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Flexibly Modeling Alcohol Use Disorder Risk: How Many Drinks Should We Count?

Ashley N. Linden-Carmichael[1,2], **Michael A. Russell**[2,3], and **Stephanie T. Lanza**[1,2]

[1]Edna Bennett Pierce Prevention Research Center, The Pennsylvania State University

[2]Department of Biobehavioral Health, The Pennsylvania State University

[3]The Methodology Center, The Pennsylvania State University

Abstract

Objective—Previous research has called the validity of the commonly used 4+/5+ (women/men) definition for heavy episodic drinking (HED) into question. This definition does not allow researchers to capture the considerable heterogeneity among heavy, "at-risk" drinkers. Spline regression methods were used to identify a flattening in the curve in the relationship between number of drinks consumed and prevalence of past-year alcohol use disorder (AUD). This analysis could identify the number of drinks above which no significant additional risk for AUD is conferred.

Methods—Data were from the National Epidemiologic Survey on Alcohol and Related Conditions-III (NESARC-III). The analytic sample consisted of young adult past-year drinkers (n = 6,422).

Results—Sex-specific drinking thresholds varied as a function of the number of drinks consumed during past-year typical and heaviest drinking occasion. For typical drinking, the risk for AUD continued to increase through approximately 10 (women) and 11 (men) drinks, after which AUD risk remained constant. That is, young adult drinkers experienced incremental risk for AUD through approximately a typical amount of 10 drinks, after which the risk for AUD plateaued. For heaviest drinking occasion, risk for AUD continued to increase for men, and tapered for women around 14 drinks.

Conclusions—There is incremental information gained at each level of drinking in predicting AUD, well beyond the traditional 4+/5+ HED thresholds. Relying solely on this threshold may limit our understanding of serious harms that many young adults who drink at higher levels can experience.

Correspondence concerning this article should be addressed to Ashley Linden-Carmichael, Ph.D., 303 Biobehavioral Health Building, The Pennsylvania State University, University Park, PA, 16802. Phone: (814) 865-7177. Fax: (814) 865-2530. ALindenCarmichael@psu.edu.

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Keywords

heavy episodic drinking; young adults; time-varying effect modeling; alcohol use disorder; sex differences

A disproportionate number of young adults meets criteria for a past-year alcohol use disorder (AUD) relative to other age groups. In 2014, approximately 4.3 million or 12.3% of young adults in the United States met criteria for a past-year AUD relative to 2.7% of adolescents aged 12 to 17 and 5.9% of adults aged 26 and older (Center for Behavioral Health Statistics and Quality, 2015). Although normative, frequent and heavy drinking in young adulthood is a major contributor to one's likelihood for experiencing an AUD (see Courtney & Polich, 2009). There are several established drinking guidelines, such as day-level and week-level limits developed by the U.S. Department of Health and Human Services and more specifically the National Institute on Alcohol Abuse and Alcoholism (NIAAA, 2004) that are intended to help individuals consume alcohol safely and to protect themselves from experiencing serious alcohol-related harms. Engagement in heavy episodic drinking (HED; or "binge drinking"), which is often defined as drinking fewer than 4 (for women) or 5 (for men) drinks during a drinking occasion or within a 2-hour period (see Courtney & Polich, 2009; Wechsler, Dowdall, Davenport, & Rimm, 1995), is widely used as an indicator of risky drinking behavior. Moreover, frequency of engagement in drinking at the 4+/5+ rate is encouraged by the Food and Drug Administration for use as a measure of treatment efficacy in alcohol clinical trials in the United States (Allen, 2003; Falk et al., 2010).

The validity of the 4+/5+ definition has recently been called into question (see Pearson, Kirouac, & Witkiewitz, 2016 for a debate). In particular, in 2004 the NIAAA Council recommended that HED be defined as a pattern of drinking that produces a blood alcohol concentration (BAC) of 0.08% or above (above the legal limit to operate a motor vehicle). This level was thought to translate to approximately 5 or more drinks for men and 4 or more drinks for women over approximately a 2-hour period. Importantly, several field tests have failed to find that drinking at this level produces BACs of 0.08% or above (Beirness, Foss, & Vogel-Sprott, 2004; Lange & Voas, 2001; Thombs, Olds, & Snyder, 2003). For example, Beirness and colleagues found that fewer than half of participants who drank 4+/5+ drinks on the night interviewed had a BAC over 0.08%. These findings highlight a growing concern that this widely accepted definition does not provide as much information about intoxication levels and associated risk for AUD as would be desired.

Another concern regarding the use of this definition is that many young adults drink above this threshold (White, Kraus, & Swartzwelder, 2006). For example, an estimated 35.6% of young adults reported past-month heavy episodic drinking (HED; Substance Abuse and Mental Health Services Administration [SAMHSA], 2014). Thus, in using this definition, researchers fail to capture the heterogeneity among heavy drinkers; thereby grouping alcohol users who consume 5 drinks in an occasion with users who consume 20 drinks in an occasion. A burgeoning area of research has investigated high-intensity drinking, or drinking at levels of 8+ (women)/10+ (men) drinks in one occasion (see Patrick, 2016). Among recent

young adult drinkers, the prevalence of high-intensity drinkers is similar to that of HED-only drinkers (Linden-Carmichael, Vasilenko, Lanza, & Maggs, 2017). However, high-intensity drinkers are at heightened risk for experiencing consequences from drinking in comparison to those who only drink at HED levels (Linden-Carmichael et al., 2017). These findings suggest that the widely used 4+/5+ drink threshold, when used without consideration to the heterogeneity between those who tend to drink above this threshold, creates a false equivalency in terms of risk for alcohol consequences between those who drink just above the 4+/5+ definition and those who drink far above it. In doing so, researchers may underestimate the risk associated with drinking at high-intensity levels.

