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## A Time-varying Effect Model of the Dynamic Association between Alcohol Use and Consequences over the First Two Years of College

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### Abstract

College students experience myriad negative consequences from alcohol misuse. The strength of the association between level of alcohol use and consequences may change across the initial years of college, as students develop tolerance or learn to avoid negative effects of drinking. Time varying effect models (TVEM) allow for statistical examination of the changing strength of associations between two variables as they unfold across time. Goals of the present study were to test the hypothesis that the association between weekly quantity of alcohol use and the odds of an alcohol consequence that week would decrease in strength from the first week of freshman year to the end of sophomore year, and to examine gender differences in the association between use and consequences over time. Participants (N=812 college student drinkers, 60% female) completed 36 assessments of alcohol use and consequences across two years (every other week). TVEM models revealed that the proportion of those for whom alcohol use led to a consequence declined across time. Aside from the first few weeks of college, the association between alcohol use and odds of a consequence was consistently stronger for women than men. Among men, the odds of a consequence declined relatively steadily over time. Among women, the strength of this association was more dynamic. This study provides initial insight into the complex relationship between drinking and consequences. Future research focusing on understanding factors that explain the decreasing association between use and consequences with time can contribute to college student alcohol education and interventions.

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### Contributors

Dr. Nancy Barnett designed the study and oversaw data collection. Dr. Jennifer Merrill conceptualized the research question, conducted the statistical analysis and wrote the first draft of the manuscript. Dr. Shannon Kenney assisted with literature searches and manuscript drafts. All authors contributed to and have approved the final manuscript.

### Conflict of Interest

All authors declare that they have no conflicts of interest.

## Keywords

alcohol; alcohol consequences; college students; time varying effect model

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## 1. Introduction

College students report both excessive alcohol consumption and related consequences, such as problems with academics, interpersonal relationships, and alcohol-induced memory loss (White & Hingson, 2014). However, alcohol use explains only a moderate amount of the variance in alcohol consequences (LaBrie, Hummer, Neighbors, & Larimer, 2010; Larimer et al., 2001). The association between drinking and consequences may be dependent on physiological, behavioral, and contextual factors (e.g., Mallett et al., 2011). Thus, the strength of this association may change over time. Gaining insight into how the strength of the alcohol use-alcohol consequences relationship differs over the course of college may highlight times when students are at heightened risk for consequences as a function of their drinking, and in turn can inform alcohol risk reduction interventions.

Overall, initial transitions to college are associated with escalations in drinking (Stone, Becker, Huber, & Catalano, 2012; White et al., 2006), and alcohol use fluctuates during the school year such that the initial weeks of academic semesters and school breaks (e.g., spring break) are associated with heavier drinking (Del Boca, Darkes, Greenbaum, & Goldman, 2004). However, few studies have examined temporal patterns of students' alcohol-related *consequences*. In a study examining only freshmen year in the present sample, the highest levels of negative consequences occurred during the initial weeks of the fall and spring semesters (Barnett et al., 2014). In the current study, we advance this research by examining prospectively not only changes in consequences, but potential changes in the *association* between students' weekly drinking and consequences over the first two full academic years of college.

The effect of alcohol consumption on consequences varies as a function of experience with consequences (Mallett, Marzell, & Turrise, 2011) as well as behavioral (e.g., use of protective behaviors; Martens et al., 2004), physiological (e.g., gender-related differences in metabolism of alcohol; Sugarman, DeMartini, & Carey, 2009), and contextual (e.g., drinking game playing; Zamboanga et al., 2014) influences. For example, Neal and Carey (2007) showed that at the event-level, heavier drinkers can drink more relative to lighter drinkers before experiencing consequences, perhaps suggesting that increased tolerance attenuates the strength of the drinks-consequences relationship. Similarly, with increased drinking experience that naturally occurs for many students over the first two college years, the same number of drinks may confer less risk for negative consequences over time if students learn to implement strategies to reduce problems. Indeed, it has been shown that the strength of the effect of binge drinking on one particular consequence – alcohol-induced blackouts – declined across three annual assessments (Marino & Fromme, 2016). Alternatively, the strength of the association may fluctuate over time depending on contextual changes that may increase or decrease the likelihood of consequences at similar levels of drinking (e.g., changes in academic responsibilities and associated stress toward the end of a semester may

result in more opportunities for negative consequences to occur regardless of level of drinking). Despite these possibilities, little research has examined links between use and consequences at the within-person level over time. As an important first step, in the present study we utilize longitudinal data to identify the points during the first two college years when alcohol use may be less (or more) strongly related to drinking-related consequences, opening up opportunities for future research to identify alternative predictors of risk or changes over time in mechanisms of the links between use and consequences.

