Undergraduate Drinking and Academic Performance: A Prospective Investigation With Objective Measures*

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ABSTRACT. Objective: Findings from previous prospective research suggest the association between alcohol use and undergraduate academic performance is negligible. This study was designed to address weaknesses of the past research by relying on objective measures of both drinking and academic performance. **Method:** A prospective study was conducted with repeated measures of exposure to alcohol linked to institutional academic records. Alcohol data were collected in residence halls at a nonselective, midwestern, public university in the United States. A total of 659 first- and second-year undergraduate students were tracked over the course of 15-week semesters. **Results:** A statistically significant negative association with semester academic performance was found for different alcohol indicators: frequency of breath alcohol concentration (BrAC) above .08, mean BrAC, standard deviation, and maximum BrAC recorded. These associations remained statistically significant when con-

trolled for sociodemographic variables and individual level confounders, but the effect sizes were relatively small with a contribution to explained variance of less than 1%. When additionally adjusted for residence hall building, all alcohol indicators no longer reached statistical significance ($p \geq .05$). **Conclusions:** Consistent with past prospective research, the magnitude of the association between undergraduate alcohol use and academic performance is small when the effects of high school academic aptitude and performance are accounted for in multivariable analyses. This is the first study to find that living environment may have a robust effect on the academic achievement of undergraduates. Future research should examine more closely the relation between residence and academic performance and the role that alcohol use may play in creating residential environments. (*J. Stud. Alcohol Drugs* 70: 776-785, 2009)

PUBLIC DEMANDS FOR ACCOUNTABILITY in higher education have pressured colleges and universities to assume more responsibility for creating social environments that support a strong academic ethic and are conducive to learning (National Center on Addiction and Substance Abuse at Columbia, 2007; Rau and Durand, 2000). Thus, during the 1990s, higher education began to move away from the traditional position that they simply “offer courses” to one where they have a responsibility to engage students in the academic enterprise and to help them learn (Kuh, 2003; Hersh and Merrow, 2005; Terenzini, 1999). In this ongoing transformation of higher education, a major source of confusion has been the relationship between undergraduate alcohol use and academic performance.

In the United States, major research studies (Wechsler et al., 1998, 2000, 2002) and national reports (National Center on Addiction and Substance Abuse at Columbia, 1994, 2007) periodically note that alcohol abuse impedes undergraduate academic achievement at the nation's colleges and universities. For instance, more than a decade ago, a study involving 66 4-year American colleges and universities reported that “A” students consumed an average of 3.2 drinks per week, which was less than that consumed by “B” (4.6), “C” (5.8), and “D/F” (8.4) students (Presley et al., 1996). In the Harvard College Alcohol Study of American undergraduate alcohol use, Wechsler et al. (2000) reported that frequent heavy episodic drinkers are much more likely to miss class and get behind in schoolwork than occasional heavy episodic drinkers and non-heavy-episodic drinkers. Such findings have contributed to the widespread belief in American higher education that a strong, negative correlation exists between undergraduate alcohol use and academic performance. However, all of these studies have flaws that preclude this conclusion.

Wood et al. (1997) were the first to note the weaknesses of this research. Four shortcomings that were noted included the following: (1) reliance on cross-sectional designs, (2) lack of assessment of other etiologic variables (e.g., high school academic achievement and academic aptitude) tested in multivariable analyses, (3) use of student self-reports to measure grade-point average (GPA), and (4) use of question-

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naire measures that assessed the subjective attributions of students to determine the role of alcohol use in causing their academic difficulties. To address these design and measurement issues, Wood et al. (1997) conducted a prospective study tracking a panel of 489 undergraduates attending the University of Missouri. They found that alcohol use during the freshman year was moderately correlated with academic problems over a 6-year period ($r = .32$). However, when additional constructs were added to a structural equation model, alcohol use did not uniquely predict academic problems. The pre-existing individual differences usually associated with academic difficulties (i.e., high school class rank and academic aptitude) were the strongest predictors of subsequent academic problems. Gender also had a significant, direct relationship with academic problems. In a 6-year follow-up study of the same panel of students, Wood et al. (2000) found that alcohol involvement had a modest, negative association with educational attainment after controlling for background variables. Thus, in contrast to the cross-sectional findings reported in the general body of literature on the subject, Wood and colleagues concluded that the magnitude of the relation between alcohol involvement and academic attainment might be quite small.