To explore a more informative threshold for predicting drinking-related harms, Wechsler and Nelson (2006) estimated the prevalence of college students who reported a variety of alcohol-related problems (e.g., unprotected sex, trouble with the police, DSM-IV alcohol abuse, hurt or injured from drinking) and plotted each against the number of drinks they typically consumed during a drinking occasion. Some consequences (e.g., being hurt or injured) were positively and linearly associated with number of drinks, but others (DSM-IV alcohol abuse) were relatively nonlinear. For example, the probability of meeting criteria for a DSM-IV alcohol abuse diagnosis increased linearly from 0 to 3 drinks but tapered around 3 to 4 drinks, such that the probability held somewhat constant at 0.50 from 4 drinks to 9 or more drinks. Although fewer college students were drinking at higher drinking levels than lower levels, these findings suggest that the 4+/5+ threshold provides only limited information about drinking-related consequences.

Livingston (2013) expanded upon this work by testing fifteen risky drinking thresholds to identify the most appropriate threshold for predicting alcohol-related hazardous and delinquent behaviors (e.g., damaging property while under the influence of alcohol, going to work under the influence of alcohol). Receiver Operator Characteristic (ROC) curves were tested for each outcome to characterize the sensitivity and specificity of each threshold. Using this approach, thresholds of approximately 5–7 Australian standard drinks or 3.5–5 U.S. standard drinks were found to have optimal balance between sensitivity and specificity in predicting negative outcomes. While ROC curves provide important information about the best balance of sensitivity and sensitivity, other statistical modeling approaches can provide additional statistical information to evaluate the value of information on the increased risk associated with each additional drink. AUD prevalence could, for example, be modeled as a continuous function of quantity consumed, creating a dose-response curve. This curve can provide an estimate of the probability of AUD given a particular number of drinks. The curve may or may not identify a flattening of the curve where risk levels off. Nonparametric spline regression provides an opportunity to flexibly model this curve without making any assumptions about its shape (e.g., a linear, quadratic, or piecewise linear function across number of drinks). This approach has advantages over ROC curves. In particular, instead of examining the specificity and sensitivity at each threshold level, spline regression uses hypothesis testing while flexibly modeling continuous change in the prediction of AUD across the number of drinks to (1) infer the slope between number of drinks and log-odds of AUD at each number of drinks and (2) detect the number of drinks above which no additional information about log-odds of AUD is gained (i.e., the slope is not significantly different from zero).

Toward this end, the current study modeled the prevalence of young adults' past-year AUD as a flexible function of number of drinks consumed during (1) their typical drinking occasion in the past year and (2) their heaviest drinking occasion during the past year. In particular, spline regression was used to estimate nonlinear models to predict the risk of concurrent AUD from the typical number of drinks or heaviest number of drinks. Examination of such a model could show how one's risk of experiencing an AUD incrementally increases with each additional drink reported (typical or maximum). Furthermore, it could be used to explore whether the 4+/5+ definition or continuous measure is more appropriate for assessing one's risk for AUD. In other words, if the risk of AUD continues to increase with number of drinks above a pre-specified threshold (e.g., 4+/5+ drinks for women/men), it can be argued that the 4+/5+ definition does not provide a fully adequate measure of risk. Such information would be highly useful in brief screening tools used to identify young adult drinkers most at risk for experiencing an AUD.

Method

Participants and Procedure

The current study used data from the National Epidemiologic Survey on Alcohol and Related Conditions-III (NESARC-III; Grant et al., 2014), a nationally representative sample of 36,309 noninstitutionalized U.S. adults aged 18 and older. Responses from Hispanic, Black, and Asian adults were oversampled; thus, survey weights were used in all study analyses. Data were collected in 2012 and 2013. Participants were compensated $90 for their time. The survey protocol was approved by the institutional review board of the National Institutes of Health and Westat.

As the current study was focused on the drinking patterns of young adults, the analytic sample was restricted to those aged 18 to 29 years who reported consuming at least one alcoholic beverage in the past year (n = 6,422). Survey weights were used to calculate sample descriptives. The analytic sample was evenly divided with men (50.77%) and women (49.23%). For race/ethnicity, 59.98% identified as White, non-Hispanic; 19.50% identified as Hispanic; 13.03% identified as Black, non-Hispanic; 6.00% identified as Asian/Native Hawaiian/Other Pacific Islander, non-Hispanic; and 1.49% identified as American Indian/Alaska Native, non-Hispanic.

Measures

Typical number of drinks—Participants were asked to report the number of drinks they usually consumed on days when they drank in the last 12 months. Given the limited number of individuals reporting >20 drinks, the range was restricted to 1 to 20 drinks in an occasion, treating the few people who reported more than 20 drinks as having reported 20. The mean number of drinks reported for a typical occasion was 3.28 drinks (SD = 2.56; Mdn = 3.00).