Although college men are found to drink more than women overall, men and women experience similar levels of alcohol-related consequences (Kenney & LaBrie, 2013; White & Jackson, 2004). That women metabolize alcohol more slowly and thus reach higher blood alcohol concentrations at equivalent levels of drinking as men may partially account for college women's heightened risk. However, it is not known whether the strength of association between drinking and consequences may differ by gender. Highlighting time points of gender-specific risk would provide valuable insight into the role of gender in trajectories of alcohol risk.

Statistical methods now exist to examine such changes in the association between two variables as they unfold across time. Specifically, time varying effect models (TVEM) (Shiyko, Lanza, Tan, Li, & Shiffman, 2012; Tan, Shiyko, Li, Li, & Dierker, 2012) flexibly estimate how the relationship between an independent and dependent variable (e.g., alcohol use and consequences) differs over time, without assuming this association follows a parametric function of time. TVEM involves modeling smoothed functions that can take a variety of dynamic shapes rather than including any abrupt break points. Effects, and their significance, may take on a different value depending on where in time the effect is examined. In the present study, we utilized logistic TVEM, a variant for binary outcomes (Vasilenko et al., 2014; Yang, Tan, Li, & Wagner, 2012), to test the hypothesis that the strength of the association between weekly quantity of alcohol use and the odds of an alcohol consequence that week would decrease from the first week of freshmen year to the end of sophomore year. We also conducted an exploratory examination of gender differences in the strength of association between use and consequences over time.

## 2. Method

### 2.1 Participants

In the larger study from which these data were drawn, 1,053 participants (57.5% female) were enrolled. Participants were dropped from the present study if they did not report drinking ( $n = 241$ ; 22.9%) over the course of study. Thus, our analytic sample was  $N = 812$ . Participants were on average 18.35 years old ( $SD = 0.45$ ) at baseline. The sample was 60.2% female and 11.6% Latino/Hispanic. Participants were 68.6% White, 10.8% Asian-American, 6.8% Black, 6.0% Multiracial; 7.8% indicated "other" or did not indicate a race.

### 2.2 Procedures

A random sample of students from three college/university sites in Southern New England were invited to enroll in the summer prior to college matriculation. Following the baseline

assessment, which took place immediately following consent and prior to arriving to campus, participants were randomly assigned to one of two assessment groups, receiving surveys on alternating weeks. Monday of each week, starting with the first week of freshman year, one of the two alternating groups received an email containing a link to a brief web-based survey; participants could respond through Sunday. These assessments were conducted during the freshman and sophomore academic years, including winter but not summer breaks. For each participant, there were a total of 36 possible assessments (18 per year). Participants were compensated \$20 for the baseline survey and \$2 for every completed repeated assessment; additional raffles and bonuses were used to enhance response rates. See (reference deleted for masked review) for additional detail about study procedures.

## 2.3 Measures

**2.3.1 Demographics**—Gender, race/ethnicity, and age were contained in the baseline survey.

**2.3.2 Alcohol use**—Using an automatically produced past-week diary grid based on the day the survey was completed, participants indicated how many drinks they consumed on each day. Number of drinks in each week was summed. Prior work in which this 7 day measure was compared to a 30 day timeline followback (Sobell & Sobell, 1992) demonstrated generally good correspondence between the two (Hoepfner, Stout, Jackson, & Barnett, 2010).

**2.3.3 Alcohol consequences**—On each survey, participants who endorsed alcohol use were asked whether in the past week they had any of 13 negative consequences during or after drinking alcohol. On non-drinking weeks, participants were not asked about consequences and consequences were scored as missing<sup>1</sup>. Specific consequences were chosen from well-established measures of negative outcomes of alcohol use (e.g., Hurlbut & Sher, 1992; Kahler, Strong, & Read, 2005; Saunders, Aasland, Babor, De La Fuente, & Grant, 1993) and included: disappointed others, drove after drinking, trouble with school/police, problems with school work, passed out, felt sad/depressed, got physically sick, said something regretted, memory loss, physically hurt someone, was physically injured, regretted romantic or sexual activity, and got into a physical fight. Because count scores for consequences at the weekly level were zero-inflated, the outcome variable in our analyses was dichotomized to represent whether any consequence was experienced on each drinking week.