Subsequent investigations have yielded mixed findings about the association between alcohol use and academic performance in the collegiate setting. Pascall and Freisthler (2003) followed a panel of 465 students at the University of California, Berkeley (highly competitive admissions criteria), for 3 years and found that heavy alcohol use, alcohol-related problems, and drinking opportunities did not have a significant effect on academic performance. In an extensive review of studies on alcohol consumption and related harms in the undergraduate student population in the United Kingdom, Gill (2002) concluded that association between drinking and academic performance was "tenuous" and needed more study. A study conducted at the Katholieke Universiteit Leuven in Belgium found that, among first-year undergraduates meeting Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV; American Psychiatric Association, 1994), criteria for alcohol dependence (just 3.6% of the sample), there existed a 25% increased risk of failing first-year exams (Aertgeerts and Buntinx, 2002). However, in those students who met DSM-IV criteria for alcohol abuse (10.5% of the same sample), there was no increased risk for failing the same exam. The investigators acknowledged that a limitation of their study was the lack of assessment of academic aptitude and high school academic achievement. Also, they did not assess associations in multivariable models to account for other individual differences. In contrast to the studies reporting negative findings, Singleton (2007) found that alcohol consumption had a statistically significant, although relatively modest-size, association with alcohol consumption in multivariable analysis. However, questions can be raised about the generalizability of the findings from

this study because it was conducted at a small, liberal arts campus in the northeastern United States with rather unique academic features and an elite student body. Although Wood et al. (1997, 2000) made a substantial contribution to the research on undergraduate drinking and academic performance, the methods and measures used in their studies and those conducted since that time also can be questioned. Therefore, it is premature to conclude either that there is no relationship between alcohol use and academic performance or that it is only a very modest one.

Several measurement and design issues have not been adequately addressed in the previous prospective studies (i.e., Aertgeerts and Buntinx, 2002; Pascall and Freisthler, 2003; Singleton, 2007; Wood et al., 1997, 2000). First, there is a need to track first- and second-year undergraduates at closer time intervals using multiple measures of consumption within the context of a semester, because significant and abrupt changes occur frequently in the individual drinking trajectories of teenagers and young adults (Bennett et al., 1999; Jackson et al., 2001; Rutledge and Sher, 2001; Schulenberg et al., 1996). Second, virtually nothing is known about the relation between objectively measured drinking, especially episodic intoxication and academic performance. All previous research has relied solely on self-report measures to establish patterns of drinking. Field studies investigating college student drinking have indicated that the self-reported quantity of alcohol consumption is correlated only moderately with breath alcohol concentration (BrAC; Thombs et al., 2003, 2008). Thus, there is a need to characterize patterns using biological measures. Third, to adequately characterize undergraduate academic performance, there is a need to adjust institutional GPA to create a measure of academic performance that is weighted for course difficulty. In the field of educational assessment and evaluation, it is recognized that unadjusted institutional GPA is an imprecise indicator of a student's work during a semester because there is large variation in the rigor of grading practices across academic departments and among individual faculty within departments (Lei et al., 2001; Ramist et al., 1990; Young, 1993). Finally, there is a need to study the relationship between undergraduate drinking and academic performance at nonselective (or more typical) institutions in which predictive models may work better simply because there is more variance to explain in student achievement (Pascall and Freisthler, 2003; Singleton, 2007).

The current investigation was designed to address the measurement and design weaknesses of past studies. The specific aims were twofold: (1) to conduct a prospective study at a nonselective university—relying primarily on objective measures (multiple BrAC readings and an adjusted measure of academic performance)—and (2) to examine student alcohol use and academic performance within the context of a semester. The primary research hypothesis was the following: Higher levels of nighttime intoxication would

predict lower academic performance in first- and second-year undergraduates.

Method

Setting

Prospective studies of the association between drinking and academic performance have relied on data collected at single universities (Aertgeerts and Buntinx, 2002; Paschall and Freisthler, 2003; Singleton, 2007; Wood et al., 1997). The site of this study was Kent State University, a relatively large, nonselective, public university in Ohio. Data collection began in September 2004 and ended in December 2006 (while classes were in session during the fall and spring semesters). The university enrolls about 22,300 students on its main campus, with 6,400 (28.7%) students residing on campus in five different residence complexes consisting of two to five distinct residence hall buildings. Freshmen could not select their residence hall assignment. In the fall of 2007, the entering freshman class at this university had a mean ACT (academic aptitude) score of 21.7.

Procedure

A field-based, prospective study was conducted to test the hypothesis. On-campus residence halls were selected as data collection sites because they house primarily first- and second-year students (75% of the occupants at the host university). Research indicates that academic problems are most concentrated in the first 2 years of college (Bradburn and Carroll, 2002). Data collection took place in different residence hall buildings each semester. Thus, a single panel of students was not tracked over a five-semester period. Rather, the sample consisted of five distinct panels of students, recruited from five different residence complexes who were tracked over different 15-week semesters (i.e., students participated in the study for only one semester). During two semesters of the study, data were collected in two different residence hall buildings. Thus, the five panels of students resided in seven different residence hall buildings. The number of residents in the seven buildings ranged from 82 to 501, with study participant by number of building residents rates ranging from 26.7% to 37.4%. The proportion of first- and second-year students varied across buildings, but none of them was limited to freshmen or sophomores. The proportion of women study participants in each building ranged from 44.3% to 67.9%.

