The Journal of Social Sciences Research
ISSN(e): 2411-9458, ISSN(p): 2413-6670
Vol. 8, Issue. 4, pp: 56-71, 2022
URL: https://arpgweb.com/journal/journal/7
DOI: https://doi.org/10.32861/jssr.84.56.71

Academic Research Publishing Group

Original Research Open Access

The Effect of Physical Activity on the Attitudes toward Engaging in Driving While Impaired by Alcohol

Chong-Hwan Son
Ph.D. in Economics Department of Education and Social Sciences Hudson Valley Community College 80 Vandenburgh Ave. Troy, New York 12180, U.S.A.
Email: c.son@hvcc.edu

Article History
Received: 12 August, 2022
Revised: 29 September, 2022
Accepted: 24 October, 2022
Published: 31 October, 2022

Abstract

This study investigated the effect of physical activity on the attitudes toward engaging in driving while impaired by alcohol among adults aged 18 years or older who reported consuming alcohol in the 30 days before the interview. This study conducted the multivariate logistic regression to examine the association between health behavior and attitudes toward driving while impaired by alcohol. Data about self-reported alcohol-impaired driving episodes and the majority of the variables presented in this study were taken from the 2020 Behavioral Risk Factor Surveillance System (BRFSS), a large-scale national health survey data and a cross-sectional state-level survey data set, collected by the Centers for Disease Control and Prevention (CDC). The empirical results indicated that physical activity was associated with reduced engagement in alcohol-impaired driving. The estimated odds ratios from the multivariate logistic regression results were 0.87, 0.87, and 0.85 for overall, males, and females, respectively. In other words, respondents who participated in physical activities were less likely than respondents who were inactive to operate a motor vehicle when they were impaired by alcohol consumption. In short, physical activity was significantly associated with a decrease in the propensity toward engaging in driving while impaired by alcohol for alcohol drinkers.

Keywords: Physical activity; Alcohol-impaired driving; BRFSS; Logistic regression.

1. Introduction

It is perhaps the most well-known and recognizable that alcohol is a powerful chemical that has an extensive range of adverse effects on human behaviors, such as increasing aggression (Steele and Southwick, 1985). The short-term effects of alcohol on human behaviors are often unpredictable because alcohol alters brain function by interacting with various factors (Sullivan *et al.*, 2010). Nevertheless, one of the behavioral effects of alcohol drinking has been established as alcohol consumption is associated with risky behaviors, such as alcohol-impaired driving (Martin *et al.*, 2018). According to the study (Bingham *et al.*, 2007), drink/drivers are less likely than other drivers to accept safe driving habits and are more likely than non-drink/drivers to be risk drivers, and drink/driving is associated with many forms of high-risk driving behaviors, including speeding, riding with a drink/drivers, drug/driving, and aggressive driving. The study (Jamt *et al.*, 2020) reported that these human factors for the driver's behavior have been identified to play a significant role in the causation of road traffic accidents. In other words, driver-related behavioral factors were the dominating cause of traffic accidents and contributing factors to other crashes. Because the behavioral factors play a significant role in the harms associated with injury-related traffic crashes, the driver's behavior has been the focal interest in traffic safety research.

The United States has implemented several programs and policies to prevent alcohol-impaired driving and, also, made significant strides in reducing alcohol-related traffic accidents over the past century. However, driving under the influence (DUI) of alcohol remains a serious public concern and a major contributing factor to motor vehicle accidents (Sanem *et al.*, 2015). The National Highway Traffic Safety Administration (National Highway Traffic Safety Administration, 2020) reported that 11,654 fatalities occurred in motor vehicle crashes in which at least one driver was impaired by alcohol in 2020. These alcohol-impaired fatal motor vehicle accidents accounted for approximately one-third of all traffic fatalities in the United States. The National Highway Traffic Safety Administration (2020) defined an alcohol-impaired driver as the driver's Blood Alcohol Concentration (BAC) was 0.08 grams per deciliter (g/DL) or higher. Thus, any fatal crash involving a driver with a BAC of 0.08 (g/dL) or higher was known to be an alcohol-impaired-driving crash, and an occurrence of death by motor vehicle accidents was considered to be an alcohol-impaired-driving fatality. The alcohol-impaired driving can put anyone at risk of causing an accident, serious injuries, or death. As a result, it can contribute to increased social costs of traffic

accidents (Bishop *et al.*, 2017; Mun *et al.*, 2022), including lost productivity, workplace losses, legal and court expenses, medical costs, emergency medical services, property damage, etc.

Previous studies (Badicu *et al.*, 2020; Gilchrist *et al.*, 2020) addressed that regular physical activity benefited overall health in many ways, including helping build strong muscles and joints, helping reduce the risk of developing certain chronic diseases, helping raise self-esteem and confidence, and helping reduce feelings of stress and anxiety. Most importantly, a higher level of physical activity played an important role in improving the quality of life (Badicu *et al.*, 2020). To promote overall health and reduce the burden of chronic diseases, the Physical Activity Guidelines for Americans, issued by the U.S. department of health and human services, provided evidence-based guidance to help Americans maintain or improve their health through physical activity (Piercy *et al.*, 2018). According to the 2018 Physical Activity Guidelines for Americans, adults should do at least 150 minutes to 300 minutes a week of moderate-intensity, 75 minutes to 150 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. They should also do muscle-strengthening activities on two or more days a week and should do multi-component physical activity that includes balance training as well as aerobics.

Physical activity (health-promoting behavior) and alcohol consumption (health risk behavior) are closely linked and common behaviors related to overall health. The relationship between the two health behaviors is complex; however, the relationship can be demonstrated with the theory of consumer choice which is one of the elements of behavioral economics (Buscemi *et al.*, 2011; Gilchrist *et al.*, 2020). The consumer choice theory might predict an inverse relationship between alcohol consumption and physical activity within the time constraint, holding other things constant. It implies that they are substitutes in consumption: an increase in engagement in regular physical activity lowers presumably alcohol consumption. For example, if an individual were less concerned with her/his health (less engaging in physical activities), she/he will have more available time to consume alcohol. It increases the probability of alcohol-impaired driving episodes. On the other hand, if an individual were concerned with improving her/his health, she/he will increase participation in physical activities. As a result, the likelihood of alcohol-impaired driving is expected to fall. Hence, an increase in physical activity not only can improve overall health but also lowers alcohol-impaired driving episodes.

From a different perspective, physical activity and alcohol drinking can be complementary in consumption. Studies (Gilchrist *et al.*, 2020; Werneck *et al.*, 2018) explored the relationship between the two health-related behaviors. Their findings for the relationship between these health-related behaviors were consistent with the compensatory health belief model: alcohol drinking might precede physical activity to compensate for consuming alcohol, and the consequences of engaging in a health-risk behavior (e.g., alcohol drinking) were thought to be neutralized by subsequently engaging in a health-promoting behavior (e.g., physical activity) - drinkers might attempt to shed calories from alcohol by engaging in exercise. In contrast, engaging in physical activity might precede alcohol consumption because with more activity individuals might be more socializing. Active individuals tend to be exposed to more frequent social interaction, which in turn can lead to higher alcohol consumption (Werneck *et al.*, 2018). Furthermore, socializing could be a part of organized sports and often involves alcohol (e.g., going out to drink after a soccer game).

There was more evidence of the complementary relationship between the two health-related behaviors. The study (Lisha *et al.*, 2013) provided evidence of a complementary relationship between alcohol drinking and physical activity from the preclinical models: the mesocorticolimbic neural circuit, a brain pathway associated with reward, was activated by both alcohol and exercise and could cause the two behaviors to be coupled. They used the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC: Wave 2, 2004-2005) to investigate the association between physical activity and indices of alcohol consumption frequency. They found a positive association between physical activity and less severe forms of alcohol use disorder in U.S. adults. The studies (Buscemi *et al.*, 2011; Gilchrist *et al.*, 2020) reported that the proportion of alcohol drinkers among survey participants who were currently participating in physical exercises was greater than the proportion of alcohol drinkers among participants who did not participate in physical activities. Also, studies (Buscemi *et al.*, 2011; Dodge *et al.*, 2017; Gilchrist *et al.*, 2020; Niedermeier *et al.*, 2018; Piazza-Gardner and Barry, 2012) documented a positive relationship between physical activity and alcohol consumption among the general population. In short, the studies highlighted that alcohol drinkers were more likely than non-drinkers to participate in physical activity, and vice versa.

The health benefits of regular physical activity were described in the previous paragraph. Additionally, the studies (Amarasinghe and Anura, 2010; Gulliford *et al.*, 2014) pointed out the importance of physical activity based on a social welfare point of view. Physical activity could occur during work, transport, domestic, and leisure-time activities. According to these studies, physical inactivity was a key risk factor contributing to higher rates of many chronic diseases, including diabetes, cardiovascular diseases, and some cancers. For instance, promoting physical activity in primary care would have the potential to increase life years lived free from physical illnesses and reduce many preventable chronic diseases (Abu-Omara *et al.*, 2017; Cobiac *et al.*, 2009; Laine *et al.*, 2014). As a result, physical activity could contribute to reducing health care expenditure based on their cost-effectiveness and cost-benefit analyses, and an increase in physical activity could lead to substantial improvement in population health at social cost saving to the health sector.