## 2.4 Data Analytic Plan

Models were fit using the logistic\_TVEM SAS macro, downloaded from methodology.psu.edu (Yang et al., 2012). The P-spline estimation option was used, which automatically selects the best-fitting model with an appropriate number of knots or splitting

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<sup>1</sup>Participants were assigned scores of 0 for number of consequences for drinking weeks on which they did not experience any consequences. Number of consequences was coded as missing for weeks on which no drinking was reported. We chose not to enter zeros for consequences on non-drinking weeks, as these two scenarios (0 consequences because one didn't drink and 0 consequences on weeks when one did drink) are qualitatively different. Further, entry of 0 for consequences on weeks when participants had 0 drinks might inflate the strength of the associations tested (due to perfect correlations between drinking and consequences on all non-drinking weeks).

points (Tan et al., 2012; Yang et al., 2012). As a preliminary step, we first used intercept-only TVEM models to descriptively examine how rates of any negative alcohol consequence in a given week on which drinking occurred changed over the course of the first two academic years of college, and whether these rates differed by gender. To test our hypotheses, we estimated how alcohol use was associated with the odds of a negative alcohol consequence at each week, and whether this differed by gender. Because alcohol use was assessed at all surveys, we estimated a time-varying effect of this predictor.

As participants were in assessment groups that alternated by week and could submit their survey anytime during the week, the actual date of each individual survey submission was used to create a variable representing time. Specifically, weeks (represented with decimal values) ranged from 0 to 37 in freshmen year and 53 to 89 in sophomore year. However, in order to model a continuous function of time and avoid analytic problems posed by a large gap in time, weeks of sophomore year were recoded to 38 through 74. To increase confidence that our approach of modeling time was justified, we tested for but found a non-significant effect of year in school (freshman vs sophomore) on the outcome of consequences, and subsequently removed this effect from final models.

### 3. Results

Table 1 shows survey response rates, as well as valid percentage of the sample (i.e., percentage of those who completed the survey) reporting any consequence and mean drinks per week reported at each survey, collapsed across males and females. The total number of surveys completed was negatively associated with reports of alcohol use ( $r=-.18$ ,  $p<.01$ ) and consequences ( $r=-.26$ ,  $p<.01$ ) but not gender ( $r=.04$ ,  $p=.27$ ). For TVEM model results, since coefficients are estimated at too many points in time to present in tables, results are presented as figures. Tabled results are available from the first author upon request. A few caveats to results are worth noting. Importantly, as consequences were not assessed on weeks without alcohol use, effects at any given time point represent the proportion of those who drank who also experienced a consequence. Further, since the function is smoothed, we do not interpret individual days/dates over the year, but rather we examine tendencies and global patterns. Finally, effects at the beginning and end points of the time continuum have wider confidence intervals and should be interpreted more tentatively.

#### 3.1 What proportion of male and female students report a consequence each drinking week?

Figure 1 shows results for intercept-only models, our preliminary test of how the proportion of students experiencing a negative consequence changes over weeks, separately for male and female students. Each solid curve indicates the estimated proportion of students experiencing a consequence at each week from the first week of freshmen year through the end of sophomore year. For both male and female participants, the proportion of those who drank who also experienced a negative consequence was about 50% at the beginning of freshmen year. This declined to 30% and 40% by the end of sophomore year, for males and females, respectively. Dotted lines indicate 95% confidence intervals (CIs). Examination of weeks on which the CIs for men and women crossed one another revealed that between

weeks 1 and 51 male and female students were equally likely to have a negative consequence (i.e., confidence intervals overlapped). However, between weeks 52 and 71, a greater proportion of females who drank had a negative consequence than males who drank (as determined by the non-overlapping confidence intervals in Figure 1); at week 66, nearly 36% of females had a negative consequence compared with 29% of males. This difference disappeared by week 72.

