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Exploring the Relationship Between Early Drinking Patterns and Vehicle Control Measures in Driving Simulation Among Sober Young Adults

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Abstract

Background: Among young drivers, drinking is a primary contributor to motor vehicle crashes. Drinking history metrics have been related to vehicle control among sober drivers. Younger drinking is associated with alcohol- and non-alcohol-related risky behaviors and neurocognitive vulnerabilities. Although early drinking translates to a health-risking profile (i.e., impaired driving, neurocognitive vulnerabilities), few studies have examined the relationship between early drinking initiation/patterns and sober young driver behavior.

Objective: To explore the relationship between early drinking patterns and vehicle control among sober young adult drivers.

Methods: Participants: U.S. licensed drivers (18-25-year-old) were recruited. Drinking Measures: Self-reported age of first: drink (AgeDrink), drunk (AgeDrunk), and 5 or more drinks (Age5Plus). Driving Simulation: Vehicle control measures were collected using a ½-cab miniSim® simulator and a scenario with straight and curved roadways, turns, and intersections: standard deviation (SD)/average steering wheel angle, SD lane position, minimum headway time/distance, and SD/minimum/maximum speed.

Results: Data from 18 participants were included. All measures were inversely related to lane position on straight roads; average steering wheel angle on curved roads; average steering wheel angle while turning, and positively related to SD steering wheel angle on curved roads and while turning. AgeDrink and AgeDrunk were inversely related to minimum headway time/distance on curved roads. AgeDrunk and Age5Plus were inversely related to SD speed through intersections. AgeDrink and Age5Plus were inversely related to maximum speed through intersections. AgeDrink was inversely related to SD steering wheel angle on straight roads and SD lane position through intersections.

Conclusions: Our findings offer an initial perspective on how, even while sober, drinking at a younger age is associated with greater variability in vehicle control measures that are linked to increased crash-risk. These findings point to a need to broaden our understanding of how youth drinking may relate to sober driving performance and potentially heighten crash risk.

Keywords: Driving simulation; youth; age of drinking initiation; vehicle control; young adults

1. Introduction

Across the world and in the United States, motor vehicle crash-injuries are a leading cause of death for both adolescents and young adults [1-3]. Motor vehicle crash-related injuries outnumber fatalities 100 to 1 and drinking remains a primary contributor to motor vehicle crashes, particularly among young drivers [4]. In the U.S., graduated driver licensing programs pose strict penalties for young novice drivers who are caught driving under the influence of alcohol/substances) [5]. However, even with the implementation of graduated driver licensing programs, drinking and driving is still a frequently reported high-risk behavior among young drivers [6]. Although, far more commonly, driving occurs while the driver is not intoxicated. Together this suggests a critical need to understand how factors, such as the neuroscience of driving and the potential alcohol-related deficits on the developing brain, lead to motor vehicle crashes, and related injuries and deaths, particularly among young drivers.

It is during young adulthood when risky taking propensity is at the highest across the lifespan, with drinking being one of the most frequently reported risky behaviors. In the United States, the legal drinking age is 21. Therefore, choosing to drink before reaching the legal drinking age carries an inherent legal risk. Research has demonstrated that younger age of drinking initiation is also related to multiple health risks. For example, adolescents who initiate drinking at younger ages have an increased likelihood of developing alcohol use disorders, heavier alcohol use patterns, and alcohol-related problems [7, 8]. Although driving most often occurs while the driver is not intoxicated, little research has examined how younger age of drinking initiation impacts driving while in a sober state.