Interview data and BrAC readings were collected from students in residence hall lounges at night. Trained research teams were positioned near the primary entrance to the building to intercept as many residents as possible on Wednesday through Saturday nights from 10:00 PM to 3:00 AM. Project personnel used a secure Web site that provided students an

opportunity to learn more about the study, including how to enroll, the conditions of participation, and financial remuneration. Participants voluntarily enrolled in the study the day following the first nighttime interview using a unique identifier generated the previous night. Enrollment in the study was closed after the first 2 weeks of the semester. Participants needed to access the enrollment Web site only one time to provide informed consent and did not have to return to the Web site for the remainder of the study. Enrollment at the Web site required participants to provide their name and social security number (for data linkage purposes), respond to a questionnaire assessing their involvement with alcohol, and permit access to their institutional academic records at the end of the semester. The identities of the participants were never known by the nighttime project personnel. The research protocol was approved by the institutional review board at the host institution.

Students who enrolled at the study Web site were screened to verify four items: that they were (1) a student at the host institution, (2) 18 years of age or older, (3) living in the targeted residence hall building, and (4) either freshmen or sophomores. They did not have to be alcohol users. Eligible students received \$10.00 for agreeing to participate in the study. Thereafter, they received an additional \$1.00 for each night that they provided nighttime data during the semester. To bolster participation, students received a \$4.00 bonus for those weeks they provided data on all 4 nights. Compensation was issued to students through checks provided to them at intervals throughout their semester of participation.

Measures

Three sets of data were collected on the participants. During Web site enrollment at the beginning of the study, alcohol involvement was assessed via an electronic, self-report questionnaire. Throughout the semester in residence hall lounges at night, brief interview data and BrAC readings were collected from participants returning home and from participants who did not leave the building but who wanted to provide data. Although it was a violation of residence hall policy, many residents, including study participants, consumed alcohol in their rooms. After completion of each semester, project personnel retrieved participants' academic information from the university's database.

Alcohol use

Age at drinking onset was assessed by asking participants how old they were when they "first started drinking alcohol, not counting small tastes or sips" (Grant and Dawson, 1997). Frequency of alcohol use during the senior year of high school was assessed with a 10-point scale ranging from "never" (scored as 0) to "more than once a week" (scored as 9). Quantity of alcohol consumption (on a typical drinking

occasion) during the senior year of high school was assessed by a two-digit Web prompt. Frequency of drunkenness during the senior year of high school was also assessed by a 10-point scale, ranging from “never” (scored as 0) to “more than once a week” (scored as 9). A version of the 10-item Alcohol Use Disorders Identification Test was also administered at the project Web site to identify existing harmful patterns of drinking in the sample (Babor et al., 1992).

Nighttime measures

Nighttime data collected during the 2- to 3-minute interviews were entered directly into the study database via a secure Internet connection. Before being breath tested, participants were asked to provide the number of drinks they consumed that day, the number of minutes since their last drink, and their intention to drink more that night. A hand-held breath-testing device approved by the U.S. Department of Transportation was used to obtain BrAC readings. (These devices were regularly calibrated based on manufacturer instructions.) Per manufacturer guidelines, participants who indicated they had consumed alcohol in the previous 15 minutes were asked to wait to clear their mouth of residual alcohol. If participants indicated they intended to drink more that night, they were asked to return to the research station after finishing their drinking for the night. Participants were not given their BrAC reading at night because of concerns that some participants might return to drinking if they perceived their level of intoxication to be low enough to continue drinking (Russ et al., 1988; Thombs et al., 2007) or to make a game of breath testing. They were provided an opportunity at the conclusion of the semester to obtain a list of their BrAC readings.

To maintain eligibility after enrollment, participants had to provide a minimum of five nighttime BrAC readings during the semester. For each participant, six measures were derived to characterize alcohol use: (1) frequency (proportion of measures) with BrAC > .0; (2) frequency (proportion of measures) with BrAC > .05; (3) frequency (proportion of measures) with BrAC > .08; (4) mean BrAC recorded in late night measures in percentage; (5) standard deviation across observed BrACs recorded in late night measures; and (6) maximum recorded BrAC in late night measures in percentage. These measures were calculated after imputing missing BrAC values for individuals. Imputation procedures were applied to correct for differences between individuals in the number of BrAC measures and to standardize between individuals in terms of the proportions of BrAC measures taken on different days of the week over the semester, and thus to remove bias resulting from differential patterns of missing data. A two-step, hot deck imputation method was used (Kim and Fuller, 2004). The first step used an individual's own data for a given weekday as the donor data if at least four BrAC readings had been collected for that weekday. The

second step, used when less than four BrAC readings had been collected on a given weekday, used donor data from individuals of the same gender and term of participation. A total of 47.1% of the BrAC data was imputed using these procedures.