Heaviest drinking occasion—Participants were asked to report the largest number of drinks consumed in a single day in the last 12 months. Similar to typical drinks, the range was restricted to 1 to 20 drinks in an occasion. The mean number of drinks reported for the heaviest occasion was 5.98 drinks (SD = 4.43, Mdn = 5.00).

Alcohol use disorder—Past-year AUD was determined using the Alcohol Use Disorder and Associated Disabilities Interview Schedule – DSM-5 Version (AUDADIS-5; Grant et al., 2011). Participants indicated whether they experienced 11 different symptoms within the past 12 months, including whether they, "Continued to drink even though [they] knew it was causing [them] a health problem or making a health problem worse?" or, "Had times when [they] ended up drinking more, or longer than [they] intended?" Positive responses to at least two of the symptoms was indicative of an AUD. This diagnostic interview is found to have fair to good concordance with clinician-administered interviews for determining AUD status (Hasin et al., 2015).

Analytic Plan

The %WeightedTVEM macro was used in SAS 9.4 to conduct a nonparametric spline regression of AUD prevalence on drinking quantity. Spline regressions were tested through the implementation of time-varying effect modeling (TVEM; Tan, Shiyko, Li, Li, & Dierker, 2012). TVEM can flexibly model changes in estimated prevalence rates and associations between variables as flexible functions across levels of a continuous variable. TVEM is a general statistical approach for estimating regression coefficients (i.e., intercepts, slopes) as nonparametric functions of some quantitative variable, most often across developmental age (i.e., Linden-Carmichael et al., 2017; Vasilenko, Evans-Polce, & Lanza, 2017) or across real time (e.g., Lanza, Vasilenko, Liu, Li, & Piper, 2014; Mason, Mennis, Way, Lanza, Russell, & Zaharakis, 2015). In the current study, coefficients were estimated as a flexible function of number of drinks. In separate models, the prevalence of AUD was estimated as a non-linear function of (1) the number of drinks consumed on a *typical* drinking occasion and (2) the number of drinks consumed during the *heaviest* drinking occasion. Models were also estimated separately for males and females. Significant differences between men and women can be observed at points on the curve where CIs do not overlap. The most appropriate number of knots, or splitting points, was identified for each model using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) fit statistics.

To identify the point at which a further increase in the number of drinks no longer contributes to the prediction of AUD prevalence, the following analyses were conducted. First, intercept functions were estimated using cubic polynomial B-splines, joined with a single knot point, as a function of typical number of drinks and of number of drinks during heaviest episode (in separate models). This shape was considered adequately flexible and provided sufficient fit to the data after examining fit statistics (see Tan et al., 2012 and Dziak, Li, Tan, Shiffman, & Shiyko, 2015 for a review of B-spline estimation in TVEM). In this specification, the log-odds of AUD was estimated as a cubic polynomial on each half of the interval covering the range on the x-axis (i.e., one to 20 drinks), with the knot placed at the middle of the interval (i.e., approximately 10 drinks). The coefficient functions were estimated using maximum pseudo-likelihood taking weights into account (Dziak et al., 2017). The predicted log-odds of AUD at each level of drinking was also transformed for convenience into a predicted probability. Second, once the curve was estimated, the first derivative (i.e., the linear slope) was calculated at each point across the cubic B-spline function. The derivative of the fitted function was estimated by recalculating the B-spline, replacing each basis function with its numerical derivative while retaining the same

regression coefficients. The resulting derivative curve was implicitly assumed to be a quadratic function on each half of the interval covered. Pointwise 95% CIs for fitted values of the curve were calculated using Cramer's delta method (i.e., Taylor linearization; see Ferguson, 1996). If the 95% CI for the estimated derivative at each point does not include zero, this means that there is a significant positive (or negative) slope in the prevalence of AUD at that precise amount of drinking. A positive slope at 5 drinks, for example, implies that knowing whether the individual typically has 5 drinks contributes useful incremental information in predicting AUD over and above knowing whether the individual typically has fewer drinks. In contrast, if the 95% CI for the estimated derivative at 5 drinks did include zero, this would imply that knowing whether the individual typically has 5 drinks per occasion does not significantly predict AUD over and above knowing whether he or she typically has fewer drinks. Derivative curves were generally consistent holding drinking frequency constant (i.e., monthly drinker vs. less than monthly drinker). For parsimony, models are presented without the inclusion of drinking frequency as a covariate.

Results

Typical Drinking Occasion

The estimated prevalence of AUD as a function of the typical number of drinks consumed in one occasion is plotted in Figure 1a, separately for men and women. As can be seen for men (black line), the estimated rate of AUD increased steeply with the typical number of drinks consumed for the first few drinks, then the increase slowed through about 10–12 drinks and then held fairly constant at an AUD rate of nearly 80%. A similar trend emerged for women (gray line), with significantly lower AUD prevalence than men conditional upon approximately 2–3 typical drinks but significantly higher AUD rates conditional upon 5–9 typical drinks. Prevalence rates indicate that for men, approximately 40.1% of male drinkers who consumed about 3 drinks during a typical drinking occasion met criteria for a past-year AUD. Rates increased to 49.3% at about 4 drinks, 57.4% at about 5 drinks, and 64.1% at about 6 drinks. Rates plateaued at approximately 12 drinks, with 81.1% reporting a past-year AUD. For women, prevalence rates for AUD were at 20.1% for those who consumed 2 drinks during a typical occasion, 37.6% at about 3 drinks, 51.5% at about 4 drinks, and 63.1% at about 5 drinks. Rates plateaued earlier for women than for men, with about 84.5% of women who drank about 9 drinks during a typical drinking occasion meeting criteria for a past-year AUD.