Moreover, physical activity can improve several skills associated, particularly, with driving performance, such as responsiveness to unexpected circumstances while driving. Although physical activity directly contributes to improving the safety driving performance, what happens if individuals who participate in physical activity are more likely than individuals who are inactive to consume alcoholic beverages with a higher likelihood of engaging in

alcohol-impaired driving? This is an important question that physical activity is associated with risky behaviors, such as alcohol-impaired driving (Martin *et al.*, 2018). If that were the case, a reduction in health care expenditure (social costs) by improving public health with an increase in participation in physical exercise is expected to be fully offset by an increase in economic costs of fatal and nonfatal preventable injury-related crashes due to an increase in alcohol-impaired driving. Currently, relatively little is known about the impacts of physical activity on drivers' propensity to engage in risky driving behaviors, such as alcohol-impaired driving. If individuals who participate in physical activity have a higher risk-taking propensity, the net gains of social welfare due to increasing physical activities might be questionable.

Finally, this study hypothesizes that the protective health behavior of physical activity has some relationship with high-risk behavior, driving while impaired by alcohol, and investigates the attitudes of alcohol drinkers who participate in any physical activity toward risk-taking behavior. This study conducted the multivariate logistic regression to examine the association between health behavior and attitudes toward driving while impaired by alcohol among drinkers aged 18 years or older in the United States. Data about self-reported alcohol-impaired driving episodes and the majority of the variables presented in this study were taken from the 2020 Behavioral Risk Factor Surveillance System (BRFSS), a large-scale national health survey data and a cross-sectional state-level survey data set, collected by the Centers for Disease Control and Prevention (CDC). A detailed description of the BRFSS data and the definition of all variables are presented in section 3.

2. Analytical Framework

An episode of alcohol-impaired driving referred to a participant who had driven at least once after having perhaps too much to drink during the past 30 days. An episode of engaging in alcohol-impaired driving served as a dichotomous dependent variable in the empirical models. Each respondent was coded as either '1' if the respondent reported having driven after having perhaps too much to drink or '0' if not. The explanatory variables were physical activity, socio-demographic variables (sex, marital status, employment status, household annual income, race, age, and education), risk behaviors (smoking, binge drinking, seat belt use), and alcohol policy variables (alcohol control states and the Mothers Against Drunk Driving grades) (Sanem *et al.*, 2015; Son, 2014; Sunshine *et al.*, 2018). A method for estimating the probability of reporting having an episode of alcohol-impaired driving for each observation could be developed as a general linear probability equation:

$$y_i = \beta_0 + x_{ik}\beta_k + u_i \quad (1)$$

where the subscript i denoted an observation, and y_i was the probability of engaging in alcohol-impaired driving at the i^{th} observation. x_{ik} was an i x k matrix of explanatory variables where k was the number of explanatory variables. β_0 was a constant term, and β_k was a coefficient matrix of the equation with a dimension of k x1. u_i was the error term at each observation i with the expected value of u_i, $E(u_i) = 0$. Thus, the conditional expected value of the dependent variable was expressed as $E(y_i|x_{ik}) = \beta_0 + x_{ik}\beta_k$. However, the predicted value of the dependent variable for each observation from the linear probability equation model could fall outside of a certain probability of occurrence, from zero to one. As a result, the predicted probability of engaging in alcohol-impaired driving from the general linear probability model could be quite different from the actual value for each observation. This is one of the major problems with the linear probability models.

However, a wide range of alternatives is available to resolve this issue. One alternative model is logistic regression used to predict the log odds of a discrete variable arising. The logistic regression model could avoid the unbounded predicted probabilities and has been widely used in research dealing with a dichotomous dependent variable (Kleinbaum and Klein, 2002; Maddala, 1992; Son, 2014; Stoltzfus, 2011). In the logistic regression, an unknown probability (y) could be estimated for any given linear combination of independent variables, and the dependent variable follows the Bernoulli distribution (Marshall and Olkin, 1985) that is a case of the binomial distribution with one trial: success is '1', and failure is '0'. If the probability of success is y, the probability of failure is $(1 - y)$. Here, it is required to link all together the independent variables to essentially the Bernoulli distribution. The link function is called the logit. The probability is unknown in the binomial (Bernoulli) distribution problems in logistic regression. As mentioned above, the purpose of using logistic regression is to estimate the unknown probability (y) for a given linear combination of independent variables. The estimate of y is called y-hat, $\hat{y}$. To tie together the linear combination of independent variables and in the essence of the Bernoulli distribution, the function that linked them together or mapped the linear combination of variables could result in any value in the Bernoulli probability distribution with a domain from zero to one. The natural log of the odds ratio (the logit) is the link function:

$\ln(\text{odds}) = \ln\left(\frac{y}{1-y}\right)$ is expressed as 'logit (y) or $\ln(y) - \ln(1-y)$', such as

$$\text{logit}(y) = \ln\left(\frac{y}{1-y}\right) \quad (2)$$

In equation (2), if $y = 0$, logit (y) would be $-\infty$; if $y = 1$, logit (y) would be $+\infty$; and if $y = 0.5$, logit (y) would be zero. In the graph of the logit link function, the probability (y) ranges from 0 to 1 alone on the x-axis with vertical asymptotes at 0 and 1, but the probability (y) should be on the y-axis. It could be achieved by taking an inverse of the logit function. First, to rewrite the logit function:

$$\text{logit}(y) = \ln\left(\frac{y}{1-y}\right), \text{ and then set } \ln\left(\frac{y}{1-y}\right) = \alpha$$

where α is some number, and y ranges between 0 and 1. The inverse of the logit function becomes:

$$\text{logit}^{-1}(y) = \left(\frac{y}{1-y}\right) \text{ or } \left(\frac{y}{1-y}\right) = e^{\alpha}$$

Solve for y,

$$y = \left(\frac{e^{\alpha}}{1+e^{\alpha}}\right) \quad (3)$$

This study assumes that α is a linear combination of independent variables and their coefficients as $\alpha = \beta_0 + x_{ik}\beta_k$ in equation (1). Eventually, the probability becomes the Sigmoid function curve (Ezeafulukwel *et al.*, 2018;2020), known as the 'S' curve in a range of 0 to 1 inclusive alone on the y-axis. Thus, equation (3) becomes the logistic function, substituting $\beta_0 + x_{ik}\beta_k$ for α, and then the probability would be a function of independent variables (x_s):

$$P(x) = \left(\frac{e^{\beta_0 + x_{ik}\beta_k}}{1+e^{\beta_0 + x_{ik}\beta_k}}\right) \quad (4)$$

In equation (4), when $\beta_0 + x_{ik}\beta_k$ approaches to $-\infty$, P(x) becomes 0:

$$P(x) = \left(\frac{e^{-\infty}}{1+e^{-\infty}}\right); \left(\frac{e^{-\infty}}{1+e^{-\infty}}\right) = \left(\frac{1}{1+e^{\infty}}\right); \text{ and then } \left(\frac{1}{1+e^{\infty}}\right) \cong 0$$

In equation (4), when $\beta_0 + x_{ik}\beta_k$ approaches to $+\infty$, P(x) becomes 1:

$$P(x) = \left(\frac{e^{+\infty}}{1+e^{+\infty}}\right) = 1, \text{ and then } \left(\frac{e^{+\infty}}{1+e^{+\infty}}\right) \cong 1$$

Ultimately, the range of the logistic function in equation (4) would be between 0 and 1, regardless of the value of α, a linear combination of independent variables with constant coefficients. It is the primary reason the logistic model is wildly used in research dealing with a binary dependent variable.

To solve for logit (y) from equation (2), substitute equation (3) for y in the odds in equation (2), and then the algebraic procedure is the following:

$$\left(\frac{y}{1-y}\right) = \frac{\frac{e^{\alpha}}{1+e^{\alpha}}}{1-\frac{e^{\alpha}}{1+e^{\alpha}}} = \frac{\frac{e^{\alpha}}{1+e^{\alpha}}}{\frac{1+e_{\alpha}}{1+e^{\alpha}} - \frac{e^{\alpha}}{1+e^{\alpha}}} = \frac{\frac{e^{\alpha}}{1+e^{\alpha}}}{\frac{1}{1+e^{\alpha}}} = e^{\alpha}$$

where $\alpha = \beta_0 + x_{ik}\beta_k$. Thus, the logit($y$) in equation (2) becomes:

$$\text{logit}(y) = \ln\left(\frac{y}{1-y}\right); \ln\left(\frac{y}{1-y}\right) = \ln(e^{\alpha}); \ln(e^{\alpha}) = \alpha \text{ ; and then } \ln(e^{\alpha}) = \beta_0 + x_{ik}\beta_k$$

Thus,

$$\text{logit}(y) = \beta_0 + x_{ik}\beta_k \quad (5)$$

Equation (5) indicates that the natural logarithm of the odds ratio becomes a linear function of the independent variables. From equation (2) to equation (5), the above algebraic processes result in the inverse of the logit function linked to the estimated regression equation. Thus, the estimated probability from equation (4) becomes:

$$\hat{y} = \left(\frac{e^{\hat{\beta}_0 + x_{ik}\hat{\beta}_k}}{1+e^{\hat{\beta}_0 + x_{ik}\hat{\beta}_k}}\right) \quad (6)$$