Institutional academic measures

A weakness of past research on the association between drinking and academic performance is the failure to recognize that the conventional or unadjusted GPA is not a precise measure of undergraduate academic performance. In this study, the grade residual method was used to adjust the course grades of the participating students (Ramist et al., 1990; Young, 1993). A regression equation was used to predict the mean course GPA from the ACT (or SAT) and high school class rank scores of the students in each course taken by the participants. The difference between the predicted mean GPA and the actual mean GPA for the course (i.e., the “grade residual”) was computed and applied to the participants' assigned grade in each of their courses. Large, positive residuals represented less challenging (or easier) courses, whereas large, negative residuals represented highly challenging courses. For example, if a student's assigned course grade was 3.0 (or “B”) and the grade residual for the course was -1.0, then the adjusted course grade was 2.0 (or “C”).

One reason the conventional or unadjusted semester GPA is an imprecise measure of academic performance is that it does not account for number of completed credit hours in a term. For instance, a 3.00 semester GPA can be earned by completing 12 or 18 credit hours. Therefore, to create a realistic index of *semester* academic performance, the adjusted grades were summed to account for variation in course load. This summative measure characterized both the quality of the academic work and the number of credit hours completed during the semester. For example, if students' adjusted grades were 3.0 (or “B”) in five 3-hour courses, then their adjusted academic performance for the semester was 45.0. Academic aptitude score (ACT or SAT score), high school class percentile rank, gender, and age also were retrieved from the participant's institutional record.

Analyses

Multiple linear regression models were used to describe the association between the six alcohol indicators and difficulty-adjusted academic performance at the end of the semester, while simultaneously adjusting for demographic characteristics and high school academic aptitude and performance. The following potential confounders were considered and retained in the regression model if the coefficient of the alcohol indicator variable changed by at least 10% with removal of the potential confounder: gender, age, race, aca-

TABLE 1. Self-reported high school senior year and beginning of the study semester drinking practices; first- and second-year college students in a prospective study of nighttime breath alcohol concentration on difficulty-adjusted academic performance ($n = 659$)

Variable	
High school senior year drinking practices	
Age started drinking, frequency (%)	
Never started	72 (10.9)
<12 years	6 (0.91)
12-13 years	33 (5.01)
14-17 years	431 (65.4)
≥18 years	117 (17.8)
Frequency of drinking, frequency (%)	
Never	129 (19.6)
1-10 times	211 (32.0)
More than monthly but less than weekly	175 (26.6)
Once per week	90 (13.7)
More than once per week	54 (8.19)
Drinks per occasion, mean (SD)	5.21 (7.91)
(Range: 0-96; median 4)	
None, frequency (%)	132 (20.0)
1-4, frequency (%)	205 (31.1)
≥5, frequency (%)	322 (48.9)
Frequency of being drunk, frequency (%)	
Never	192 (29.1)
1-10 times	227 (34.5)
More than monthly but less than weekly	138 (20.9)
Once per week	72 (10.9)
More than once per week	30 (4.55)
Beginning of semester drinking practices	
Frequency of drinking/frequency consuming	
≥6 drinks, frequency (%)	
Never	79/191 (12.0/29.0)
Monthly or less	159/190 (24.1/28.8)
2-4 times per month	192/151 (29.1/22.9)
2-3 times per week	219/124 (33.2/18.8)
≥4 times per week	10/3 (1.5/0.5)
Drinks per occasion, mean (SD)	
(Range: 0-74; median: 5)	5.34 (6.16)
AUDIT score, ^a mean (SD)	7.33 (5.39)
AUDIT problem drinker, ^a frequency (%)	
Yes	291 (44.2)
No	368 (55.8)

^aBecause of an error in the offered response options, the Alcohol Use Disorders Identification Test (AUDIT) score obtained is overly conservative.

demic aptitude, high school rank percentile, semester status (fall vs spring), and class rank (freshman vs sophomore). Gender $\times$ Alcohol, Gender $\times$ High School Rank Percentile, and Gender $\times$ Academic Aptitude interaction terms were examined and maintained in the model if statistically significant at the $\beta = .05$ level.

