to Underage and Intoxicated Patrons. *Hlth Educ. Behav.* **28**: 186-199, 2001.
- ULMER, R.G., WILLIAMS, A.F., AND PREUSSER, D.F. Crash involvements of 16-year-old drivers. *J. Safety Res.* **28**: 97-103, 1997.
- VOAS, R.B., MARQUES, P.R., TIPPETTS, A.S., AND BEIRNESS, D.J. The Alberta Interlock Program: The evaluation of a province-wide program on DUI recidivism. *Addiction* **94**: 1849-1859, 1999.
- VOAS, R.B., TIPPETTS, A.S., AND FELL, J.C. Assessing the effectiveness of minimum legal drinking age and zero tolerance laws in the United States. *Accid. Anal. Prev.* **35**: 579-587, 2003.
- VOAS, R.B., WELLS, J., LESTINA, D., WILLIAMS, A., AND GREEN, M. Drinking and driving in the United States: The 1996 National Roadside Survey. *Accid. Anal. Prev.* **30**: 267-275, 1998.
- WILLIAMS, A.F. Teenage drivers: Patterns of risk. *J. Safety Res.* **34**: 5-15, 2003.
- WILLIAMS, A.F., FERGUSON, S.A., AND MCCARTT, A.T. Passenger effects on teenage driving and opportunities for reducing the risks of such travel. *J. Safety Res.* **38**: 381-390, 2007.
- WILLIAMS, A.F., LEAF, W.A., SIMONS-MORTON, B.G., AND HARTOS, J.L. Vehicles driven by teenagers in their first year of licensure. *Traffic Injury Prev.* **7**: 23-30, 2006.
- ZADOR, P.L., KRAWCHUK, S.A., AND VOAS, R.B. Alcohol-related relative risk of driver fatalities and driver involvement in fatal crashes in relation to driver age and gender: An update using 1996 data. *J. Stud. Alcohol* **61**: 387-395, 2000.
- ZWERLING, C. AND JONES, M.P. Evaluation of the effectiveness of low blood alcohol concentration laws for younger drivers. *Amer. J. Prev. Med.* **16** (1 Suppl.): 76-80, 1999.