This estimated probability equation links to the logistic regression. From equation (6), the odds ratio could be derived as follows. Suppose, there is only one independent variable in the model. If the value of the independent variable, x, changes by one, let y_0 be the probability of success when $x = 0$; y_1 be the probability of success when $x = 1$. If the value of x changes from 0 to 1 or any increment by one, the odds of success for $x = 0$ and $x = 1$ are the following:

$$\text{the odds of success for } x = 0, \left(\frac{y_0}{1-y_0}\right) = e^{\hat{\beta}_0 + X\hat{\beta}_1}, \text{ and then } e^{\hat{\beta}_0 + X\hat{\beta}_1} = e^{\hat{\beta}_0}$$

and the odds of success for $x = 1$, $\left(\frac{y_1}{1-y_1}\right) = e^{\hat{\beta}_0 + X\hat{\beta}_1}$, and then $e^{\hat{\beta}_0 + X\hat{\beta}_1} = e^{\hat{\beta}_0 + \hat{\beta}_1}$

Thus, the odds ratio between $x = 0$ and $x = 1$ could be derived when the value of an independent variable (e.g., x) changes by one (from $x = 0$ to $x = 1$).

$$\frac{\left(\frac{y_1}{1-y_1}\right)}{\left(\frac{y_0}{1-y_0}\right)} = \frac{e^{\hat{\beta}_0 + \hat{\beta}_1}}{e^{\hat{\beta}_0}}; \quad \frac{e^{\hat{\beta}_0 + \hat{\beta}_1}}{e^{\hat{\beta}_0}} = \frac{e^{\hat{\beta}_0} e^{\hat{\beta}_1}}{e^{\hat{\beta}_0}}; \text{ and then } \frac{e^{\hat{\beta}_0} e^{\hat{\beta}_1}}{e^{\hat{\beta}_0}} = e^{\hat{\beta}_1}$$

The odds ratios in the logistic regression are expressed as exponentials of the estimated coefficients ($\hat{\beta}_k$) of independent variables shown above the algebraic procedures.

The odds ratios in this study were obtained from a multivariate logistic regression analysis described above to measure the effects of physical activity on the propensity of alcohol drinkers toward engaging in alcohol-impaired driving. The study (Shults *et al.*, 2002) documented that rates of alcohol-impaired driving episodes differed by sex due to gender differences in risk-taking behaviors. Also, the National Highway Traffic Safety Administration (2020) reported that there were four male alcohol-impaired drivers involved for every female alcohol-impaired driver involved. In all drivers involved in fatal crashes, there were three male drivers for every female driver in 2020. Thus, this study constructed separate logistic models for men and women in addition to the model containing all respondents.

3. Empirical Implementation

The data for this study were drawn from the 2020 BRFSS, a large-scale national health survey. The survey was conducted by the Center for Disease Control and Prevention (CDC) collaborated with all 50 states and the District of Columbia in the United States. The objectives of the BRFSS were to gather uniform state-specific data on health-related risk behaviors, chronic diseases, chronic health conditions, access to health care, and use of preventive services related to the leading causes of death and disability from the non-institutionalized adult population aged 18 years or older residing in the United States. The BRFSS field operations were managed by the state health department that followed the protocols provided by the states with technical assistance, including identifying demographic variation in health-related behaviors; evaluating public health programs; addressing emergent and critical health issues; proposing legislation for health initiatives; and measuring progress toward state health objectives.

The BRFSS questionnaire consisted of three main components: a core component as a standard set of questions asked by all states and the District of Columbia, optional CDC modules supported by the CDC as questions on.

Table-1. Definition of Variables

Variables	Definition
Alcohol-impaired driving	Self-reported alcohol-impaired driving episode. Respondent who reported having driven after having perhaps too much to drink during the past 30 days.
Physical Activity	Respondent participates in any physical activities or exercises, such as running, calisthenics, golf, gardening, or walking for exercise, other than his or her regular job during the past month.
Married	Respondent is married or a member of an unmarried couple.
Employment	
Employed	Respondent is employed for wages.
Self-employed	Respondent is self-employed.
Employed others	Respondent is neither employed nor self-employed, such as out of work, a homemaker, a student, retired, or unable to work.
Income	
Income 35	Respondent's annual household income from all sources < $35,000.
Income 35-75	$35,000 ≤ respondent's annual household income from all sources < $75,000.
Income 75+	Respondent's annual household income from all sources ≥ $75,000.
Race	
White, non-Hispanic	Respondent is white only, non-Hispanic.
Black, non-Hispanic	Respondent is black only, non-Hispanic.
Hispanic	Respondent is Hispanic.
Others, non-Hispanic	Respondent is other race, non-white, non-black, and non-Hispanic.
Age	
Age 18-20	Respondent aged 18-20 years.
Age 21-24	Respondent aged 21-24 years.

Age 25-34	Respondent aged 25-34 years.
Age 35-54	Respondent aged 35-54 years.
Age 55+	Respondent aged 55 years or older.
Education	
Less high school	Respondent did not graduate high school
High school	Respondent completed grade 12 or GED (high school graduate).
Some college	Respondent completed college 1 year to 3 years (some college or technical school).
College graduation	Respondent completed college 4 years or more (college graduate).
Smoker	
Current smoker	Respondent now smokes cigarettes every day or some days.
Former smoker	Respondent has smoked at least 100 cigarettes in his/her entire life, but he/she had quit at the time of interview.
Never smoker	Respondent never smoke.
Binge drinker	Respondent have five or more drinks for men or 4 or more drinks for women on one occasion during the past 30 days.
Seatbelt	
Seatbelt always	Respondent always use seat belt when he/she drive or ride in a car.
Seatbelt nearly always	Respondent nearly always use seat belt when he/she drive or ride in a car.
Seatbelt sometimes seldom	Respondent sometimes/seldom use seat belt when he/she drive or ride in a car.
Seatbelt never	Respondent never use seat belt when he/she drive or ride in a car.
Alcohol control states	Respondent's state is an alcoholic beverage control state.
MADD state rating	
MADD 05-20	0.5 ≤ Mothers Against Drunk Driving state rating of ≤ 2.0 from 0.5 to 2.0
MADD 25-30	2.5 ≤ Mothers Against Drunk Driving state rating of ≤ 3.0 from 0.5 to 2.0
MADD 35-40	3.5 ≤ Mothers Against Drunk Driving state rating of ≤ 4.0 from 0.5 to 2.0
MADD 45-50	4.5 ≤ Mothers Against Drunk Driving state rating of ≤ 5.0

Source: 2020 Behavioral Risk Factor Surveillance System (BRFSS) at https://www.cdc.gov/brfss/annual_data/annual_2020.html.

Table-2. Descriptive Statistics[a]

	Men (n = 78,789)			**Women (n = 74,555)**			**Total (n=153,344)**		
		95% CI			**95% CI**			**95% CI**	
Variables	**Percent**	**Lower**	**Upper**	**Percent**	**Lower**	**Upper**	**Percent**	**Lower**	**Upper**
Overall AID Prevalence[b]	3.26	3.26	3.27	1.50	1.50	1.51	2.45	2.45	2.46
Physical Activity	83.37	83.36	83.38	83.14	83.13	83.15	83.27	83.26	83.27
Married	61.16	61.14	61.17	57.24	57.23	57.25	59.36	59.35	59.37
Employment									
Employed	59.16	59.15	59.17	54.24	54.22	54.25	56.90	56.89	56.90
Self-employed	11.74	11.73	11.74	7.60	7.60	7.61	9.84	9.83	9.84
Employed others	29.11	29.09	29.12	38.16	38.15	38.18	33.27	33.26	33.28
Income									
Income 35	22.26	22.25	22.28	25.86	25.84	25.87	23.92	23.91	23.92
Income 35-75	27.83	27.82	27.84	28.71	28.69	28.72	28.23	28.22	28.24
Income 75+	49.91	49.89	49.92	45.44	45.42	45.45	47.85	47.84	47.86
Race									
White, non-Hispanic	66.75	66.74	66.76	68.66	68.65	68.67	67.63	67.62	67.64
Black, non-Hispanic	9.46	9.45	9.47	11.51	11.50	11.52	10.40	10.40	10.41
Hispanic	16.12	16.11	16.13	13.16	13.15	13.17	14.76	14.75	14.77
Others, non-Hispanic	7.67	7.67	7.68	6.67	6.66	6.68	7.21	7.21	7.22
Age									
Age 18-20	2.78	2.77	2.78	2.48	2.47	2.48	2.64	2.64	2.64
Age 21-24	7.65	7.65	7.66	8.47	8.46	8.48	8.03	8.02	8.03
Age 25-34	21.17	21.16	21.18	20.50	20.49	20.51	20.86	20.85	20.87
Age 35-54	35.17	35.16	35.18	35.57	35.56	35.59	35.36	35.35	35.37
Age 55+	33.23	33.22	22.24	32.98	32.97	33.00	33.12	33.11	33.13
Education									
Less high school	8.56	8.55	8.56	5.36	5.35	5.37	7.09	7.08	7.09
High school	26.06	26.04	26.07	19.67	19.65	19.68	23.12	23.11	23.13