The derivative of the curve of log odds as a function of number of drinks, is presented in Figure 1b highlight the number of drinks for men and women at which the first derivative (i.e., the slope of functions plotted in Figure 1a) becomes non-significant. Specifically, the derivatives suggest that we are gaining significant new information about the likelihood of AUD with each additional drink for both men and women until a particular point. At approximately 11 drinks for men and 10 drinks for women, the slope is not significantly different from zero (i.e., the CI includes zero). This result indicates that for women (men), no statistically significant incremental information is gained in determining one's likelihood of currently having an AUD if an individual's typical number of drinks surpasses 10 (11) drinks per occasion – in other words, the risk remains constant beyond this point.

Heaviest Drinking Occasion

The estimated prevalence of AUD for men and women as a function of the number of drinks an individual reports on their heaviest drinking occasion are presented in Figure 2a. For men (black line), the estimated AUD prevalence increased fairly linearly with the number of drinks through about 10 drinks; thereafter, the rate of increase slowed but continued in a positive direction through 20 drinks. For women (gray line), the estimated rate of AUD increased steeply through about 7 drinks, then slowed and plateaued at around 12 drinks. For women, however, their risk of AUD was significantly higher than that for men from approximately 5 drinks to 14 drinks. In terms of prevalence of AUD, approximately 17.5% of male drinkers who consumed about 4 drinks during their heaviest drinking occasion met criteria for a past-year AUD. Prevalence rates increased to 24.4% at about 5 drinks, 33.3% at about 6 drinks, and 40.4% at about 7 drinks. For women, 20.0% of female drinkers who consumed about 4 drinks during their heaviest drinking occasion met criteria for an AUD in the past year. These rates rose with number of drinks, to about 31.1% at about 5 drinks, 42.7% at 6 drinks, and 54.7% at 7 drinks. Prevalence rates tapered off at approximately 14 drinks with 79.5% of women who drank at this level during their heaviest occasion meeting criteria for a past-year AUD.

The derivative curve displayed in Figure 2b shows that for men, at no number of drinks does the slope include zero. This implies that new information is gained in predicting AUD for each additional drink through at least 20 drinks. For women, the slope becomes non-significant at approximately 14 drinks, suggesting that knowing how many drinks women consumed on their heaviest drinking occasion beyond 14 drinks provides no statistically significant additional information on risk for currently having AUD.

Discussion

The current investigation aimed to shed light on a continuing controversy surrounding the use of standard definitions for heavy episodic drinking (HED) (see Pearson et al., 2016). The use of a 4+ (women)/5+ (men) drink definition is widely used among alcohol researchers. Increasing evidence suggests that being at or over this threshold is not consistently associated with BAC levels of 0.08% or above (Beirness et al., 2004; Lange & Voas, 2001; Thombs et al., 2003) and is not consistently related to certain negative consequences (Wechsler & Nelson, 2006). As the practical purpose of a threshold is to identify individuals at particularly high risk, our study sought to identify the drinking level at which additional knowledge about whether and how risk of AUD continues to increase above the 4+/5+ HED threshold. To do this, spline regression was used to study the relationship between the number of drinks consumed and the prevalence of past-year AUD, focusing on finding the approximate point where the relationship becomes non-significant. Slopes were tested for both men and women and as a function of both typical number of drinks consumed and heaviest number of drinks consumed in a drinking occasion during the past year.

Our findings revealed that sex-specific drinking risk varied as a function of the number of drinks consumed during a typical drinking occasion and during a heaviest drinking occasion. We found that there was incremental influence of typical number of drinks consumed during a drinking episode as well as number of drinks consumed during a heavy drinking episode.

In other words, a young adult's risk for experiencing a past-year AUD corresponded with each additional drink reported. For typical drinking, number of drinks was approximately linearly associated with AUD for both men and women through approximately 10 drinks (women) and 11 drinks (men). For heaviest drinking occasion, risk for AUD continued to increase for men, and tapered for women at approximately 14 drinks. Results from our study examining the outcome of AUD are consistent with prior work examining the predictive utility of different drinking thresholds on harms. Specifically, findings from an 8-week daily diary study (Jackson, 2008) and from cross-sectional studies (Wechsler & Nelson, 2006) indicate that higher drinking thresholds than the traditional 4+/5+ definition may be more suitable for severe outcomes, demonstrating that knowledge of severity beyond the 4+/5+ definition is likely useful in predicting clinical risk.