Overall, driving is a highly complex task that is commonly initiated during adolescence and young adulthood – a critical period of development wherein cognitive functions are still maturing [9]. Well-documented evidence supports the link between youth drinking and deficits in cognitive functions that are critical for driving, including attention, working memory, and inhibitory control [10-12]. More specific to the current topic, earlier age of drinking initiation and earlier age of onset of heavy and regular drinking has been linked with poorer attention, working memory, and inhibitory control while sober [13]. Additionally, evidence also suggests a link between deficits in cognitive functions and risky driving behaviors. Driving simulation studies of young adults found that deficits in working memory and inhibitory control were associated with increased variability in vehicle control (i.e., poorer lane maintenance and increased speeds [14-16]. Worse sustained attention is associated with more frequent lapses in attention while driving [16] and lane maintenance during simulated driving [17]. Given the links between youth drinking, deficits in cognitive function, and poor vehicle control, research studies have begun to intentionally study history of drinking in the context of sober driving. For example, among young adult sober drivers, a history of binge drinking and drinking-related symptoms (i.e., blackout, injuries) has been related to poorer attention while driving, as measured by neural processing during secondary task engagement [18]. Higher overall scores on the Alcohol Use Disorder Identification Test [19], a self-report measure of drinking intensity, frequency, and related problems, have been associated with increased variability in vehicle control (i.e., standard deviation of lane position, speed) during driving simulation, even while sober [20]. Altogether, these studies suggest important relationships between drinking, cognitive functioning, and vehicle control (even when not acutely intoxicated). However, few studies have specifically examined how age of drinking initiation, first episode of drunkenness, or first episode of binge drinking may translate to simulated vehicle control driving measures which are linked to real-world risky driving.

The objective of this study was to explore the relationship between early drinking patterns and vehicle control in high-fidelity driving simulation among sober young adult drivers. We focus this study on young adults because of the convergence of high prevalence of risky drinking, ongoing neurodevelopment, independent licensure, and motor vehicle crashes. The primary hypothesis was that the three measures of drinking initiation (age of first drink, age of first drunken experience, and age of first 5 or more drinks on one occasion) would be associated with poorer vehicle control in the simulated setting. This study addressed an urgent public health need to better understand the underlying determinants of risky driving behaviors that contribute to the continued high prevalence of non-fatal and fatal motor vehicle crashes among adolescents and young adults in the U.S. and across the world.

2. Methodology

2.1 Participants: Twenty-four young adults (18-25 years old; 9 males) from the New Haven, CT, U.S.A. area were recruited as part of an ongoing larger young adult driving study which collected driving simulation measures, electrophysiology tasks, and self-report questionnaires on behaviors (i.e., demographic information, Behavioral Ratings Index of Executive Function). All procedures were carried out in the Yale Developmental Neurocognitive Driving Simulation Research Center (DrivSim Lab). Participants were eligible for participation if they met the following criteria: 1) currently have a valid United States driver's license (to ensure driving basics were known (e.g., how to start a vehicle, U.S. driving rules)); 2) negative screen for simulator sickness; 3) no history or diagnosis of autism spectrum disorder and/or seizure disorder; 4) no history of head injury with loss of consciousness. During recruitment participants were informed they would be reimbursed 55 USD for study participation with the opportunity to earn an additional 5 USD during the driving task (parameters described in Section 2.3). All participants provided written informed consent which was approved by the Human Investigative Committee at Yale University School of Medicine.

2.2 Drinking Measures: Once consent procedures were completed, all participants were screened for current blood alcohol concentrations (BACtrack S80 PRO; BAC=0.00%). All participants completed self-reported questionnaires on measures of early drinking behaviors. Participants were asked to report age of first: drink (AgeDrink; "How old were you the first time you had a drink of an alcoholic beverage? Please do not include any time you only had a sip of two from a drink."); drunk (AgeDrunk; "Now think about the first time you got drunk. How old were you?"); and 5 or more drinks (Age5Plus; "Now think about the first time you drank 5 or more drinks on a single occasion. How old were you?"). All questions were adapted from the NEXT Generation Health Study [21, 22].