Some college	30.26	30.25	30.27	33.40	33.38	33.41	31.70	31.69	31.71
College graduation	35.13	35.11	35.14	41.58	41.57	41.59	38.09	38.08	38.10
Smoker									
Current smoker	17.07	17.06	17.08	12.98	12.97	12.98	15.19	15.18	15.20
Former smoker	28.93	28.91	28.94	23.74	23.73	23.75	26.54	26.53	26.55
Never smoker	54.00	53.99	54.02	63.29	63.27	63.30	58.27	58.26	58.28
Binge drinker	35.76	35.74	35.77	25.23	25.22	25.24	30.92	30.91	30.93
Seatbelt									
Always	85.57	85.56	85.58	91.87	91.86	91.87	88.47	88.46	88.47
Nearly always	7.92	7.91	7.92	5.32	5.31	5.32	6.72	6.71	6.72
Sometimes seldom	4.32	4.31	4.32	2.00	2.00	2.01	3.25	3.25	3.26
Never	2.20	2.20	2.20	0.82	0.81	0.82	1.56	1.56	1.57
Alcohol control states	23.94	23.92	23.95	24.57	24.56	24.58	24.23	24.22	24.24
MADD state rating[c]									
MADD 05-20	9.40	9.39	9.41	9.91	9.90	9.92	9.64	9.63	9.64
MADD 25-30	56.28	56.26	56.29	55.41	55.40	55.43	55.88	55.87	55.89
MADD 35-40	21.61	21.60	21.62	21.86	21.85	21.87	21.72	21.71	21.73
MADD 45-50	12.72	12.71	12.72	12.82	12.81	12.83	12.76	12.76	12.77
Sex									
Female	---			---			45.97	45.96	45.98
Male	---			---			54.03	54.02	54.04

Notes: a. Percentages are calculated with the BRFSS sample weight factor. All percentages are statistically significant using two tailed t-test with 95% confidence interval (CI). b. Among BRFSS respondents who reported drinking at least one alcoholic beverage in the month before the survey, percentage of respondents who gave a response of one or more times to the question, "During the past month, how many times have you driven when you've had perhaps too much to drink?" c. Mothers Against Drunk Driving's aggregate state grade for the Rating the States 2019 survey.

Specific topics that states elected to use on their questionnaires, and state-added questions developed or acquired by participating states which were added to their questionnaires. The state health department and the CDC agreed on the content of the core component and optional modules each year. The BRFSS provided guidelines that all states must ask the core component questions without modification, but states may choose to add any, all, or none of the optional modules. Total baseline observations for adults aged 18 years or older from all states and the District of Columbia were 401,958. Among them, 191,565 respondents reported having at least one drink of alcohol during the month preceding the interview (Amlung *et al.*, 2016; Shults *et al.*, 2002; Zhang and Sloan, 2014). The observations with 'missing values', 'unanswered questions', 'don't know/not sure', 'questions not asked', or 'refusals' were excluded. Finally, 153,344 respondents answered all the questions on variables in this study, including alcohol-impaired driving episodes, physical activities, socio-demographic variables, and risky behavior variables: 78,789 male and 74,555 female respondents. The definitions of variables are shown in Table 1, and Table 2 presents descriptive statistics for variables.

3.1. Alcohol-Impaired Driving

In the content of the BRFSS core questionnaire, the specific survey question related to driving after drinking alcohol was administered every other year. The questions on alcohol-impaired driving, a measure of risky driving behaviors, were in 'Core 14' in 2020. In the drinking and driving module, respondents who reported having at least one alcoholic beverage in the past 30 days were asked, "During the past 30 days, how many times have you driven when you've had perhaps too much to drink?" If a respondent reported 'at least one' for the question, she/he was considered as an alcohol-impaired driving driver. Respondents were dichotomized into either has or has not driven while impaired by alcohol at least once in the month preceding the survey. 2.45 percent of current drinkers, 3.26 percent of male drinkers, and 1.50% of female drinkers reported engaging in at least one episode of alcohol-impaired driving (Table 2).

3.2. Physical Activity

The methodology and questionnaires employed to assess physical activity within the BRFSS have been published elsewhere. Previous studies (Loprinzi *et al.*, 2015; Yore *et al.*, 2007) advocated that the BRFSS questionnaires had been shown both reliable and valid in assessing physical activity behaviors with different definitions of the use of physical activity level in each study: number of days, hours, frequency, intensity, sports, domestic, active or inactive, etc. To assess the prevalence of participation in physical activity, the BRFSS interviewers asked, "During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?" About 83 percent of the survey respondents reported participating in physical activities during the past 30 days.

3.3. Socio-Demographic Variables

Socio-demographic variables from the BRFSS were marital status, employment status, income level, race, age group, and education (Sanem *et al.*, 2015; Shults *et al.*, 2002). They were all categorical independent variables. Leonard and Eiden (2007), reviewed the association between marital status and family processes in the context of alcohol use. They reported that marriage served as a protective factor among alcohol drinkers with serious alcohol problems due to spousal influences of their partner's risky behaviors. According to their findings, the marital status would be a strong indicator of engaging in risky driving behaviors. The marital status was measured using the question: "What is your marital status?" This question included six coding categories: married, divorced, widowed, separated, never married, and a member of an unmarried couple. These six categories were then classified into two marital subgroups: married (married or a member of an unmarried couple) and the others. 61.16 percent of male respondents were married, and 57.24 percent of female respondents were married. In the BRFSS questions on demographic characteristics, there were eight mutually exclusive categories of current employment status: employed for wages, self-employed, out of work for more than 1 year, out of work for less than 1 year, a homemaker, a student, retired, and unable to work. This study kept 'employed for wages' and 'self-employed' separately because of the different nature of the working environment between the two categories and combined the rest of the categories. 56.90 percent of respondents were employed, 9.84 percent of respondents were self-employed, and 33.27 percent of respondents were the other types of employment status.

Respondents to the survey reported their annual household income from all sources. The participants could choose one of the eight categories of income levels from 'less than $10,000' to '$75,000 or more'. This study divided them into three classes of annual household income: 'less than $35,000', '$35,000 or more and less than $75,000', and 'more than $75,000'. Race/ethnicity was measured using two questions: "Which one of these groups would you say best represents your race? (with seven response choices)" and "Are you Hispanic or Latino? (yes/no)". The section name of 'calculated race variables' had five categories that this study reduced to four: White, non-Hispanic; Black, non-Hispanic; Hispanic; and others (multi-racial or other race, non-Hispanic). Age was measured based on the question: "What is your age?" From this continuous variable, this study collapsed into five mutually exclusive categories. Young adults were stratified into two separate age groups: one group of underage drinkers aged 18-20 (2.78 percent for males and 2.48 percent for females) because the sale of alcohol to persons younger than 21 years was illegal in all states; and the other group of young legal drinkers aged 21-24 (7.65 percent for male and 8.47 percent for female). The other three age groups were 25-34, 35-54, and 55 or older. The studies (Wong *et al.*, 2014; Wright *et al.*, 2017) examined the relationship between risky health behaviors and educational attainment. They documented that engagement in multiple risk behaviors was strongly associated with poorer educational attainment. In other words, educational attainment was a powerful mechanism to lower risky health behaviors. The educational level was measured based on the question in the demographic module: "What is the highest grade or year of school you completed?" The categorical variable with six elements that this study collapsed to four: less than high school graduation, high school graduation, some college or technical school, and college graduate. 38.09 percent of participants graduated from four-year colleges or higher.

3.4. Risky Behaviors

It was largely recognized that risky behaviors, such as cigarette smoking, binge drinking, and seatbelt use, represented an underlying propensity for risk-taking. Engagement in any of the risky behaviors might normalize other similar behaviors. The survey respondents were asked about their use of tobacco: "Have you smoked at least 100 cigarettes in your entire life?" Respondents who responded 'no' were categorized as never smokers; respondents who responded 'yes' and 'smoked every day' or 'smoked some days' were categorized as current smokers; and respondents who responded 'yes' and smoked 'now not at all' were categorized as former smokers. Among the survey participants, the proportion of current and former smokers for men was higher than the proportion of current and former smokers for women; on the other hand, the proportion of never smokers for women was higher than the proportion of never smokers for men.

Binge drinking, hazardous drinking, was defined as responding 'one or more times' to the following question: "Considering all types of alcoholic beverages, how many times during the past 30 days did you have 5 or more drinks for men or 4 or more for women on an occasion?" Thus, binge drinkers in this study were male respondents who reported having five or more drinks on one occasion and female respondents who reported having four or more drinks on one occasion during the past 30 days. One drink was equivalent to a 12-ounce beer, a 5-ounce glass of wine, or a drink with one shot of liquor. Hence, a 40-ounce beer would count as 3 drinks, or a cocktail drink with 2 shots would count as 2 drinks. Binge drinking was more common in males (35.76%) than in females (25.23%).

Another risky behavior in this study was seatbelt use. The study (Bingham *et al.*, 2007) found that lower rates of safety belt use were associated with higher levels of drink/driving, and drink/drivers were less likely than other drivers to adopt safe driving behaviors and were more likely than non-drink/drivers to be risky drivers. In another study (Sanem *et al.*, 2015), using state-level countermeasures and community-level programs, seat belt use initiatives were associated with a lower likelihood of driving a car while impaired and fewer fatal crashes involving alcohol. In the United States, wearing a seat belt is a primary offense. The law requires that all drivers, all front seat passengers, and all passengers under the age of 18 fasten their safety belts. The seatbelt use was measured based on the question: "How often do you use seat belts when you drive on a ride in a car? Would you say 'always', 'nearly always', 'sometimes', 'seldom', or 'never'?" 88.47 percent of participants reported 'always used seatbelts'; 6.72 percent of participants reported 'nearly always use seat belt'; 3.25 percent of participants reported 'sometimes or seldom use seat belt'; and 1.56 percent of participants reported 'never use seat belt'.