### **3.2 Does gender moderate the effect of drinks per week on the odds of a consequence each week?**

We next ran a model that included effects of gender and a time-varying interaction between gender and number of drinks in the prediction of the odds of a negative consequence. Odds ratios (ORs) in Figure 2 can be interpreted in the same way as all odds ratios; an OR of 1 suggests that the odds of a consequence is equal across the presence or absence of the correlate (i.e., there is no significant association between the two). However, in this case, the correlate of interest is the gender x drinks interaction. As such, in Figure 2, where odds ratios (ORs) for the interaction term are presented at different points in time, the dotted lines (representing 95% confidence intervals) that do not cross 1 simply indicate statistical significance of the interaction term. Significant interactions at a given point in time indicate that, at that time, the effect of number of drinks on the odds of experiencing a negative consequence is significantly different for men vs women.

With the exception of the initial weeks of college, there was a significant interaction between gender and number of drinks on the odds of experiencing a negative consequence (Figure 2). The interaction was most pronounced (i.e., odds ratio was highest) around freshman weeks 11–18 (during which time odds ratios ranged from 1.084 to 1.088) and again at the end of sophomore year, weeks 70–74 (odds ratios ranged from 1.085 to 1.094). However, this interaction test alone does not tell us much about the nature of the interaction between number of drinks and gender on the odds of experiencing a negative consequence. As such, we proceeded to examine associations between number of drinks and odds of a negative consequence separately by gender.

### **3.3. What is the strength of the effect of drinks per week on consequences each week, separately by gender?**

Figure 3 shows that number of drinks was a significant predictor of negative consequences for both male and female participants at all weeks. However, this association differed in strength by week and gender: for males, the association between number of drinks and experiencing any negative consequence declined relatively steadily over time. At the beginning of freshmen year, each additional drink was associated with 1.12 greater odds of experience a consequence. By the end of sophomore year, each additional drink was associated with only 1.04 greater odds of a consequence. Among females, the association between number of drinks and odds of a negative consequence was more variable over time. While the strength of this association for women did decrease through freshmen year and into the beginning of sophomore year, it increased toward the end of sophomore year. Specifically, the odds started at 1.18 in week 1, dropped to 1.12 in week 52, and increased back up to 1.16 in week 72. The overlapping confidence intervals for males and females



observed only in the first 3 weeks of college suggest that the strength of the association between alcohol use and consequences was invariant across gender in these initial weeks, but differed between men and women thereafter, becoming consistently stronger for women than for men. That is, with the exception of the initial weeks of college, more drinking increases the risk for consequences to a greater extent for women than for men, across time.

#### 4. Discussion

This was the first study to use time-varying effect modeling (TVEM) to examine dynamic associations between alcohol use and consequences over the first two years of college. With rich, intensively repeated measures data and TVEM, we were able to examine time-varying associations between alcohol use and consequences rather than assuming a static or parametric (linear, quadratic) relationship between these variables. Moreover, TVEM allowed us to examine how gender influences the strength of the association between use and consequences to a different extent at different points in time. We demonstrated that the strength of the association between alcohol use and consequences changes across the first two college years, and does so differentially for males and females.

The proportion of both male and female students who reported at least one negative consequence on a drinking week declined over the first two years of college. These findings are consistent with the substantial body of research highlighting the initial college transition as particularly risk enhancing (Stone et al., 2012; White et al., 2006) and support the continued focus on harm reduction education and intervention targeted prior to or immediately upon entry into college. Moreover, the generally steady decline in alcohol risk over the course of the first two years in college indicates that increased exposure to drinking environments may play an important role in reducing alcohol-related risk. Of note, however, declines in consequences occurred more quickly and more steadily for males than females. It is possible that even though men tend to drink more frequently and excessively than women, college drinking environments may be inherently safer for males relative to females, or men may develop stronger tolerance to alcohol that reduces the likelihood of negative outcomes in the short-term.

In examining how the strength of the relationship between drinking and consequences changed over time, we found that while more drinking increased the odds of a negative consequence in general, drinking and consequences seemed to become “de-coupled” over time. That is, earlier in college, level of alcohol use accounted for more of the variance in the odds of experiencing a consequence. With time, other factors likely contribute to whether or not one will experience negative outcomes of drinking. This decoupling was especially apparent, occurring in a near linear fashion, among men. On the other hand, for women, there were ebbs and flows in the strength of the association between alcohol use and the odds of a negative consequence, such that following an initial decline in the link between drinking and consequences, the association became stronger towards the end of sophomore year (Figure 3). This is combined with the finding that women experience an uptick in rates of any consequence around the same time (Figure 1). It is possible that these results were a function of reporting (e.g., women may be more or less accurate reporters of alcohol use amounts, or more or less likely to admit consequences), or of the specific types of

consequences experienced toward the end of academic year that may differ by gender (e.g., more academic consequences).