2.3 Driving Simulation: Driving simulation procedures were completed in a miniSim® (National Advanced Driving Simulator (NADS), University of Iowa) high-fidelity driving simulator with NADSDyna™ software located in the Yale Developmental Neurocognitive Driving Simulation Research Center (DrivSim Lab). The simulator was instrumented to a sedan half cab which extends from the front bumper to behind both the driver's and passenger front seats. The simulation is displayed using four high resolution projectors on to a smooth, floor to ceiling cylindrical screen and a rear projection panel. Prior work supports using driving simulation to assess driving behaviour [23]. After participants were seated in the driver's seat, they were asked to adjust the seat to a comfortable position and buckled the seatbelt for all driving simulation procedures. During the appointment, participants were asked to drive two scenarios. All participants first drove a practice drive to become oriented to the driving simulator and virtual environment. Before the second drive, participants were instructed to reach a target location by following the driving directions that were presented through the preprogrammed scenario while abiding by the speed limit and traffic laws (i.e., no illegal turns). The driving simulation scenario required participants to navigate curved roadways and turns, cross over an intersection**,** and continue a straight path. These conditions were chosen because previous research has shown them to be associated with motor vehicle crashes among young and older drivers [24]. To encourage compliance to the driving rules, participants were able to earn an additional 5 USD incentive if they arrived at the target location and maintained a speed within 5 mph of the posted speed limit, did not break driving laws, and did not have any crash incidents. All participants were informed that their driving behaviors would be monitored throughout the scenario and there would be cash penalties for each infraction (0.50 USD for speed, driving infractions; 0.75 USD for crashes). Both scenarios were set in a city environment. The city scenario was designed for participants to navigate straight and curved roadways, intersections, and turns.

2.4 Vehicle control measures: Vehicle, environment, and driver behavior data were collected at 60Hz. All data were reduced to provide summary data for each simulation scenario segment. Dependent measures included measures of lateral and longitudinal vehicle control: standard deviation (SD)/average steering wheel angle, SD lane position, minimum headway time/distance, and SD/minimum/maximum speed. All vehicle control measures were collected for all roadway types.

2.5 Checkpoints Risky Driving Scale (C-RDS): All participants completed the C-RDS, a validated survey that is significantly associated with real-world risky driving which measures frequency of speeding, aggressive driving, and risky driving behaviors [25].

2.6 Simulator Sickness Questionnaire: All participants completed a 16-item questionnaire evaluating feelings of simulator sickness after the practice drive and test drive conditions [26]. Participants were also continuously monitored for behavioral signs of simulator sickness during both driving simulation procedures.

3. Analysis and Results

3.1 Analysis: Pearson correlations were used to explore the relationships between early drinking patterns and drinking initiation, and lateral and longitudinal vehicle control measures. Pearson correlations were used to explore the relationships between early drinking patterns and drinking initiation, and C-RDS scores.

3.2 Results

3.2.1 Participants: Data from 18 (9 males) participants were included in the current analyses. Participant data were excluded from the current analyses if they were unable to complete the task drive, if they were experiencing feelings of simulator sickness (n=4), or if there was no history of alcohol use (n=2). All participants were aged 18 to 25 (M = 22.11; SD = 2.49). The Human Investigative Committee at the Yale University School of Medicine approved all protocol procedures.

3.2.2 Age of First Drink (AgeDrink; M = 17.22; SD = 2.5): There was a significant inverse relationship between AgeDrink and SD wheel angle ($r(17) = -.58$, $p = .01$) and SD lane position ($r(17) = -.6$, $p = .006$) on straight roads. On curved roads, there was a significant inverse relationship between AgeDrink and average steering wheel angle ($r(17) = -.55$, $p = .02$), minimum headway time ($r(17) = -.5$, $p = .03$), and minimum headway distance ($r(17) = -.5$, $p = .03$). There was a significant positive relationship between AgeDrink and SD of steering wheel angle ($r(17) = .5$, $p = .03$) on curved roads. While navigating an intersection, there was an inverse relationship between AgeDrink and maximum speed ($r(17) = -.5$, $p = .03$) and SD of lane position ($r(17) = -.51$, $p = .03$). During turns, there was a significant positive relationship between average steering wheel angle ($r(17) = .56$, $p = .02$) and SD of steering wheel angle ($r(17) = .6$, $p = .008$). There was no significant relationship between AgeDrink and C-RDS scores.