3.5. Alcohol Policy

3.5.1. The Alcohol Control States

Individual states in the United States could choose to control the circulation of alcohol within their boundaries after the prohibition ended in 1933. Some states allowed for prohibiting alcohol, and others allowed local jurisdictions to create their liquor laws. The National Alcohol Beverage Control Association (NABCA; www.nabca.org) classifies states regarding controlling sales of alcohol: seventeen states (Alabama, Idaho, Iowa, Maine, Michigan, Mississippi, Montana, New Hampshire, North Carolina, Ohio, Oregon, Pennsylvania, Utah, Vermont, Virginia, West Virginia, and Wyoming) adopted forms of the control model. They control the sales of distilled spirits and, in some cases, wine and beer through government agencies at the wholesale level. Some of the states also exercise control over retail sales for off-premises consumption, either through government-operated package stores or designated agents (Hahn *et al.*, 2012). The study (Hahn *et al.*, 2012) reported that privatization of retail alcohol sales was associated with a substantial increase in per capita sales of the privatized alcoholic beverages, a well-established proxy for excessive alcohol consumption. In this study, each respondent was assigned to the alcohol control state or not for her/his state. 23.94 percent of male respondents lived in the alcohol control states, and 24.57 percent of female respondents lived in the alcohol control states.

3.5.2. Mothers Against Drunk Driving

Mothers Against Drunk Driving (MADD) rating the state survey provided the most comprehensive source of information about state-level driving under the influence of alcohol (DUI). The MADD is a non-profit organization that was founded in 1980 with the mission of stopping drunk driving, supporting the victims of drunk driving, and preventing underage drinking. The MADD developed rating the state survey in 1991 and has administered an updated version of the survey every few years. The primary purpose of the survey was to bring national attention to the status of each state's comprehensive efforts to reduce DUI, to support every state's efforts to stop drunk driving, and to protect the public. Each state receives a cumulative total measuring its successes in overall legislative measures and law enforcement support. It helps the MADD see at a glance how quickly the state is progressing toward ending drunk driving.

Each state and the District of Columbia receive a grade ranging from 0 to 5 based on the five rating categories that have two subcategories each: all-offender ignition interlocks (law present/compliance-based removal); sobriety checkpoints (conducts checkpoints/done at least monthly); administrative license revocation (law present/interlock device upon first-time arrest); child endangerment (DUI misdemeanor/DUI felony); and alcohol test refusals (expedited warrants/interlock device and/or criminalized refusals). Description of the five rating categories is available at www.madd.org and elsewhere. The grades for each of the categories were combined to produce the MADD aggregate number grade. The aggregate grade may best represent each state's comprehensive efforts to reduce alcohol-impaired driving. The aggregate grade in the 2019 survey was calculated using 0.5 points on each of the subcategories. To obtain an aggregate grade of '5', a state conducted all of the DUI laws and enforcement. 56.28 percent of male respondents lived in MADD state rating between 2.5 and 3.0, and 55.41 percent of female respondents lived in MADD state rating between 2.5 and 3.0.

4. Analysis and Results

4.1. Descriptive Analysis

The prevalence of respondents who drove while alcohol-impaired by explanatory variables is presented in Table 3. The percentages were calculated with the BRFSS sampling weighting factor. 2.45 percent of the current drinkers reported engaging in alcohol-impaired driving. The proportion of male participants who reported engaging in the alcohol-impaired driving episode was significantly higher than the proportion of female participants who reported engaging in alcohol-impaired driving: 3.26% for males versus 1.50% for females. It indicated that male participants were more likely to engage in risky driving. The proportion of engagement in alcohol-impaired driving among self-employed participants was twice as high as the proportion for participants who were categorized as the other employment status: 3.63% for self-employed participants and 1.90% for participants who were categorized as the other employment status. The percentage of engaging in alcohol-impaired driving decreased as income level increased: 2.79% for income level less than $35,000; 2.53% for income level between $35,000 and $75,000; and 2.24% for income level $75,000 or higher. The proportion of participants who reported having alcohol-impaired.

Table-3. Prevalence of Alcohol-Impaired Driving Among Current Drinkers by Variables[a]

	Men (n = 78,789)			Women (n = 74,555)			Total (n=153,344)		
		95% CI			95% CI			95% CI	
Variables	**Percent**	**Lower**	**Upper**	**Percent**	**Lower**	**Upper**	**Percent**	**Lower**	**Upper**
Overall AID Prevalence[b]	3.26	3.26	3.27	1.50	1.50	1.51	2.45	2.45	2.46
Physical Activity	3.09	3.08	3.09	1.42	1.42	1.43	2.32	2.32	2.33
Married	2.62	2.61	2.62	0.08	0.08	0.08	1.83	1.83	1.83
Employment									
Employed	3.24	3.24	3.25	1.71	1.71	1.72	2.57	2.57	2.58
Self-employed	4.50	4.48	4.52	2.05	2.03	2.06	3.63	3.62	3.64

Employed others	2.80	2.79	2.81	1.10	1.09	1.10	1.90	1.90	1.91
Income									
Income 35	3.59	3.58	3.60	1.99	1.98	2.00	2.79	2.79	2.80
Income 35-75	3.42	3.41	4.43	1.51	1.50	1.51	2.53	2.52	2.53
Income 75+	3.03	3.02	3.03	1.22	1.22	1.23	2.24	2.23	2.24
Race									
White, non-Hispanic	3.10	3.09	3.11	1.39	1.38	1.39	2.30	2.30	2.30
Black, non-Hispanic	3.17	3.16	3.19	1.70	1.69	1.71	2.42	2.41	2.43
Hispanic	4.22	4.21	4.23	1.90	1.89	1.92	3.27	3.26	3.28
Others, non-Hispanic	2.76	2.75	2.78	1.56	1.54	1.57	2.25	2.24	2.26
Age									
Age 18-20	4.18	4.15	4.21	2.44	2.41	2.46	3.43	3.40	3.45
Age 21-24	4.23	4.21	4.25	2.26	2.14	2.27	3.27	3.26	3.28
Age 25-34	3.37	3.36	3.38	2.09	2.08	2.09	2.79	2.79	2.80
Age 35-54	3.41	3.41	3.42	1.34	1.33	1.34	2.45	2.45	2.46
Age 55+	2.73	2.72	2.74	1.05	1.05	1.06	1.96	1.96	1.97
Education									
Less high school	5.07	5.05	5.09	1.63	1.62	1.65	3.87	3.86	3.89
High school	3.37	3.36	3.38	1.63	1.62	1.63	2.69	2.68	2.69
Some college	3.50	3.49	3.51	1.46	1.46	1.47	2.51	2.51	2.52
College graduation	2.54	2.53	2.55	1.46	1.45	1.46	2.00	1.99	2.00
Smoker									
Current smoker	6.02	6.01	6.04	2.93	2.91	2.94	4.81	4.80	4.82
Former smoker	2.85	2.85	2.86	1.57	1.57	1.58	2.33	2.32	2.33
Never smoker	2.61	2.60	2.61	1.18	1.18	1.19	1.90	1.89	1.90
Binge drinker	7.60	7.59	7.61	4.61	4.60	4.62	6.48	6.47	6.49
Seatbelt									
Always	2.71	2.70	2.71	1.29	1.29	1.30	2.03	2.03	2.04
Nearly always	4.38	4.36	4.40	3.41	3.39	3.43	4.03	4.02	4.05
Sometimes seldom	6.47	6.44	6.50	5.21	5.16	5.25	6.11	6.09	6.14
Never	14.45	14.39	14.52	3.45	3.35	3.47	11.80	11.75	11.85
Alcohol control states	3.39	3.38	3.40	1.55	1.54	1.55	2.53	2.52	2.54
MADD state rating[c]									
MADD 05-20	3.82	3.44	4.20	2.06	2.04	2.07	2.73	2.72	2.74
MADD 25-30	3.45	3.25	3.66	1.50	1.49	1.50	2.50	2.50	2.50
MADD 35-40	3.50	3.28	3.73	1.36	1.36	1.37	2.26	2.25	2.26
MADD 45-50	2.85	2.57	3.14	1.32	1.31	1.33	2.36	2.35	2.37
Sex									
Female	---			---			1.42	1.42	1.43
Male	---			---			3.26	3.26	3.27

Notes: a. Percentages are calculated with the BRFSS sample weight factor. All percentages are statistically significant using two tailed t-test with 95% confidence interval (CI). b. Among BRFSS respondents who reported drinking at least one alcoholic beverage in the month before the survey, percentage of respondents who gave a response of one or more times to the question, "During the past month, how many times have you driven when you've had perhaps too much to drink?" c. Mothers Against Drunk Driving's aggregate state grade for the Rating the States 2019 survey.