Those time periods during which the weakest associations between drinking and consequences were observed represent time periods that should be further examined to understand other variables that account for one's experience of negative outcomes. Here, we can only speculate on what might explain the decrease in the strength of the use-consequences link over time. For example, through increased exposure to drinking situations, students may learn to effectively utilize protective strategies (e.g., avoiding high risk contexts such as drinking game or prepartying; Madson & Zeigler-Hill, 2013) to minimize risks. It is also possible that drinkers develop tolerance to alcohol that minimizes alcohol's effect on cognitions and behaviors, thus enabling students to drink more alcoholic drinks with fewer (or no) consequences. Learning more about how factors other than number of drinks influence the experience of consequences to different extents over time may inform what to target within interventions.

Limitations of this study highlight exciting avenues for continued research. An alternative explanation for our findings is that students (especially males) became more reluctant to report consequences rather than truly being less likely to experience them, despite drinking, over time. It is also important to acknowledge that there may be more error in the estimation of effects at the two extreme ends of our time spectrum, where the model has less information on which to base estimates and where confidence intervals are therefore larger. Based on correlations between number of surveys completed and drinking behavior observed here, our data may not be missing at random. Because TVEM has not yet been studied extensively, the impact of missing data is yet unknown (Shiyko, Burkhalter, Li, & Park, 2014). As we dichotomized consequences at the weekly level, we cannot make conclusions about links between additional drinks and the total number of different consequences experienced. Nonetheless, only a minority of students each week experienced more than one negative consequence. As TVEM models become more advanced in their capabilities (e.g., with non-normal outcomes), additional tests of associations between drinking and level of risk should be conducted. In this study, we measured within-week associations between alcohol use and consequences; however, it is possible that the consequences of one week's drinking extended into later weeks (e.g., problems with school work). This may in part explain why stronger associations between alcohol use and consequences within week were not observed. In this study, we did not measure whether consequences reported may have been a function of co-use of alcohol and other drugs (e.g., marijuana) use, preventing us from teasing apart the unique influence of number of drinks on consequences, but representing yet another exciting future direction. Finally, we only tested links between drinking and consequences in the first two years of college, leaving unknown how these processes play out in upperclassmen. Despite these limitations, the current study advances the broader literature on college student alcohol behaviors and risk by illustrating that the strength of the relationship between drinking and consequences changes substantially over freshman and sophomore years. Future research that builds on the current study, particularly by understanding what factors explain the decreasing association between use and consequences with time, can contribute to college student alcohol education and interventions.