Given emerging research suggesting that many young adults consume alcohol far beyond the traditional HED threshold (Linden-Carmichael et al., 2017; Patrick, 2016; Patrick & Terry-McElrath, 2017; White et al., 2006) and the current findings that there is incremental risk associated with number of drinks consumed well beyond the level of 4 or 5 drinks, future work may benefit from taking into consideration the higher levels of drinking exhibited by many young adults. In addition, given that over one-third of young adults report past-month HED-level drinking (SAMHSA, 2014), this threshold may be overly sensitive (and less specific) in identifying at-risk drinkers. These findings do not suggest that drinking 4 or 5 drinks is not risky; indeed, our study found that at approximately 4 drinks on a typical occasion, more than half of participants reported a past-year AUD. However, our findings suggest that the 4+/5+ threshold is limiting our knowledge of the actual level of risk potentially incurred by drinking at heavier levels. It is clear that measuring drinking level more continuously to a certain point would provide researchers with more information about one's risk for AUD. The use of the 4+/5+ definition for heavy drinking may still be useful for prevention purposes and for classifying individuals who are at increased risk (see commentary by Carey & Miller, 2016).

Our findings have important implications for clinical work, particularly in identifying an optimal measure of treatment efficacy for alcohol clinical trials. The determination of what constitutes as a "successful" treatment outcome remains a serious concern (Witkiewitz, 2013a). The Food and Drug Administration recommends the use of percentage of no heavy (4+/5+ drinks) drinking days as an indicator of treatment efficacy in clinical trials, yet recent work fails to find support for the utility and clinical meaningfulness of this binary threshold (e.g., Pearson et al., 2016; Pearson, Bravo, Kirouac, & Witkiewitz, 2017). Our findings lend credence to this concern, as we found that each additional drink was associated with significant increases in AUD. Within the context of a clinical trial, these results may suggest that the reduction in *number* of drinks as opposed to *whether* they surpassed 4+/5+ drinks may be more clinically meaningful. Additional clinical work is needed to further investigate the utility of number of drinks as a treatment outcome, such as determining the number of drinks to reduce and whether it is more salient to focus on reduction of an absolute number of drinks or to focus on reduction of drinks relative to an individual's average use. There are many other treatment outcomes that may also be useful to consider in defining treatment success, such as self-reported temptations to drink or experience of negative consequences (e.g., Witkiewitz, 2013a, 2013b).

This innovative statistical approach also has implications for future work examining the predictive utility of drinking behavior on alcohol-related consequences. In particular, our study used spline regression to identify the flattening in the curve average and heaviest number of drinks consumed when predicting AUD. There are alternatives that may have differential predictive utility for alcohol-related harms. For example, researchers could inquire about subjective effects of intoxication (Midanik, 1999), such as asking participants how often they had too much to drink (Andreasson, 2016). However, as noted in a recent debate article by Pearson and colleagues (2016), the use of the HED definition may be most relevant in real-time settings. That is, a threshold may be useful for determining the number of drinks or intoxication level one can drink most safely before increasing their risk for negative consequences. One way to achieve this goal is through the use of objective measures of intoxication, a rapidly developing area in the addictions field (see Greenfield, Bond, & Kerr, 2014). For example, an array of transdermal alcohol sensors (NIAAA, 2016) can non-invasively monitor one's transdermal alcohol concentration (a proxy for BAC) in real time without relying on participants to keep track of their drinking. Future work could use this statistical approach to infer the point at which level of intoxication is predictive of a variety of same- or next-day harms.

Several limitations should be noted. Although NESARC-III interviews involved providing participants with example photos of standard alcoholic drinks, self-reported drinking data has potentially serious limitations. Self-reported alcohol use is reasonably reliable and valid (Del Boca & Darkes, 2003), but can be subject to recall biases, potentially resulting in inaccurate aggregate estimates in these population-based survey data. Future work using daily, ecological momentary, or objective assessments (e.g., via wearable alcohol sensor) would reduce the potential for recall bias. Such designs also would allow for an investigation of person-specific thresholds, to account for potential differences in body mass and variability in drinking. Also, as the HED thresholds are created with the general population of drinkers in mind, we decided to include all current drinkers in our analysis so as to not bias our results. Future work may build from these findings not only to increase generalizability to adolescents or older adults but also based on drinking level, college education status, racial/ethnic group, or SES. Exploring such heterogeneity of individuals across drinking levels would be highly informative for future work focused on personalized intervention. Lastly, our study focused solely on risk for AUD given our wide range of drinkers in this sample. Future work could build upon our findings by examining more specific drinking outcomes (e.g., blacking out from drinking, getting into fights) within a similar population or more severe outcomes (e.g. medical, legal) in a higher-risk sample.

Our study sought to examine the flattening in the curve corresponding to the relationship between number of drinks consumed during a typical occasion and heaviest drinking occasion and past-year AUD. Our results suggest that there is incremental information gained at each level of drinking in predicting AUD, well beyond the point of traditional 4+/5+ HED thresholds for women and men. It is clear that using this definition, rather than measuring heavy drinking continuously up to a certain threshold, limits our understanding of serious alcohol-related harms that many young adults who drink at higher levels can experience.

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References

Allen JP (2003). Measuring outcome in interventions for alcohol dependence for problem drinking: Executive summary of a conference sponsored by the National Institute on Alcohol Abuse and Alcoholism. Alcoholism: Clinical and Experimental Research, 27, 1657–1660.

Andreasson S (2016). Better options than self-report of consumption. Addiction, 111, 1727–1728. [PubMed: 26929117]

Beirness DJ, Foss RD, & Vogel-Sprott M (2004). Drinking on campus: Self-reports and breath tests. Journal of Studies on Alcohol and Drugs, 65, 600–604.