Driving episodes decreased with increases in the age group. 3.43% of young participants aged 18-20 reported having alcohol-impaired driving episodes, whereas 1.96% of adult participants aged 55 or older reported having alcohol-impaired driving episodes. Especially, only 1.05% of female participants aged 55 or older reported having alcohol-impaired driving episodes. The percentage of participants who reported engaging in alcohol-impaired driving decreased as the level of education increased: 3.87%, 2.69%, 2.51%, and 2.00% from lower to the high level of education.

Table-4. Odds Ratios of Alcohol-Impaired Driving among Adults Aged 18 Years or Older Who Consume Alcohol[a]

	Men (n = 78,789)			Women (n = 74,555)			Total (n=153,344)		
		95% CI			95% CI			95% CI	
Variables	**Odd Ratio**	**Lower**	**Upper**	**Odd Ratio**	**Lower**	**Upper**	**Odd Ratio**	**Lower**	**Upper**
Physical Activity	0.87	0.87	0.87	0.85	0.85	0.86	0.87	0.86	0.87
Married	0.73	0.73	0.73	0.42	0.41	0.42	0.62	0.62	0.62
Employment									
Employed	1.10	1.10	1.11	1.43	1.42	1.44	1.24	1.24	1.25
Self-employed	1.35	1.35	1.36	2.04	2.02	2.06	1.55	1.54	1.56
Employed others	1.00	---	---	1.00	---	---	1.00	---	---
Income									
Income 35	1.00	---	---	1.00	---	---	1.00	---	---
Income 35-75	1.25	1.24	1.25	0.87	0.87	0.88	1.10	1.10	1.11
Income 75+	1.31	1.30	1.31	0.90	0.90	0.91	1.14	1.14	1.15
Race									
White, non-Hispanic	1.00	---	---	1.00	---	---	1.00	---	---
Black, non-Hispanic	1.08	1.08	1.09	0.94	0.93	0.95	1.06	1.06	1.06
Hispanic	1.23	1.23	1.24	1.26	1.25	1.27	1.24	1.24	1.25
Others, non-Hispanic	0.98	0.98	0.99	1.04	1.03	1.05	1.02	1.01	1.02
Age									
Age 18-20	0.63	0.62	0.63	0.74	0.73	0.75	0.65	0.65	0.66
Age 21-24	0.73	0.73	0.74	0.70	0.69	0.70	0.70	0.70	0.71
Age 25-34	0.57	0.57	0.57	0.78	0.77	0.78	0.61	0.61	0.62
Age 35-54	0.73	0.73	0.73	0.74	0.73	0.74	0.72	0.72	0.73
Age 55+	1.00	---	---	1.00	---	---	1.00	---	---
Education									
Less high school	1.00	---	---	1.00	---	---	1.00	---	---
High school	0.82	0.82	0.83	1.33	1.32	1.35	0.89	0.89	0.90
Some college	1.05	1.04	1.05	1.35	1.33	1.36	1.09	1.08	1.09
College graduation	1.03	1.03	1.04	1.87	1.85	1.89	1.19	1.18	1.19
Smoker									
Current smoker	1.43	1.42	1.43	1.46	1.45	1.47	1.43	1.42	1.43
Former smoker	0.97	0.97	0.97	1.20	1.20	1.20	1.03	1.03	1.04
Never smoker	1.00	---	---	1.00	---	---	1.00	---	---
Binge drinker	9.16	9.12	9.20	9.51	9.45	9.56	9.33	9.30	9.36
Seatbelt									
Always	1.00	---	---	1.00	---	---	1.00	---	---
Nearly always	1.43	1.42	1.44	2.02	2.01	2.03	1.58	1.58	1.59
Sometimes seldom	1.79	1.78	1.80	2.46	2.43	2.48	1.93	1.92	1.94
Never	3.95	3.93	3.97	2.12	2.08	2.16	3.66	3.64	3.68
Alcohol control states	1.05	1.05	1.06	0.94	0.94	0.95	1.03	1.02	1.03
MADD state rating[b]									
MADD 05-20	1.00	---	---	1.00	---	---	1.00	---	---
MADD 25-30	1.05	1.05	1.06	0.71	0.71	0.72	0.93	0.93	0.93
MADD 35-40	1.02	1.01	1.02	0.65	0.64	0.65	0.88	0.87	0.88
MADD 45-50	1.13	1.12	1.14	0.63	0.62	0.64	0.94	0.94	0.95
Sex									
Female	---			---			1.00	---	---
Male	---			---			1.59	1.58	1.59

Notes: a. Logistic regressions are weighted by the BR FSS sample weight factor. Odds ratios shown with confidence interval (CI) are adjusted for other variables in the column. b. Mothers Against Drunk Driving's aggregate state grade for the Rating the States 2019 survey.

The risky behaviors were strongly associated with a higher likelihood of engaging in alcohol-impaired driving. First of all, 4.81 percent of the respondents who were current smokers reported engaging in alcohol-impaired driving. That was significantly high compared with the percentages for respondents who were former smokers (2.33%) and never smokers (1.90%). 30.92 percent of drinkers reported binge drinking in the past month (Table 2). Males (35.76%) were more likely than females (25.23%) to report having binge drinking episodes. Those high-risky drinkers had the highest rate of engagement in alcohol-impaired driving episodes among all test variables: 7.60% for men; 4.61% for women; and 6.48% overall. According to the descriptive analyses, 85.57 percent of male respondents reported 'always using a seat belt', and 91.87 percent of female respondents reported 'always using a seat belt'. It referred that, relative to females, male respondents tended to place a greater likelihood of engaging in risky driving behaviors. In Table 3, the proportion of respondents who reported engaging in alcohol-impaired driving increased as the level of engagement in risk-taking behavior increased from 'always use seat belt' toward 'never use seat belt': in the estimated prevalence, 2.03 percent of participants who reported 'always used seat belt' reported engaging in alcohol-impaired driving, whereas 11.8 percent of participants who reported 'never used seat belt' reported engaging in alcohol-impaired driving. These suggested that seat belt use was significantly effective in the reduction of the prevalence of alcohol-impaired driving.

The prevalence of self-reported alcohol-impaired driving was higher in alcohol control states than the prevalence in the other states (Table 3). Also, the statewide laws related to alcohol-impaired driving were estimated to contribute to preventing individuals' driving behaviors from engaging in alcohol-impaired driving. The percentage of respondents who reported engaging in alcohol-impaired driving decreased as the MADD rating increased: 3.82 percent of participants who lived in the states received MADD grade 0.5-2.0; 3.45 percent of participants who lived in the states received MADD grade 2.5-3.0; 3.50 percent of participants who lived in the states received MADD grade 3.5-4.0; and 2.85 percent of participants who lived in the states received MADD grade 4.5-5.0.

4.2. Logistic Regression Results

Table 4 presents estimated odds ratios of alcohol-impaired driving for variables among adults aged 18 years or older who reported consuming alcohol in the 30 days before the interview. The estimated odds ratios of engaging in alcohol-impaired driving for respondents who reported participating in physical activities from the multivariate logistic regression results were 0.87, 0.87, and 0.85 for overall, males, and females, respectively. Those results indicated that the respondents who participated in physical activities were less likely than respondents who were inactive to operate a motor vehicle when they were impaired by alcohol consumption. In other words, physical activity was a significant factor in drinkers' attitudes toward engaging in driving while impaired by alcohol. The effects of physical activity on engaging in alcohol-impaired driving were greater for females than for males. Also, male participants were more likely than female participants to engage in alcohol-impaired driving: the odds ratio for male participants = 1.59; the odds ratio for female participants =1.00.

Respondents who were married or unmarried couples were about 38% less likely to engage in alcohol-impaired driving compared with respondents who were not married or unmarried couples. Especially, those respondents who were female were 48% less likely to engage in driving while impaired by alcohol compared with their counterparts. Their risky driving behaviors could be influenced by their spouse who may interrupt her/his partner's risk behavior, and/or it could be linked to the awareness of their family responsibilities. For employment status, 'employed' and 'self-employed' were significantly associated with a greater likelihood of engaging in alcohol-impaired driving compared with the other employment status. Remarkably, self-employed respondents were 55% more likely than respondents who were not 'employed' or 'self-employed' to engage in driving while impaired by alcohol. Income level was positively associated with engagement in alcohol-impaired driving: the estimated odds ratio for income levels between $35,000 and $75,000 was 1.10; the odds ratio for income levels $75,000 or more was 1.14 compared with income levels less than $35,000 as a reference category. That was, the higher the respondents' annual household income, the more likely they were to engage in alcohol-impaired driving episodes. For the race category, the rank order of the propensity to commit risky driving based on the estimated odds ratios was as follows: Hispanic (1.24); Black, non-Hispanic (1.06); other races, non-Hispanic (1.02); and White, non-Hispanic (1.00). Hispanic adults were most likely to engage in alcohol-impaired driving, whereas White adults, non-Hispanic, were least likely to engage in alcohol-impaired driving. Respondents aged 18-20, who were too young to legally purchase alcoholic beverages, were less likely than any other age group to engage in alcohol-impaired driving. When holding all other variables constant, the predicted odds ratios indicated that the older the respondents, the more likely they were to engage in driving a vehicle while impaired by alcohol: the odds ratio increased as the age group increased.