Results

In the sample of 659 first- and second-year students, 59.9% were women, 89.2% were white, and the mean (SD) age was 19.0 (0.6) years. These characteristics were quite similar to those of the residence hall population at the host university. The high school drinking practices of the sample are summarized in Table 1. By age 17, a majority of the participants had initiated alcohol use. Relatively few initiated alcohol use after the age of 17 (17.8%), and 10.9% of the participants reported no history of consuming alcohol. Almost one fifth of the students in the sample reported that they had not consumed alcohol during their senior year in high school, 58.6% had used alcohol but not on a weekly basis, and 21.9% drank on a weekly basis. With respect to number of consumed drinks, five to eight drinks was the amount most commonly consumed on typical drinking occasions. About 12% reported that they consumed nine or more drinks on typical drinking occasions during their senior year in high school, and about 2% indicated that they had consumed more than 20 drinks a month during the same period. Current (start of semester) drinking practices are also described in Table 1. A majority of the participants reported drinking at least two times per month, and about one third indicated they drank at least twice a week. The monthly rate of heavy episodic drinking (six or more drinks on an occasion) was 42.2%, quite similar to rates reported in nationwide surveys of American college students (Wechsler et al., 2000, 2002). On typical occasions, a majority of the men and almost one half of the women reported consuming five or more drinks.

Table 2 provides additional information about the distribution of the BrAC readings per individual study participant. The average mean BrAC for the study was .016 (i.e., the sum of individual mean BrACs divided by the number of students in the study). The average maximum BrAC was .077. The proportions of BrACs greater than .05 and .08 for the average student were 14.3% and 8.1%, respectively. The lowest levels of intoxication were measured on Wednesday nights (mean BrAC = .003) and increased each evening to a high of .026 on Saturday nights.

In the sample of 659 first- and second-year students, the mean ACT score was 21.6 (3.39), nearly identical to

TABLE 2. Measures of breath alcohol concentration (BrAC) per individual study participant; first- and second-year college students in a prospective study of nighttime BrAC on difficulty-adjusted academic performance ($n = 659$)

Variable	Mean (SD)	95% CI	Median	Min.	Max.
Mean BrAC	.016 (.019)	.014-.017	.009	0	.097
Max. BrAC	.077 (.058)	.073-.082	.078	0	.030
Proportion of BrAC > .05	.143 (.178)	.130-.157	.073	0	.813
Proportion of BrAC > .08	.081 (.134)	.071-.091	.000	0	.688

Notes: Average mean BrAC is the sum of each student's mean BrAC for the semester divided by the number of students in the sample. Average maximum BrAC is the sum of each student's single highest BrAC measurement for the semester divided by the number of students in the sample. Proportion of BrACs > .05 is each student's calculated proportion of BrACs greater than .05 (and subsequently .08). CI = confidence interval; min. = minimum; max. = maximum.

the ACT mean for the host institution and the U.S. college student population (ACT, 2009). The mean high school percentile rank was 61.3. Application of the grade adjustment procedure (accounting for course difficulty and based on a

15 credit-hour load) resulted in 5.2% of the students having an average grade in the "A" range, 24.3% in the "B" range, 35.8% in the "C" range, 26.3% in the "D" range, and 8.5% in the "F" range.

TABLE 3. Results of multiple regression models predicting adjusted academic performance; first- and second-year college students in a prospective study of nighttime breath alcohol concentration (BrAC) on difficulty-adjusted academic performance ($n = 659$)