3.2.3 Age of First Drunk (AgeDrunk; M = 18.61; SD = 1.98): On straight roads, there was a significant inverse relationship between AgeDrunk and SD lane position ($r(17) = -.5$, $p = .05$). There was a positive relationship between AgeDrunk and minimum time to collision ($r(17) = -.5$, $p = .05$) on straight roads. On curved roads, there was a significant inverse relationship with average steering wheel angle ($r(17) = -.7$, $p = .001$) and minimum headway time ($r(17) = -.5$, $p = .03$) and distance ($r(17) = -.5$, $p = .03$). There was also a significant positive relationship between AgeDrunk and SD steering wheel angle ($r(17) = .67$, $p = .002$) on curved roads. There was a significant positive relationship between AgeDrunk and average steering wheel angle ($r(17) = .64$, $p = .004$) and SD of steering wheel angle ($r(17) = .63$, $p = .005$) during turns. There were no significant relationships for AgeDrunk and any of the vehicle control metrics while navigating intersections. There was no significant relationship between AgeDrunk and C-RDS scores.

3.2.4 Age of First 5 or More Drinks (Age5Plus; M = 18.56; SD = 2.06): On the straight roads, Age5Plus was inversely related to SD lane position ($r(17) = -.5$, $p = .05$). There was a significant inverse relationship with average steering wheel angle ($r(17) = -.54$, $p = .02$) and a positive relationship with SD steering wheel angle ($r(17) = .56$, $p = .01$) on curved roads. While navigating intersections there was a significant inverse relationship between Age5Plus and average steering wheel angle ($r(17) = .5$, $p = .05$), SD of speed ($r(17) = -.5$, $p = .05$), and maximum speed ($r(17) = -.5$, $p = .04$). There were significant positive relationships between Age5Plus and average steering wheel angle ($r(17) = -.5$, $p = .04$) and SD of steering wheel angle ($r(17) = -.5$, $p = .03$) while turning. There was no significant relationship between Age5Plus and C-RDS scores.

Table 1: Pearson Correlations Between Drinking Initiation and Vehicle Control Metrics

	STRAIGHT		CURVED				TURN		INTERSECTION			
	SD Steering Wheel Angle	SD Lane Position	Average Steering Wheel Angle	SD Steering Wheel Angle	Minimum Headway Time	Minimum Headway Distance	Average Steering Wheel Angle	SD Steering Wheel Angle	SD Speed	Maximum Speed	Average Steering Wheel Angle	SD Lane Position
AgeDrink	-.58**	-.60**	-.55*	.50*	-.50*	-.52*	-.56*	.60**	-.44	-.49*	-.35	-.51*
AgeDrunk	-.45	-.50*	-.70**	.67**	-.50*	-.50*	-.64**	.63**	-.45*	-.41	-.42	-.11
Age5Plus	-.45	-.50*	-.54*	.56**	-.45	-.45	-.50*	.52*	-.46*	-.48*	-.46*	-.19

*Correlation is significant at the .05 level (2-tailed).
**Correlation is significant at the .01 level (2-tailed).

4. Discussion

The ability to maintain vehicle control is directly linked to motor vehicle crash incidence. Although prior work has linked age of drinking onset and self-report of risky driving behaviors [27], to the best of our knowledge, this is the first study to directly examine the relationship between three frequently used definitions of drinking initiation and simulated vehicle control while sober. The findings also support the hypothesis that earlier age of first drink, first drunken experience, and age of first 5 or more drinks on one occasion are associated with poorer vehicle control in the simulated setting. These findings support previous work which shows noncausal relationships between self-report of drinking, and vehicle control and driving relevant behaviors [18, 20]. Because vehicle control measures are closely associated with driving kinematics which are directly linked to real-world risky driving, our findings suggest that age of early alcohol exposure may be a key indicator for risky driving profiles when developing and informing prevention efforts aimed at reducing motor vehicle crashes among young drivers.