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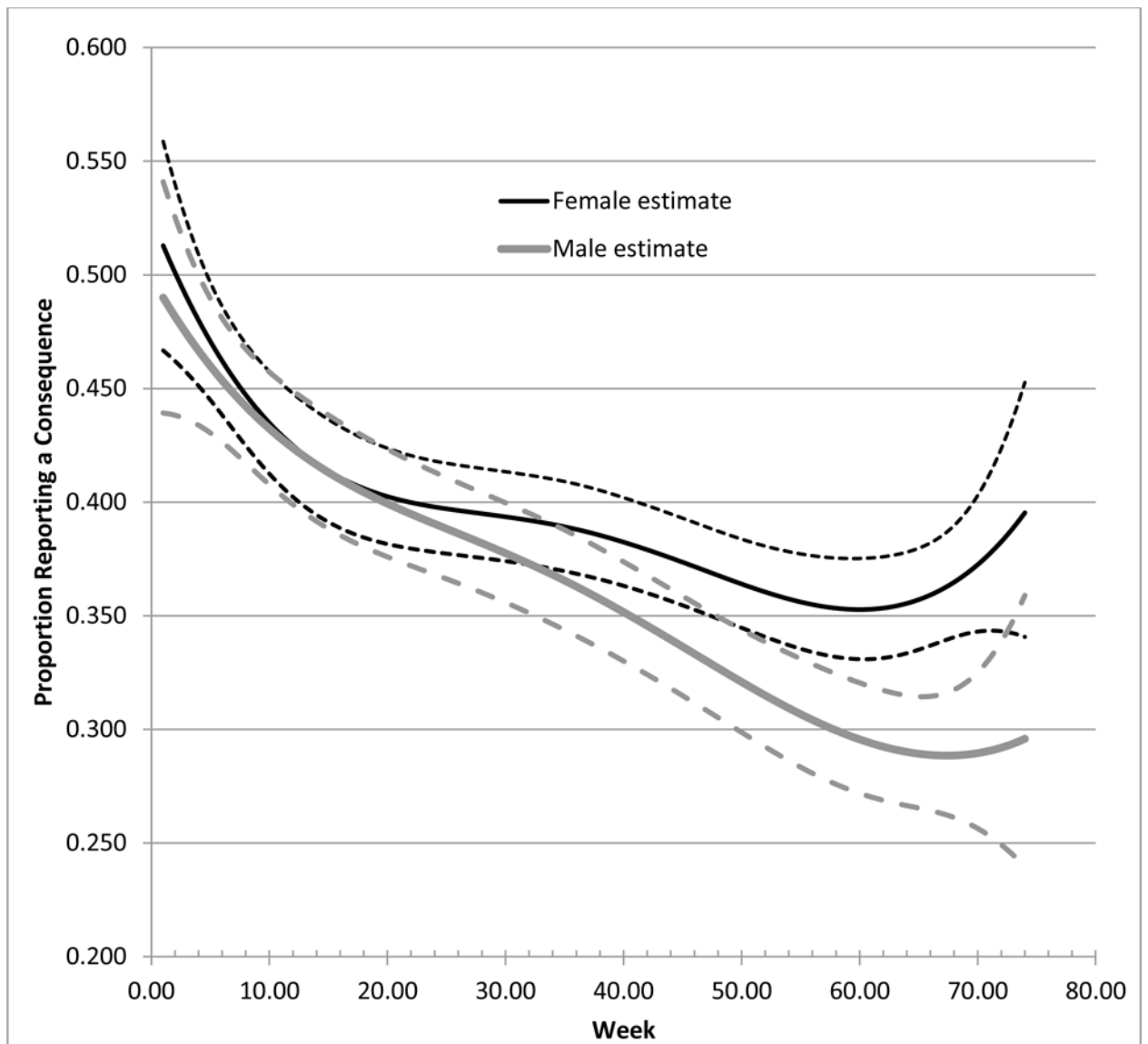
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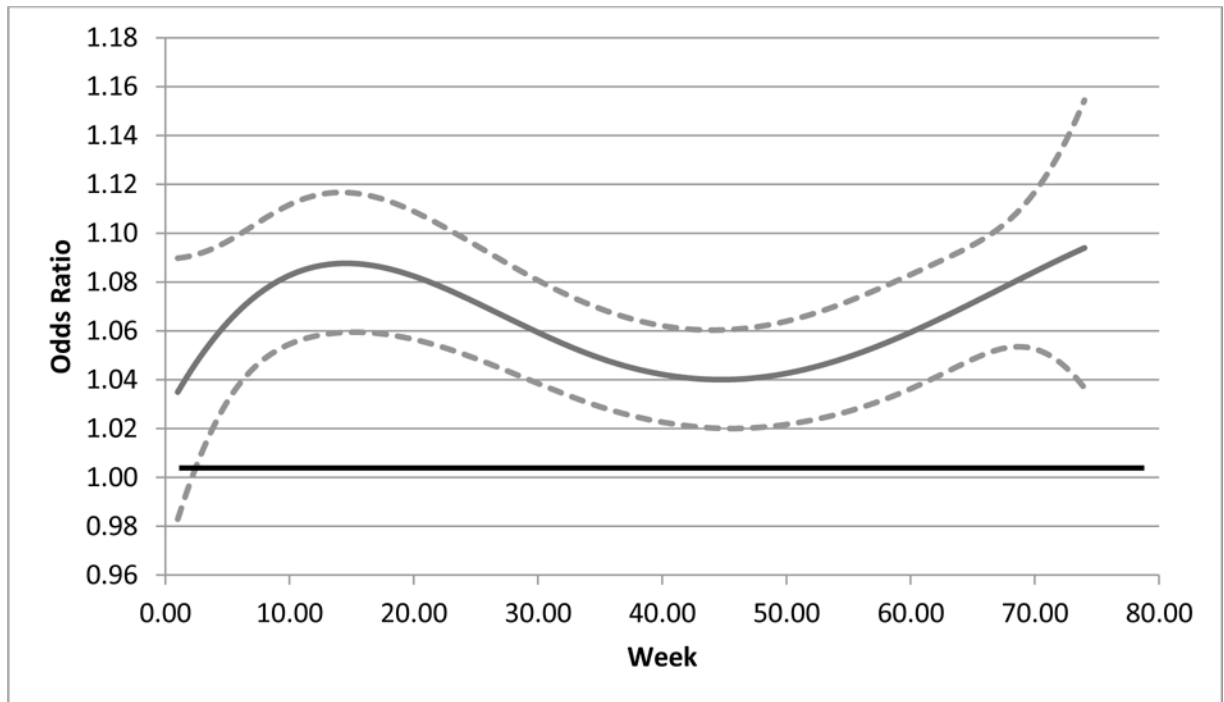
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### Highlights