Model	Model not adjusting for residence hall			Model adjusting for residence hall		
	Regression coefficient	Standard error	Partial F test p value (df)	Regression coefficient	Standard error	Partial F test p value (df)
Model 1	Model adjusted $R^2 = .223$ (Alcohol contribution to $R^2 = .46\%$)			Model adjusted $R^2 = .264$ (Alcohol contribution to $R^2 = .20\%$)		
Frequency (proportion of measures) with BrAC > .0	-0.347	0.185	$p = .061$	-0.234	0.187	$p = .211$
Academic aptitude ^a	0.072	0.015	$p < .001$ (1)	0.069	0.015	$p < .001$ (1)
Gender (male vs female)	1.239	0.468	$p = .008$ (1)	1.007	0.464	$p = .030$ (1)
Gender and academic aptitude interaction	-0.061	0.021	$p = .004$ (1)	-0.053	0.021	$p = .012$ (1)
High school percentile rank	0.017	0.002	$p < .001$ (1)	0.016	0.002	$p < .001$ (1)
Categorical indicator for residence hall (seven buildings)	—	—	—	—	—	$p < .001$ (6)
Model 2	Model adjusted $R^2 = .224$ (Alcohol contribution to $R^2 = .49\%$)			Model adjusted $R^2 = .265$ (Alcohol contribution to $R^2 = .25\%$)		
Frequency (proportion of measures) with BrAC > .05	-0.437	0.226	$p = .053$ (1)	-0.317	0.227	$p = .162$ (1)
Academic aptitude ^a	0.072	0.015	$p < .001$ (1)	0.069	0.015	$p < .001$ (1)
Gender, male vs female	1.240	0.468	$p = .008$ (1)	1.010	0.464	$p = .030$ (1)
Gender and academic aptitude interaction	-0.061	0.021	$p = .004$ (1)	-0.053	0.021	$p = .012$ (1)
High school percentile rank	0.017	0.002	$p < .001$ (1)	0.016	0.002	$p < .001$ (1)
Categorical indicator for residence hall (seven buildings)	—	—	—	—	—	$p < .001$ (6)
Model 3	Model adjusted $R^2 = .225$ (Alcohol contribution to $R^2 = .58\%$)			Model adjusted $R^2 = .265$ (Alcohol contribution to $R^2 = .26\%$)		
Frequency (proportion of measures) with BrAC > .08	-0.618	0.293	$p = .036$ (1)	-0.425	0.296	$p = .151$ (1)
Academic aptitude ^a	0.072	0.015	$p < .001$ (1)	0.069	0.015	$p < .001$ (1)
Gender, male vs female	1.227	0.468	$p = .009$ (1)	1.003	0.464	$p = .031$ (1)
Gender and academic aptitude interaction	-0.061	0.021	$p = .005$ (1)	-0.053	0.021	$p = .012$ (1)
High school percentile rank	0.017	0.002	$p < .001$ (1)	0.016	0.002	$p < .001$ (1)
Categorical indicator for residence hall (seven buildings)	—	—	—	—	—	$p < .001$ (6)
Model 4	Model adjusted $R^2 = .226$ (Alcohol contribution to $R^2 = .69\%$)			Model adjusted $R^2 = .252$ (Alcohol contribution to $R^2 = .34\%$)		
Mean BrAC recorded in late night measures in percent	-0.047	0.020	$p = .022$ (1)	-0.034	0.021	$p = .102$ (1)
Academic aptitude ^a	0.072	0.015	$p < .001$ (1)	0.069	0.015	$p < .001$ (1)
Gender, male vs female	1.226	0.468	$p = .009$ (1)	1.002	0.463	$p = .031$ (1)
Gender and academic aptitude interaction	-0.060	0.021	$p = .005$ (1)	-0.053	0.021	$p = .013$ (1)
High school percentile rank	0.017	0.002	$p < .001$ (1)	0.016	0.002	$p < .001$ (1)
Categorical indicator for residence hall (seven buildings)	—	—	—	—	—	$p < .001$ (6)
Model 5	Model adjusted $R^2 = .226$ (Alcohol contribution to $R^2 = .70\%$)			Model adjusted $R^2 = .252$ (Alcohol contribution to $R^2 = .34\%$)		
Standard deviation across observed BrACs recorded in late night measures	-4.683	2.024	$p = .021$ (1)	-3.409	2.066	$p = .099$ (1)
Academic aptitude ^a	0.072	0.015	$p < .001$ (1)	0.069	0.015	$p < .001$ (1)
Gender, male vs female	1.216	0.468	$p = .010$ (1)	0.995	0.463	$p = .032$ (1)
Gender and academic aptitude interaction	-0.061	0.021	$p = .005$ (1)	-0.053	0.021	$p = .012$ (1)
High school percentile rank	0.017	0.002	$p < .001$ (1)	0.016	0.002	$p < .001$ (1)
Categorical indicator for residence hall (seven buildings)	—	—	—	—	—	$p < .001$ (6)
Model 6	Model adjusted $R^2 = .228$ (Alcohol contribution to $R^2 = .90\%$)			Model adjusted $R^2 = .253$ (Alcohol contribution to $R^2 = .48\%$)		
Maximum recorded BrAC in late night measures in percent	-0.015	0.006	$p < .009$ (1)	-0.012	0.006	$p = .052$ (1)
Academic aptitude ^a	0.073	0.015	$p < .001$ (1)	0.070	0.015	$p < .001$ (1)
Gender, male vs female	1.212	0.467	$p = .010$ (1)	0.993	0.463	$p = .032$ (1)
Gender and academic aptitude interaction	-0.061	0.021	$p = .004$ (1)	-0.053	0.021	$p = .012$ (1)
High school percentile rank	0.017	0.002	$p < .001$ (1)	0.016	0.002	$p < .001$ (1)
Categorical indicator for residence hall (seven buildings)	—	—	—	—	—	$p < .001$ (6)

Notes: In all models, student's age and race (white vs "other") were removed from the multivariable analyses. Neither age nor race made an additional contribution to the fit of any of the models, nor did adjustment for age or race affect the observed relationship between the nighttime intoxication measures and difficulty-adjusted academic performance. ^aACT score (or ACT equivalent) obtained during high school senior year.