Across three roadway types (i.e., curves, turning, continuing straight through intersections), poorer lane keeping abilities were associated with earlier drinking initiation for all definitions. The inability to maintain lane keeping is linked to over 30% of motor vehicle crash fatalities in the United States and Sweden [28, 29]. Earlier age of drinking was also related to increased speed and increased variability in speed. Higher speed is also a leading contributor to motor vehicle crashes and directly relates to crash-severity, especially among young drivers [6, 30]. Together these data directly link earlier drinking age with known contributors to motor vehicle crashes and severity, however further research is needed to understand the intricacies between differing definitions of drinking initiation and driving behaviors. By understanding how younger drinking initiation is associated with increased risky driving performance and therefore increased likelihood for motor vehicle crashes, training and intervention programs can be tailored based on these “out-of-cab” behaviors.

Although the current analyses did not directly measure cognitive functioning (i.e., working memory, inhibitory control, attention) in the context of early drinking patterns or vehicle control, the findings support prior evidence of how widespread cognitive deficits are correlated with initiating drinking at a younger age. These data also support the need to encourage youth to delay alcohol initiation for as long as possible. Young drivers are at a unique point of vulnerability for alcohol exposure and initial drinking. By foregoing drinking for a couple of years, adolescents not only avoid exposure to the potential neurotoxic effects of alcohol, but they may also reduce their likelihood of risky driving and potential MVCs while sober. The current findings also support previous research that suggests that there is also a broader health-risking profile related to younger age of drinking initiation [27, 31, 32]. For example, younger age of drinking initiation has been associated with greater likelihood of other substance use (i.e., tobacco, marijuana), sexual risks (i.e., unprotected sex, multiple partners, pregnancy, being intoxicated during intercourse), and driving while intoxicated/riding with an intoxicated driver [31-34]. Altogether, these data suggest age of drinking initiation may be a marker for a person’s overall risk profile, which may include risky driving behaviors. Therefore, by postponing alcohol exposure, youth may improve their developmental trajectory and life outcomes by reducing the overall health-risking profile.

This study has several limitations. Self-reported drinking history may be susceptible to recall or social desirability bias. However, alcohol and risky behavior research commonly relies on self-report methods and the validity of using these methods, even with youth, have previously been supported [35, 36]. Data was collected after drinking initiation therefore, we cannot suggest a causal relationship between earlier drinking and driving performance. The sample size for this study was relatively small, increasing likelihood of potential Type II error. The current analyses do not include a control group which would provide further insight into the results. However, these preliminary results are part of an ongoing larger study that is still recruiting (to be completed in Spring 2022) and will include additional groups. The current analyses do not include additional behavioral or neurocognitive factors (i.e., frequency of current binge drinking, impulsivity, cognitive functioning) which may translate to the driving environment. Despite these limitations, our highly novel study supports the need to better understand behaviors that occur outside of the cab as a way to identify those that are at greater risk for MVCs and ultimately inform tailored driver training programs [20, 37, 38].

5. Conclusions

In summary, the current study provided preliminary evidence which shows how, even while sober, drinking at a younger age may be associated with greater variability in vehicle control measures that are linked to increased crash-risk. Our findings point to a need to broaden our understanding of how youth drinking relates to sober driving behaviors and how this might heighten crash risk. Prevention efforts often encourage youth and their parents to delay drinking initiation for as long as possible in order to reduce the likelihood for alcohol use disorders and other adverse outcomes. Our findings suggest that prevention efforts may also benefit from messaging which highlights the possibility that delaying drinking initiation may also diminish crash risk during sober states. Together, early drinking initiation could be considered as an indicator for risky driving profiles and may be a useful indicator when developing tailored prevention and driver safety policies.

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