The risky behaviors (smoking, binge drinking, and seat belt use) were strong predictors of drinkers' behaviors toward engaging in alcohol-impaired driving. First, respondents who were current smokers were significantly more likely than respondents who never smoked to engage in alcohol-impaired driving. Meanwhile, respondents who were former smokers were slightly more likely than respondents who never smoked to engage in alcohol-impaired driving. Second, the logistic regression results showed that binge drinking was the strongest predictor of driving under the influence of alcohol among all explanatory variables used in this study. Binge drinkers, 30.92 percent of total observations (Table 2), had 9.33 times the odds of engaging in alcohol-impaired driving compared with non-binge drinkers. The estimated odds ratios for binge drinking were 9.16 and 9.51 for male and female respondents, respectively. Third, the empirical results indicated that 'seat belt use' and risky driving behaviors were strongly associated. An increase in the frequency of 'seat belt use' was negatively related to the odds of driving a motor

vehicle while impaired by alcohol. The estimated odds ratios were 1.00, 1.58, 1.93, and 3.66 for participants who reported 'always use', 'nearly always use', 'sometimes or seldom use', and 'never use seat belts', respectively.

Respondents who lived in alcohol control states were slightly more likely than respondents who lived in the other states to engage in alcohol-impaired drinking. The estimated odds ratio of operating a motor vehicle while impaired by alcohol for respondents who lived in the control states was 1.03 compared with respondents who lived in the other states. The logistic regression results indicated that the likelihood of driving a motor vehicle while impaired by alcohol among participants who lived in states with lower MADD grades was higher: participants who lived in states that received the MADD grade between 4.5 and 5.0 were 13% more likely for males and 37% less likely for females to engage in alcohol-impaired driving than those who lived in states that received MADD grade between 0.5 and 2.0.

5. Discussion

It is well documented in the literature that regular physical activity could help to improve overall health and fitness and could reduce many preventable chronic diseases. As a result, physical activity contributed significantly to reducing the health care expenditure in primary care, and an increase in physical activity could lead to substantial improvement in population health at social cost saving to the health sector. However, it is conceivable that a reduction in health care expenditure (social costs) by improvement in overall health and wellness by increasing participation in physical exercise could be fully offset by an increase in economic costs of fatal and nonfatal preventable injury-related crashes due to alcohol-impaired driving if individuals who participate in physical activities (health behavior) have a higher propensity to engage in alcohol-impaired driving. Furthermore, previous research (Badicu *et al.*, 2020; Buscemi *et al.*, 2011; Gilchrist *et al.*, 2020; Lisha *et al.*, 2013; Niedermeier *et al.*, 2018; Piazza-Gardner and Barry, 2012) reported a positive relationship between alcohol consumption and physical activity: the more physically active individuals are, the more alcohol they drink. Thus, it is an important argument to clarify whether the propensity of individual drinkers who participate in physical activities toward risk-taking behaviors, such as alcohol-impaired driving, is greater than the propensity of individual drinkers who do not participate in physical activities or not. If that is greater, the total social welfare might decrease as a result of increasing in physical activities.

Thus, this study investigated the effect of physical activity on the attitudes toward engaging in driving while impaired by alcohol among adults aged 18 years or older who reported consuming alcohol in the 30 days before the interview. The empirical results indicated that physical activity or exercise was associated with reduced engagement in alcohol-impaired driving. The estimated odds ratios from the multivariate logistic regression results were 0.87, 0.87, and 0.85 for overall, males, and females, respectively. In other words, respondents who participated in physical activities were less likely than respondents who were inactive to operate a motor vehicle when they were impaired by alcohol consumption. In short, physical activity was significantly associated with a reduction in the propensity toward engaging in driving while impaired by alcohol for alcohol drinkers. The effects of physical activity on engaging in alcohol-impaired driving were greater for females than for males. Also, disregarding physical activity, male participants were more likely to engage in alcohol-impaired driving compared with female participants: the odds ratio for male participants = 1.59 and the odds ratio for female participants =1.00.

Previous studies (Shults *et al.*, 2002; Sloan *et al.*, 2017; Sunshine *et al.*, 2018) related driving under influence and driving while intoxicated or impaired by alcohol had used the episodes of self-reported alcohol-impaired driving from the BRFSS. It has been a reliable alternative source of research data for estimates of alcohol-impaired driving. For example, using the level of drivers' blood alcohol concentration (BAC) to determine an alcohol-impaired driving episode would be somewhat cumbersome due to the different circumstances of alcohol consumption and individual differences in metabolism even if the number and type of drink are the same. A driver's BAC is the percentage of the driver's blood volume that is alcohol. The individual's BAC level can be different each time she/he drinks depending on the facts, such as the number of drinks consumed, how quickly drinks are consumed, gender, weight, food in the stomach, etc. The reliability of the measure of the episodes of alcohol-impaired driving from the BRFSS has been proven elsewhere, and it has been widely used in studies on alcohol-impaired driving road traffic accidents. However, using self-reported alcohol-impaired driving has some limitations. First, the number of episodes of self-reported alcohol-impaired driving in surveys could be underestimated because of the interview bias, such as the tendency for respondents to underreport their undesirable/unlawful attitudes or behaviors. Second, the self-reported alcohol-impaired driving defined by the BRFSS cannot be used to determine a specific BAC level; however, 81.66% (not shown in tables) of the episodes were reported by respondents who also reported binge drinking. Third, the BRFSS survey respondents were aged 18 years or older. The episodes of alcohol-impaired driving among young drinkers and drivers were excluded. Thus, the prevalence of alcohol-impaired driving does not represent all drivers and drinkers.

In conclusion, previous research has documented that regular physical activity could help to improve health and fitness and reduce many preventable chronic diseases. Also, physical activity contributed significantly to reducing the health care expenditure in primary care, and increases in physical activity could lead to substantial improvement in population health at social cost saving to the health sector. Importantly, this study found that physical activity was significantly associated with a decrease in alcohol drinkers' propensity to engage in alcohol-impaired driving. From a public health point of view, investing in physical activity promotion would be the best choice to reduce the social costs of fatal and nonfatal preventable injury-related crashes due to alcohol-impaired driving, in addition to strengthening drinking and driving laws. To boost the overall benefit of physical activity,

health policy-makers and health professionals should promote individuals to participate more in regular physical activities, especially for physically inactive middle-aged and elderly adults, intervene to prevent age-related declines in physical activity, and address health disparities among older adults through public health campaigns and programs to promote an active lifestyle in the population. The findings of this study could be an important advocated resource to policymakers in promoting participation in regular physical activity. Additionally, the empirical results suggest that stronger state-level drinking-driving laws, such as the MADD grades, were associated with lower rates of self-reported alcohol-impaired driving. Drinking and driving behavior could be influenced not only by individual choice but also by environmental-level influences.

References

Abu-Omara, K., Rüttena, A., Burlacua, I., Schätzleina, V., Messinga, S. and Suhrckeb, M. (2017). The Cost-Effectiveness of physical activity interventions: A systematic review of reviews. *Preventive Medicine Reports*, 8: 72-78. Available: https://doi.org/10.1016/j.pmedr.2017.08.006

Amarasinghe and Anura, K. (2010). Cost-Effectiveness implications of GP intervention to promote physical activity: Evidence from perth, Australia. *Cost Effectiveness and Resource Allocation*, 8(10): Available: https://doi.org/10.1186/1478-7547-8-10

Amlung, M., Morries, D. H., Hatz, L. E., Teeters, J. B., Murphy, J. G. and McCarthy, D. M. (2016). Drinking-and-Driving-Related cognitions mediate the relationship between alcohol demand and Alcohol-Impaired driving. *Journal of Studies on Alcohol and Drugs*, 77(4): 656-60. Available: https://doi.org/10.15288/jsad.2016.77.656

Badicu, G., Zamani, S., Seyed, H. and Fathirezaie, Z. (2020). Predicting tobacco and alcohol consumption based on physical activity level and demographic characteristics in romanian students. *Children*, 7(71): Available: https://doi.org/10.3390/children7070071

Bingham, C., Raymond., Elliott, M. R. and Shope, J. T. (2007). Social and behavioral characteristics of young adult drink/driver adjusted for level of alcohol use. *Alcohol Clin Exp Res*, 31(4): 655-64. Available: https://doi.org/10.1111/j.1530-0277.2007.00350.x

Bishop, C., Liu, S., Stephens, A. N. and Fitzharris, M. (2017). Association between Alcohol Consumption Patterns and Attitudes towards Alcohol Interlocks. *Accidents Analysis and Prevention*, 108: 83-90. Available: https://doi.org/10.1016/j.aap.2017.08.021

Buscemi, J., Martens, M. P., Murphy, J. G., Yurasek, A. M. and Smith, A. E. (2011). Moderators of the relationship between physical activity and Alcohol Consumption in College stidents. *Journal of American College Health*, 59(6): 503-09. Available: https://doi.org/10.1080/07448481.2010.518326

Cobiac, L. J., Vos, T. and Barendregt, J. J. (2009). Cost-Effectiveness of interventions to promote physical activity: A modeling study. *PLoS Med*, 6(7): e1000110. Available: https://doi.org/10.1371/journal.pmed.1000110

Dodge, T., Clarke, P. and Dwan, R. (2017). The relationship between physical activity and Alcohol use among adults in the united states: A systematic review of the literature. *American Journal of Health Promotion*, 31(2): 97-108. Available: https://doi.org/10.1177/0890117116664710