Table 3 presents multiple linear regression models for each of six indicators of nighttime alcohol use, predicting adjusted academic performance, and controlling for high school senior academic aptitude. Wherein the alcohol indicator was characterized as the frequency of any nonzero BrAC value or as the frequency of a BrAC reading of .05 (Models 1 and 2, left side), the variable failed to reach statistical significance in the respective adjusted models. A statistically significant, negative association with semester academic performance was found for each of the remaining four alcohol-use indicators: (1) frequency of a BrAC above .08, (2) mean recorded BrAC over the study, (3) standard deviation of BrACs, and (4) maximum recorded BrAC value (Table 3). Interpreting the magnitude of effect for mean BrAC values, every additional .01 increase in BrAC averaged across all recordings (e.g., an increase of .05 to .06) was associated with a decrease of 4% of the equivalent of one letter grade in adjusted academic performance in a semester of 15 credit hours (the standard course load for full-time undergraduates in the United States). The difference between averaging a BrAC of .00 (no drinking) and a BrAC of .05 was associated with a decline in adjusted GPA of a magnitude roughly equal to one fifth of a letter grade. Among the six alcohol indicators examined, the maximum BrAC recorded at night and semester academic performance made the greatest contribution to variance explained in the covariate-adjusted regression models, although the magnitude of variance explained by this single variable, at just one less than 1%, remains very small.

The right-hand side of Table 3 presents comparable models for each alcohol indicator but also adjusted for which of the seven residence hall buildings the participant lived in (as a fixed effect). In all of these models, adjustment for residence reduced the association between alcohol use and adjusted academic performance such that the alcohol indicators failed to reach statistical significance.

As a basis for comparison with past research, the models in Table 3 were estimated again, replacing the adjusted semester GPA score with traditional semester GPA (i.e., based on actual, unadjusted course grades). In each model (data not shown), the strength of association between the respective alcohol-use variables and traditional GPA was weaker than observed with our own derived academic performance score and statistical significance attenuated. In none of the models was a statistically significant association found between alcohol use and traditional GPA. The highest model R^2 continued to be found for maximum recorded BrAC. Model 6 was not adjusted for residence hall; but, again, the alcohol intake measure remained not significant ($p = .086$).

Discussion

From a measurement perspective, the present study of drinking and academic performance is distinctive for four

reasons. First, it is the first prospective study to analyze the short-term relations between the variables within the context of a semester. Second, the investigation used an objective measure of consumption to characterize nighttime alcohol use. Third, student grades were adjusted for course difficulty to enhance the precision of measuring of academic performance. Fourth, it is the first investigation of drinking and academic performance to account for the influence of the student's residence hall.

We hypothesized that higher levels of nighttime intoxication would predict lower academic performance in first- and second-year undergraduates. The data provided some support for this hypothesis, but similar to past research, the magnitude of these associations, regardless of alcohol indicator, was found to be small after adjusting for academic aptitude, high school percentile rank, and Gender $\times$ Academic Aptitude interaction (aptitude scores from high school were less predictive of college academic performance in men compared with women) (Wood et al., 2000). The small effects of alcohol use were further diminished by adjusting for the effects of residence hall building, which has not been assessed in studies of this type in the past. The study does not provide insight into the environmental influence of the dormitories because these effects were not anticipated and thus not characterized in a systematic manner before data collection. Differences in the architectural features of the buildings, residence hall staffing patterns, monitoring and supervision of residents, and academic ethic and norms (Rau and Durand, 2000) may have contributed to the observed differences in academic performance.

Previous research would suggest that heavy drinking, frequency of alcohol use at all levels, and average intake could all affect academic performance, and this analysis explored parameters of BrAC pattern reflecting all of these. Although there is limited literature on academic problems per se, an established literature exists for patterns of drinking in relation to social consequences of alcohol use. Much of this literature has identified various measures of heavy drinking occasions as important in predicting individual risk. For example, many studies have found associations between risk and the frequency of drinking larger quantities, variability in drinking, drinking beyond acquired levels of tolerance, and drinking enough to feel intoxicated (Gruenewald and Nephew, 1994; Gruenewald et al., 1996; Midanik, 1999). Rehm and Gmel (1999) found that drinking pattern was more important in predicting problems than volume and that low-frequency drinking with heavy drinking occasions represent the highest risk.

Studies that find heavy drinking more predictive than frequency or total volume have tended to include all age groups and found that high rates of alcohol-related problems in young adults are largely attributable to a pattern of relatively less frequent but heavier drinking per occasion, relative to patterns in older adults (Lock Kunz and Graham, 1998;

Midanik and Clark, 1994; Russell et al., 2004). Modeled after the methods of Wechsler and Nelson (2001), literature on problems in U.S. college students has often reported on the frequency of consuming five or more drinks on at least one occasion (four for women) in the prior 2-week period. Alcohol intake at this level or higher has consistently been found to predict drinking problems, including those related to school performance (Wechsler et al., 2002). However, consumption of larger amounts further increases the risk (Wechsler and Nelson, 2001). Reporting on a survey of University of California students, Gruenewald et al. (2003a) documented a dose-response effect with the number of drinks per occasion for a variety of problem groupings, including two school performance measures: (1) miss a class and (2) perform poorly on a test or project. Their analysis reported very strong dose-response effects, wherein the risk associated with adverse events per drinking episode increases with the number of drinks consumed on that episode; however, much of the risk accumulated across episodes was attributable to episodes of consumption of smaller amounts. In a study of 21-year-old Australians, Toumbourou et al. (2004) found that weekly drinking of amounts above per-episode drinking guidelines represented the highest risk for problems but that weekly drinking within limits was also significantly associated with harm. Thus, they concluded that, in young adults, drinking frequency and average intake also are relevant.