- College student alcohol use and consequences assessed intensively for two years
- Time varying effect models to test dynamic links between alcohol use and consequences
- Proportion of students for whom alcohol use led to a consequence declined with time
- Link between drinks and odds of a consequence consistently stronger for women than men

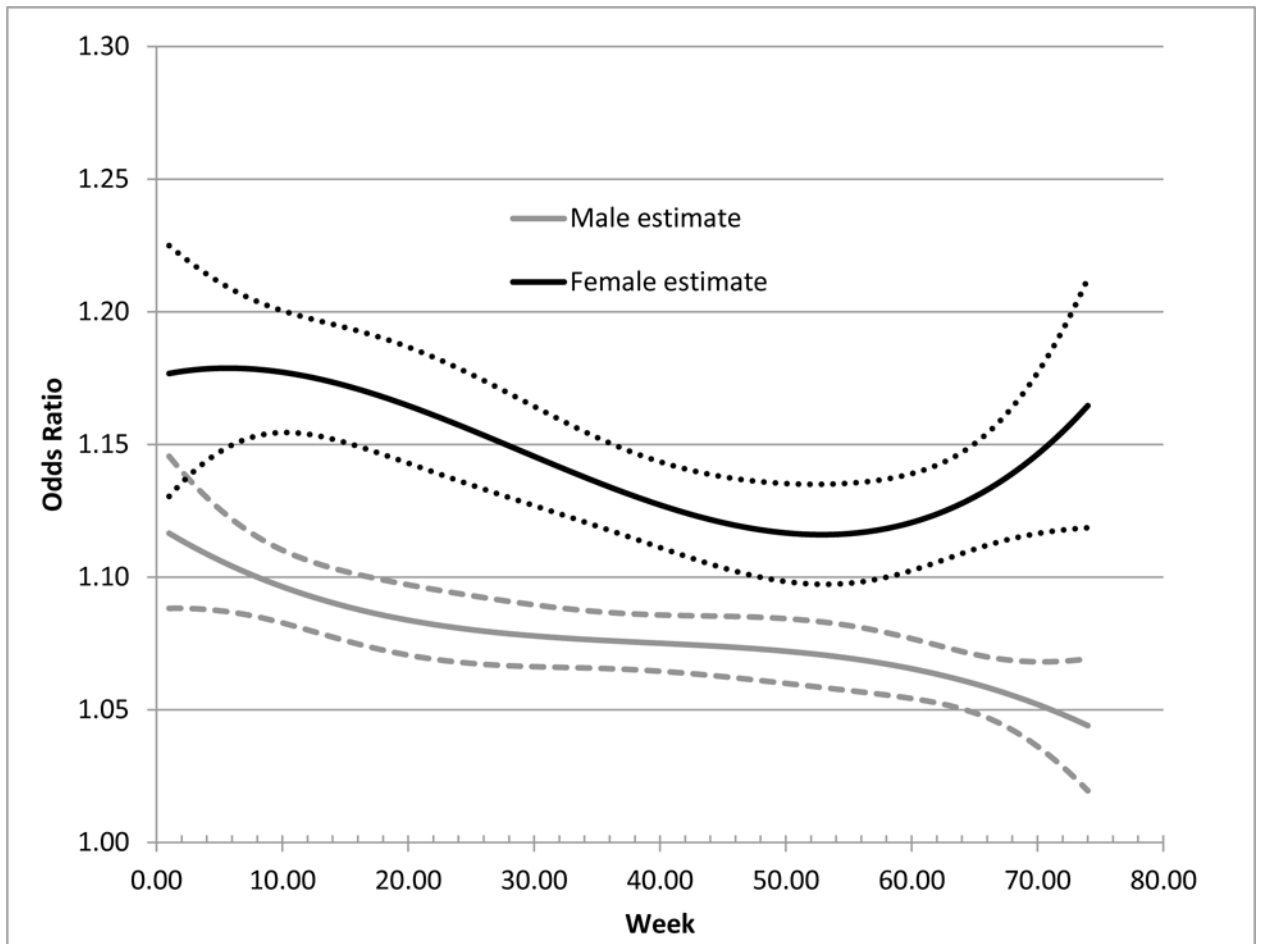


**Figure 1.** Proportion of individuals reporting a negative consequence in the past week from beginning of freshmen through end of sophomore year, estimated by an intercept-only TVEM. Dotted lines indicate 95% confidence intervals. Time is measured and analyzed continuously but is labeled in intervals of 10 weeks for ease of presentation.



**Figure 2.**

TVEM showing time-varying interaction between number of drinks and gender on odds of a negative consequence from beginning of freshmen through end of sophomore year. Dotted lines indicate 95% confidence intervals. Time is measured and analyzed continuously but is labeled in intervals of 10 weeks for ease of presentation.



**Figure 3.** TVEM showing number of drinks predicting odds of a negative consequence from beginning of freshmen through end of sophomore year. Dotted lines indicate 95% confidence intervals. Time is measured and analyzed continuously but is labeled in intervals of 10 weeks for ease of presentation.



Table 1

Response rates, percent endorsing any negative consequence, and raw mean number of drinks per week across 36 bi-weekly assessments.