Ezeafulukwel, U. A., Darus, M. and Fadipe-Joseph, O. A. (2018). On analytic properties of a sigmoid function. *International Journal of Mathematics and Computer Science*, 13(2): 171-78. Available: http://ijmcs.future-in-tech.net

Ezeafulukwel, U. A., Darus, M. and Fadipe-Joseph, O. A. (2020). The q-Analogue of Sigmoid function in the space of univalent λ-Pseudo Star-Like function. *International Journal of Mathematics and Computer Science*, 15(2): 621-26. Available: http://ijmcs.future-in-tech.net

Gilchrist, J. D., Conroy, D. E. and Sabiston, C. M. (2020). Association between Alcohol Consumption and Physical activity in breast cancer survivors. *Journal of Behavioral Medicine*, 43: 166-73. Available: https://doi.org/10.1007/s10865-019-00114-4

Gulliford, M. C., Charlton, J., Bhattarai, N., Charlton, C. and Rudisill, C. (2014). Impact and Cost-Effectiveness of a universal strategy to promote physical activity in primary care: Population-Based cohort study and markov model. *European Journal of Health Economics*, 15: 341-51. Available: https://doi.org/10.1007/s10198-013-0477-0

Hahn, R. A., Middleton, J. C., Elder, R., Brewer, R., Fielding, J., Naimi, T. S., Toomey, T. L., Chattopadhyay, S., Lawrence, B., Campbell, C. A. and Force., t. C. P. S. T. (2012). Effect of alcohol retail privatization on excessive Alcohol Consumption and related harms - a community guide systematic review. *American Journal of Preventive Medicine*, 42(4): 418-27. Available: https://doi.org/10.1016/j.amepre.2012.01.002

Jamt, R. E. G., Gjerde, H., Furuhaugen, H., Romeo, G., Vindenes, V., Ramaekers, J. G. and Bogstrand, S. T. (2020). Association between Psychoactive substance use and sensation seeking behavior among drivers in norway. *BMC Public Health*, 20(23): Available: https://doi.org/10.1186/s12889-019-8087-0

Kleinbaum, D. G. and Klein, M. (2002). *Logistic regression, second edition*. U.S.A.: Springer, New York.

Laine, J., Kuvaja-Köllner, V., Pietilä, E., Koivuneva, M., Valtonen, H. and Kankaanpää, E. (2014). Cost-Effectiveness of population-Level physical activity interventions: A systematic review. *American Journal of Health Promotion*, 29 (2): 71-80. Available: https://doi.org/10.4278/ajhp.131210-LIT-622

Leonard, K. E. and Eiden, R. D. (2007). Marital and family processes in the context of Alcohol use and Alcohol disorders. *Annual Review of Clinical Psychology*, 3: 285-310. Available: https://doi.org/10.1146/annurev.clinpsy.3.022806.091424

Lisha, N. E., Sussman, S., Fapa, F. and Leventhal, A. M. (2013). Physical activity and Alcohol use disorders. *The American Journal of Drug and Alcohol Abuse,* 39(2): 115-20. Available: https://doi.org/10.3109/00952990.2012.713060

Loprinzi, P. D., Lee, H. and Cardinal, B. J. (2015). Evidence to support including lifestyle light-Intensity recommendations in physical activity guidelines for older adults. *American Journal of Health Promotion,* 29(5): 277-84. Available: https://doi.org/10.4278/ajhp.130709-QUAN-354

Maddala, G. S. (1992). *Introduction to Econometrics, second edition.* Macmillan Publishing Company, New York: U.S.A.:

Marshall, A. W. and Olkin, I. (1985). A family of bivariate distributions generated by the bivariate bernoulli distribution. *Journal of the American Statistical Association,* 80: 332-38. Available: https://doi.org/10.1080/01621459.1985.10478116

Martin, R. J., Cox, M. J., Chaney, B. H. and Knowlden, A. P. (2018). Examination of associations between risky driving behaviors and hazardous drinking among a Sample of college students. *Traffic Injury Prevention,* 19(6): 563-68. Available: https://doi.org/10.1080/15389588.2018.1476690

Mun, E.-Y., Li, X., Lineberry, S., Tan, Z., Huh, D., Walters, S. T., Zhou, Z. and Larimer, M. E. i. C. w. P. I. T. (2022). Do Brief Alcohol interventions reduce driving after drinking among college students? A Two-step Meta-analysis of individual participant data. *Alcohol and Alcoholism,* 57(1): 125-35. Available: https://doi.org/10.1093/alcalc/agaa146

National Highway Traffic Safety Administration (2020). Traffic safety facts 2020 Data: Alcohol-Impaired driving. . *US Department of Transportation, National Highway Traffic Safety Administration, Washington, DC*: Available: https://crashstats.nhtsa.dot.gov/#!/PublicationList/7

Niedermeier, M., Frühauf, A., Kopp-Wilfling, P., Rumpold, G. and Kopp, M. (2018). Alcohol consumption and physical activity in austrian college students – A Cross-Sectional study. *Substance Use and Misuse,* 53(10): 1581-90. Available: https://doi.org/10.1080/10826084.2017.1416406

Piazza-Gardner, A. K. and Barry, A. E. (2012). Examining physical activity levels an Alcohol consumption: Are people who drink more active? *American Journal of Health Promotion,* 26(3): e95-e104. Available: https://doi.org/10.4278/ajhp.100929-LIT-328

Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., George, S. M. and Olson, R. D. (2018). The physical activity guidelines for Americans. *Journal of the American Medical Association,* 320(19): 2020-28. Available: https://doi.org/10.1001/jama.2018.14854

Sanem, J. R., Erickson, D. J., Rutledge, P. C., Lenk, K. M., Nelson, T. F., Jones-Webb, R. and Toomey, T. L. (2015). Association between Alcohol-Impaired Driving Enforcement-Related Strategies and Alcohol-Impaired driving. *Accident Analysis and Prevention,* 78: 104-09. Available: https://doi.org/10.1016/j.aap.2015.02.018

Shults, R. A., Sleet, D. A., Elder, R. W., Ryan, G. W. and Sehgal, M. (2002). Association between State level drinking and driving countermeasures and self reported Alcohol impaired driving. *Injury Prevention,* 8: 106-11. Available: https://doi.org/10.1136/ip.8.2.106

Sloan, F. A., McCutchan, S. A. and Eldred, L. M. (2017). Alcohol-Impaired driving and perceived risks of legal consequences. *Alcoholism: Clinical and Experimental Research,* 41(2): 432-42. Available: https://doi.org/10.1111/acer.13298

Son, C.-H. (2014). Differences in Alcohol-Impaired driving behaviors from the connection between Alcohol Consumption patterns and drinking and driving laws. *International Journal of Economic Perspectives,* 8(3): 52-63.

Steele, C. M. and Southwick, L. (1985). Alcohol and social behavior I: The psychology of drunken excess. *Journal of Personality and Social Psychology,* 48(1): 18-34. Available: https://doi.org/10.1037//0022-3514.48.1.18

Stoltzfus, J. C. (2011). Logistic regression: A brief primer. *Academic Emergency Medicine,* 18 (10): 1099-104. Available: https://doi.org/10.1111/j.1553-2712.2011.01185.x

Sullivan, E. V., Harris, R. A. and Pfefferbaum, A. (2010). Alcohol's effects on brain and behavior. *Alcohol Res Health,* 33(1-2): 127-43.

Sunshine, J. E., Dwyer-Lindgren, L., Chen, A., Sharar, S. R., Palmisano, E. B., Bulger, E. M. and Mokdad, A. H. (2018). Alcohol-Impaired Drving in US Counties, 2002–2012. *Population Health Metrics,* 16(2): Available: https://doi.org/10.1186/s12963-018-0158-4

Werneck, A., Oyeyemi, A. L., Szwarcwald, C. L. and Silva, D. R. (2018). Association between Physical activity and Alcohol Consumption: Sociodemographic and behavioral patterns in brazilian adults. *Journal of Public Health,* 41(4): 781-87. Available: https://doi.org/10.1093/pubmed/fdy202

Wong, M. D., Coller, K. M., Dudovitz, R. N., Kennedy, D. P., Buddin, R., Shapiro, M. F., Kataoka, S. H., Brown, A. F., Tseng, C.-H., Bergman, P. and Chung, P. J. (2014). Successful school and risky behaviors among low-income adolescents. *Pediatrics,* 134 (2): e389-e96. Available: https://doi.org/10.1542/peds.2013-3573

Wright, C., Kipping, R., Hickman, M., Campbell, R. and Heron, J. (2017). Effect of multiple risk behaviours in adolescence on educational attainment at age 16 years: a UK Birth cohort study. *BMJ Open 2018,* 8: e020182. Available: http://dx.doi.org/10.1136/bmjopen-2017-020182

Yore, M., Ham, S., Ainsworth, B., Kruger, J., Reis, J., Kohl, H. and Macera, C. (2007). Reliability and validity of the instrument used in brfss to assess physical activity. *Medicine and Science in Sports and Exercise,* 39(8): 1267-74. Available: https://doi.org/10.1249/mss.0b013e3180618bbe

Zhang, Y. and Sloan, F. A. (2014). Depression, Alcohol dependence and abuse, and drinking and driving behavior. *Journal of Behavioral Health*, 3(4): 212-19. Available: https://doi.org/10.5455/jbh.20141115011440