Carey KB, & Miller MB (2016). One size should not fit all, so use the right tool for the job. Addiction, 111, 1727–1734. [PubMed: 26929117]

Center for Behavioral Health Statistics and Quality. (2016). 2015 National Survey on Drug Use and Health: Detailed Tables. Substance Abuse and Mental Health Services Administration, Rockville, MD.

Courtney KE, & Polich J (2009). Binge drinking in young adults: Data, definitions, and determinants. Psychological Bulletin, 135, 142–156. [PubMed: 19210057]

Del Boca FK, & Darkes J (2003). The validity of self-reports of alcohol consumption: State of the science and challenges for research. Addiction, 98, 1–12.

Dziak JJ, Li R, Tan X, Shiffman S, & Shiyko MP (2015). Modeling intensive longitudinal data with mixtures of nonparametric trajectories and time-varying effects. Psychological Methods, 20, 444–469. [PubMed: 26390169]

Dziak JJ, Li R, & Wagner AT (2017). WeightedTVEM SAS Macro Users' Guide (Version 2.6). University Park: The Methodology Center, Penn State Retrieved from http://methodology.psu.edu

Falk D, Wang XQ, Liu L, Fertig J, Mattson M, Ryan M, … Litten RZ (2010). Percentage of subjects with no heavy drinking days: Evaluation as an efficacy endpoint for alcohol clinical trials. Alcoholism: Clinical and Experimental Research, 34, 2022–2034.

Ferguson TS (1996). A Course in Large Sample Theory. London, United Kingdom: Chapman & Hall.

Grant BF, Chu A, Sigman R, Amsbary M, Kali J, Sugawara Y, Jiao R, Ren W, & Goldstein R (2014). Source and accuracy statement: National Epidemiologic Survey on Alcohol and Related Conditions-III (NESARC-III). Rockville, MD: National Institute on Alcohol Abuse and Alcoholism.

Grant BF, Goldstein RB, Chou SP, Saha TD, Ruan WJ, Huang B, … Hasin DS (2011). The Alcohol Use Disorder and Associated Disabilities Interview Schedule-Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition Version (AUDADIS-5). Rockville, MD: National Institute on Alcohol Abuse and Alcoholism.

Greenfield TK, Bond J, & Kerr WC (2014). Biomonitoring for improving alcohol consumption surveys: The new gold standard? Alcohol Research: Current Reviews, 36, 39–45. [PubMed: 26258999]

Hasin DS, Greenstein E, Aivadyan C, Stohl M, Aharonovich E, Saha T, … Grant BF (2015). The Alcohol Use Disorder and Associated Disabilities Interview Schedule-5 (AUDADIS-5): Procedural validity of substance use disorders modules through clinical re-appraisal in a general population sample. Drug and Alcohol Dependence, 148, 40–46. [PubMed: 25604321]

Jackson KM (2008). Heavy episodic drinking: Determining the predictive utility of five or more drinks. Psychology of Addictive Behaviors, 22, 68–77. [PubMed: 18298232]

Lange JE, & Voas RB (2001). Defining binge drinking quantities through resulting blood alcohol concentrations. Psychology of Addictive Behaviors, 15, 310–316. [PubMed: 11767262]

Lanza ST, Vasilenko S, Liu X, Li R, & Piper M (2013). Advancing the understanding of craving during smoking cessation attempts: A demonstration of the time-varying effect model. Nicotine and Tobacco Research, 16, S127–134. [PubMed: 23975881]

Linden-Carmichael AN, Vasilenko SA, Lanza ST, & Maggs JM (2017). High-intensity drinking versus heavy episodic drinking: Prevalence rates and relative odds of alcohol use disorder across adulthood. Alcoholism: Clinical & Experimental Research, 41, 1754–1759.

Livingston M (2013). Testing different thresholds for risky episodic drinking—What's so special about five drinks? Drug and Alcohol Dependence, 133, 248–253. [PubMed: 23726976]

Mason M, Mennis J, Way T, Lanza S, Russell M, & Zaharakis N (2015). Time-varying effects of a text-based smoking cessation intervention for urban adolescents. Drug and Alcohol Dependence, 157, 99–105. [PubMed: 26507175]

Midanik LT (1999). Drunkenness, feeling the effects and 5+ measures. Addiction, 94, 887–897. [PubMed: 10665077]

National Institute on Alcohol Abuse and Alcoholism. (2004, Winter). NIAAA council approves definition of binge drinking. NIAAA Newsletter. Retrieved September 23, 2005, from http://pubs.niaaa.nih.gov/publications/Newsletter/winter2004/Newsletter_Number3.htm

Patrick ME (2016). A call for research on high-intensity alcohol use. Alcoholism: Clinical and Experimental Research, 40, 256–259.

Patrick ME, & Terry-McElrath YM (2017). High-intensity drinking by underage young adults in the United States. Addiction, 112, 82–93.

Pearson MR, Bravo AJ, Kirouac M, & Witkiewiz K (2017). The search for an elusive cutoff remains: Problems of binary classification of heavy drinking as an endpoint for alcohol clinical trials. Drug and Alcohol Dependence, 171, 91–96. [PubMed: 28038361]

Pearson MR, Kirouac M, & Witkiewitz K (2016). Questioning the validity of the 4+/5+ binge or heavy drinking criterion in college and clinical populations. Addiction, 111, 1720–1726. [PubMed: 27605077]

Substance Abuse and Mental Health Services Administration (SAMHSA). (2014). Results from the 2013 National Survey on Drug Use and Health: National Findings (Office of Applied Studies, NSDUH Series H-30, DHHS Publication No. SMA 06–4194).