Among the alcohol patterns examined in this investigation, both standard deviation in BrAC and maximum measured BrAC serve as indicators of a drinking style favoring intermittent heavy drinking, as opposed to more even levels of drinking (Greenfield et al., 2006). In the present study, both of these (as well as frequency of BrAC values reflecting intoxication) were significantly associated with poorer academic performance, whereas simple frequency of drinking was not. Furthermore, among the alcohol indicators, we found that maximum BrAC explained the largest amount of variation in undergraduate academic performance (although the magnitude of this association was very small).

Previous studies have found higher self-reported maximum consumption levels to be predictive of risk of alcohol-impaired driving, injury, criminal activity, more general alcohol-related problems, and dependence symptoms (Greenfield et al., 2006). Higher extremes may be a function of individual biological differences related to dependence and tolerance (Greenfield et al., 2003). In the college population, Gruenewald et al. (2003b) studied characteristics of students who reported higher maximum numbers of drinks than would have been estimated for them based on population-based patterns of relative frequencies of drinking different amounts. They found men and freshman were more likely to report higher extreme values than predicted by modeled drinking behaviors. Thus, high peak drinking may represent an important distinct aspect of college age drinking

practices, with relevance to prevention (Gruenewald et al., 2003b; White et al., 2006).

Limitations

The most notable limitation of the study involves questions about the generalizability of the findings. Although failure to use random sampling from the underlying population does not necessarily or often lead to biased estimates of regression model coefficients (Groves, 1989; Levy and Lemeshow, 1999; Lohr, 1999), these questions frequently arise in college alcohol studies that collect data in naturalistic (nighttime) settings, because they often cannot randomly select participants, drinking sites, or campuses as a result of logistics and cost issues (Dowdall and Wechsler, 2002). Indeed, the sample for this study was generated from residence hall students at only one university, it was predominately white, and it did not include students who lived off-campus or with parents. Thus, there is some uncertainty about the sample's ability to represent college students in general. However, we did find that the self-reported rates of drinking and alcohol problems in the sample were in a similar range to those reported in other studies of college drinking (Presley et al., 1996; Wechsler et al., 2002), and the mean college entrance academic aptitude score was nearly identical to the national average, providing reason to believe it was a typical cohort of undergraduates with respect to alcohol use and academic aptitude.

Additional questions can be raised about the validity of the nighttime data collection method. We may have failed to detect some heavy drinking episodes because there may have been occasions wherein the most intoxicated students did not return to their residence halls until after 3:00 AM. Also, the BrAC measure is an assessment of intoxication at a single point in time. We did not collect any information about drinkers' blood alcohol curve at night; therefore, the extent to which the observed intoxication levels approximated peak BrACs is not known.

Finally, 47.1% of the BrAC data had to be imputed because of missing values of intoxication on certain days. There are many reasons for this: Students may have spent the night elsewhere, especially on weekends; they may have returned to the residence hall building after 3:00 AM; and researchers lacked access to students during in-semester holidays, etc. Although it was not possible to document and quantify participation refusal, the students' general enthusiasm for participating in the study suggest that "missingness" was not related to evasion of the data collection procedure. Many participants expressed regret that their obligations and travel plans did not allow them to participate more frequently for greater remuneration. The imputation technique used in the study helped to ensure that the temporal pattern (e.g., greater drinking during the weekend compared with Wednesdays) of alcohol consumption was preserved based on the individual

pattern of drinking. Thus, imputation in our study helped to preserve existing data structures, both with respect to individual drinking patterns and with respect to weekday specific drinking schemes. Imputation was necessary to capture the typical drinking patterns of the students over the semester, because no student can be reasonably expected to provide his or her BrAC each night during the course of the study; that is, imputation avoided bias in the regression analyses that could have been created by ignoring differential patterns of missing data. Therefore, the individually recorded patterns were used to extract the data set. In addition, it should be noted that imputation (vs use of only nonimputed data) did not alter the observed regression coefficients; therefore, the specific technique used for imputation cannot have biased our conclusions.

Future research

Future research should attempt to carefully characterize the living environment of undergraduates with respect to academic norms, socializing practices, alcohol use, physical layout of the residence hall, and staff monitoring and supervision. Such research could inform campus-based alcohol policy as it applies to the creation of living-learning communities. In addition, more investigation is needed to determine whether similar findings are found in other college student populations and campus settings beyond the single campus studied in this project.

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