Fresh Week	% complete	Valid % with drinking	<i>M</i> ( <i>SD</i> ) number drinks	Valid % with any con	Soph Week	% complete	Valid % with drinking	<i>M</i> ( <i>SD</i> ) number drinks	Valid % with any con
1	86	65.3	6.53 (8.97)	48.6	1	83	65.3	7.44 (10.13)	36.2
2	89	64.6	6.02 (7.93)	50.5	2	83	64.2	6.13 (8.48)	34.3
3	89	59.7	5.66 (8.04)	45.9	3	82	57.8	5.55 (8.44)	38.4
4	91	58.1	5.40 (7.88)	47.6	4	83	59.9	5.62 (7.82)	37.8
5	91	59.9	5.43 (7.56)	43.6	5	83	57.8	5.23 (7.47)	36.8
6	90	55.2	5.25 (8.17)	40.5	6	83	54.1	4.84 (8.12)	31.6
7	90	57.2	5.01 (7.53)	44.1	7	82	55.2	5.07 (8.00)	37.8
8	84	45.9	3.83 (6.38)	34.2	8	79	46.4	3.84 (6.73)	28.0
9	82	47.4	3.87 (7.12)	36.1	9	77	50.9	4.83 (8.50)	32.5
10	83	38.5	3.16 (6.15)	31.7	10	81	39.6	3.57 (7.34)	25.7
11	88	57.1	5.87 (8.45)	45.0	11	81	59.1	6.19 (9.49)	38.1
12	88	56.7	5.45 (7.81)	44.0	12	82	53.0	5.18 (8.80)	34.2
13	87	54.5	5.20 (7.91)	40.3	13	82	53.9	4.86 (7.25)	34.5
14	86	54.8	5.38 (8.15)	40.5	14	80	58.0	5.75 (8.91)	32.9
15	87	50.1	5.51 (9.43)	35.0	15	80	48.8	5.86 (10.85)	29.5
16	87	56.3	5.03 (7.23)	36.8	16	79	58.3	5.68 (9.13)	33.6
17	85	58.9	6.90 (10.65)	42.2	17	78	55.4	5.89 (9.47)	35.7
18	86	52.7	5.41 (8.43)	40.4	18	80	52.0	4.87 (7.44)	35.2

Note: Fresh = freshman; Soph = sophomore; Con = consequence; percent with any consequences are only calculated among the subset of weeks characterized by any drinking.

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