Tan X, Shiyko MP, Li R, Li Y, & Dierker L (2012). A time-varying effect model for intensive longitudinal data. Psychological Methods, 17, 61–77. [PubMed: 22103434]

Thombs DL, Olds RS, & Snyder BM (2003). Field assessment of BAC data to study late-night college drinking. Journal of Studies on Alcohol, 64, 322–30. [PubMed: 12817820]

Vasilenko SA, Evans-Polce RJ, & Lanza ST (2017). Age trends in rates of substance use disorders across ages 18–90: Differences by gender and race/ethnicity. Drug and Alcohol Dependence.

Wechsler H, Dowdall GW, Davenport A, & Rimm EB (1995). A gender-specific measure of binge drinking among college students. American Journal of Public Health, 85, 982–985. [PubMed: 7604925]

Wechsler H, & Nelson TF (2006). Relationship between level of consumption and harms in assessing drink cut-points for alcohol research: Commentary on "many college freshmen drink at levels far beyond the binge threshold" by White et al. (2006). Alcoholism: Clinical and Experimental Research, 30, 922–927.

White AM, Kraus CL, & Swartzwelder HS (2006). Many college freshmen drink at levels far beyond the binge threshold. Alcoholism: Clinical and Experimental Research, 30, 1006–1010.

Witkiewitz K (2013a). "Success" following alcohol treatment: Moving beyond abstinence. Alcoholism: Clinical and Experimental Research, 37 (Supplement 1), E9–E13.

Witkiewitz K (2013b). Temptation to drink as a predictor of drinking outcomes following psychosocial treatment for alcohol dependence. Alcoholism: Clinical and Experimental Research, 37, 529–537.

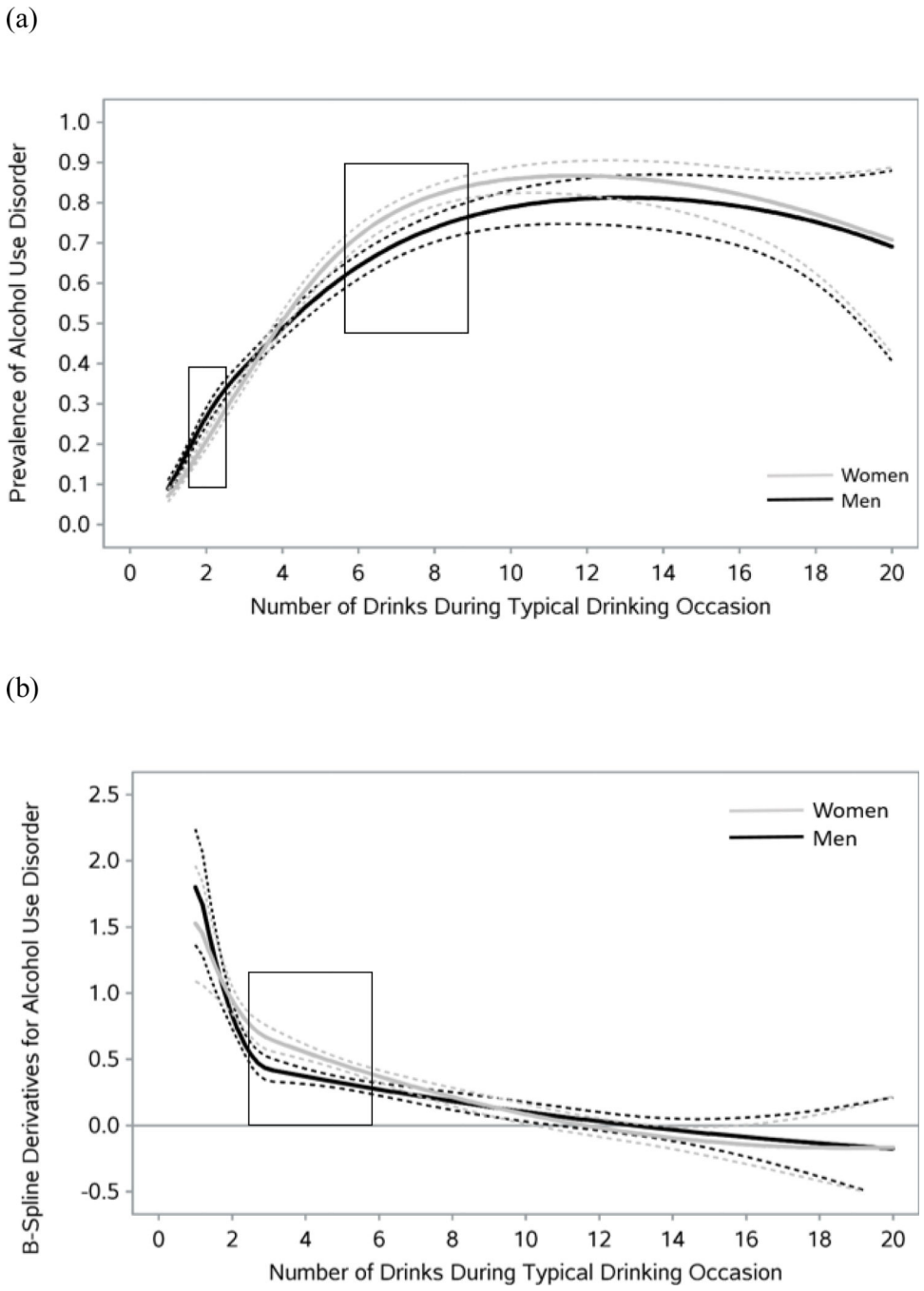

Figure 1.

(a) Intercept-only spline regression models representing the prevalence rates of alcohol use disorder (AUD) as a function of the number of drinks typically consumed on a drinking occasion in the past year and (b) the B-spline derivatives representing the slope of intercept function across number of drinks reported. The black line represents men and the gray line represents women. Significant differences between men and women can be observed at points on the curve where CIs do not overlap, which are denoted with boxes.

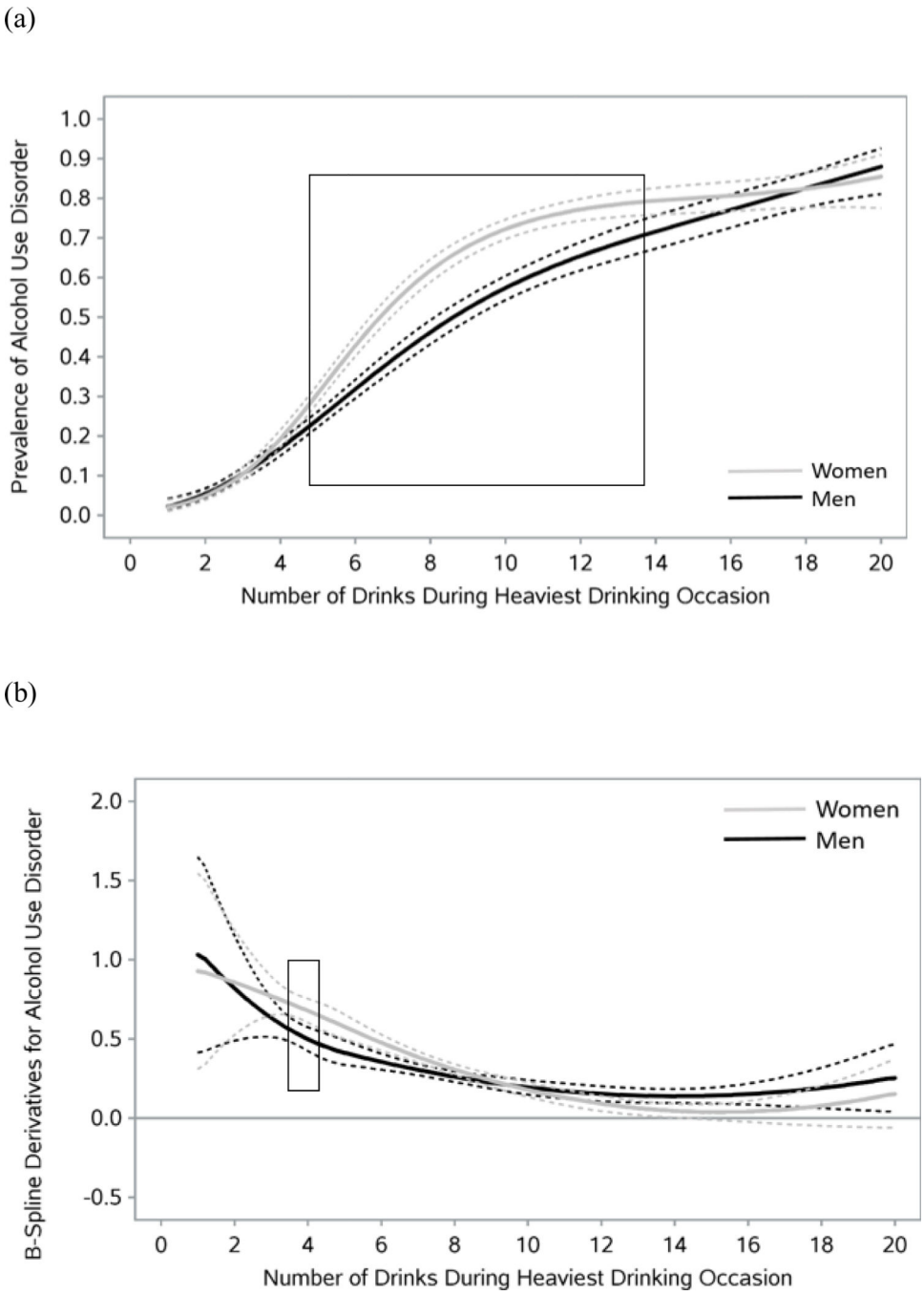

Figure 2.

(a) Intercept-only spline regression models representing the prevalence rates of alcohol use disorder (AUD) as a function of the number of drinks reported during one's heaviest drinking occasion in the past year and (b) the B-spline derivatives representing the slope of the intercept function across number of drinks reported. The black line represents men and the gray line represents women. Significant differences between men and women can be observed at points on the curve where CIs do not overlap, which are denoted with boxes.