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Psychophysiological Responses to Stress Following Alcohol Intake in Social Drinkers Who Are at Risk of Hazardous Drinking

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Abstract

We examined whether social drinkers whose drinking behavior poses a risk for harmful consequences exhibit altered psychobiological responses to stress following moderate alcohol intake. At risk (n = 17) and low risk drinkers (n = 27), as identified by the Alcohol Use Disorders Identification Test, completed two laboratory stress sessions, one in which they consumed a drink with alcohol and one without alcohol. Subjective and physiological measures were obtained throughout the study. Reported stimulation following alcohol consumption and sedation post-stress on alcohol day were greater than the no alcohol day in at risk drinkers (ps < .05). Low risk drinkers exhibited stress dampening effects on cortisol levels (p < .05). This was not the case among the high risk drinkers. These results indicate that acute alcohol intake may be associated with enhanced subjective and altered hormonal responses to stress in individuals who are at risk for becoming problem drinkers.

Keywords

alcohol; cortisol; stress; AUDIT; substance use

Introduction

Animal models related to stress and drug dependence indicate that activation of the hypothalamic-pituitary-adrenal (HPA) axis may sensitize central pathways linked with reward (Rouge-Pont et al. 1995; Rouge-Pont et al. 1998; Tidey and Miczek 1997) and instrumental action (Schwabe et al. 2011), promoting or reinforcing self-administration of the chosen drug (Koob and Le Moal 1997; Piazza and Le Moal 1998). Studies in humans have also shown the mediating role of stress-induced HPA activity in the risk for drug abuse including alcohol (Lovallo 2006); Sinha 2008; Uhart and Wand 2009). Attenuated HPA response to stress has been reported among alcoholic patients (Errico et al. 1993; Bernardy

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Conflict of interest
All authors do not have any conflict of interest in the preparation of this manuscript.

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et al. 1996; Lovallo et al. 2000) and individuals with family history of alcoholism (Croissant and Olbrich 2004; Dawes et al. 1999; Sorocco et al. 2006; Uhart et al. 2006; Zimmermann et al. 2004). Blunted cortisol secretion in response to stress has also been shown to predict future drug experimentation and drinking relapse (Junghanns et al. 2003; Junghanns et al. 2005; Moss et al. 1999). These suggest that individual differences in HPA stress regulations may be linked to alcohol-related problems.

A maladaptive HPA response to stress has also been reported in studies where participants were asked to consume alcohol prior to the behavioral challenges. One study (Dai et al. 2007) found that while persons without a family history of alcoholism and alcohol dependence exhibited the expected stress response dampening effects of alcohol in HPA measures, those with the disorder did not show this pattern. Another study (Croissant et al. 2008) found that those who reported having high levels of sensation seeking, a construct which is associated with maladaptive drug use, did not show stress dampening effects in cortisol secretion. These findings suggest that altered HPA reactions to stress following alcohol challenge may be indicative of enhanced risk for problem drinking. This model however has not been tested with healthy young individuals who are characterized as having a risk for disordered drinking. This was a goal of the present investigation.

Epidemiological data show that social drinkers who are at risk of hazardous drinking (i.e., individuals whose drinking behavior poses a risk for harmful consequences) and harmful drinking (those who have experienced alcohol-related harm but have yet to establish dependence) are common in industrialized countries (Reid et al. 1999; Saunders et al. 1993a; Saunders and Lee 2000). Standardized instruments such as the Alcohol Use Disorders Identification Test (AUDIT; Babor et al. 2001; Saunders et al. 1993b) have been developed to reliably classify individuals who have the potential of becoming problem drinkers (Reinert and Allen 2007; Bohn et al. 1995). However, only limited knowledge is available concerning psychobiological mechanisms associated with alcohol consumption and stress among this population. Research has shown that individual differences in pharmacological effects of alcohol may be moderated by stressful experience. For instance, men who reported “stimulant-like” responses to alcohol under non-stressful condition exhibited decreased stimulant effect but increased sedative effects of alcohol following stress (Childs et al. 2011). It is therefore possible that social drinkers who are at risk of hazardous drinking may show different patterns of subjective responses to stress following alcohol intake relative to low risk social drinkers.

Identifying specific markers to predict problem alcohol use in the general population is important as these markers would assist in early detection of alcohol misuse and be beneficial in minimizing the risk of developing alcohol-induced pathology (Schuckit 2009; Newlin and Thompson 1990; Saunders and Lee 2000; Conigrave et al. 1995). This study was designed to examine affective, cardiovascular, and hormonal changes in response to stress following moderate alcohol intake in individuals defined as at risk drinkers who could possibly progress to problem drinkers in the future. Based on existing research, we hypothesized that while low risk alcohol users would exhibit stress response dampening effects of alcohol, at risk individuals would not show such a pattern. We also hypothesized that at risk alcohol users would report greater subjective effects of alcohol than low risk participants.

Method

Participants

Participants were recruited through campus and community flyers and newspaper advertisements. An initial phone screening was conducted with potential participants in

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which they were asked about current or recent physical and psychiatric disorders and medication intake. Individuals with current medical conditions (e.g., heart and respiratory diseases, diabetes, depression, drug dependence) were not included. Screened participants were invited to an on-site visit. They were given a consent form, approved by the Institutional Review Board of the University of Minnesota, which described details regarding the study protocol such as alcohol administration, behavioral challenges, and measures collected during the session. After signing the form, participants completed questionnaires including demographic information and medical history. The medical history questionnaire asked whether 1) the participant or his or her biological parents and family members had major illnesses, and 2) the participant had ever received treatment for medical conditions (e.g., asthma, heart attack, depression, drug abuse). Individuals who reported that they had been receiving treatment for alcohol abuse were not included in the study. Height and weight were measured for calculation of alcohol dosage (described below). Enrolled participants were instructed to refrain from alcohol for 24 hours and caffeine, strenuous exercise, and nicotine for 4 hours prior to their scheduled laboratory sessions. Forty-six participants enrolled and 44 of them (19 women) completed the study. Data from two male participants classified as low risk drinkers were not included in reported results due to technical difficulties.

Apparatus and Measures

Participants were informed that they would receive alcohol (Everclear 95%) mixed with grapefruit juice in one session and grapefruit juice alone in the other session. For each participant, alcohol dosage was determined by a kinetic model (Curtin and Fairchild 2003; Watson et al. 1981) to obtain the individual-specific alcohol dosage that would result in a blood alcohol concentration (BAC) of 0.05% 30 minutes after the drinking period.[1] BAC levels were measured from the plasma samples that were collected multiple times during the study (see below).

Saliva samples were collected by a commercially available collection device (Salivette®, Sartstedt, Germany), and stored at −70C° until assayed. Cortisol in saliva was measured using a solid phase enzyme-linked immunosorbent assay kit based on competitive binding (IBL America, Minneapolis MN). The assay has a minimum sensitivity of 0.54 ng/mL. Inter-assay coefficient of variation (CV) is < 15% and the intra-assay coefficient of variation < 5%, as measured using an internal standard.

[1]The formula (Curtin & Fairchild, 2003; Watson et al., 1981) used to calculate alcohol dose to achieve a specific peak blood alcohol level (BAL) included the participant's total body water (TBW), alcohol metabolism rate (MR), duration of the drinking period (DDP), and time to peak BAL (TPB). Specifically:

$$Alcoholdose(g) = \frac{10 \times BAL \times TBW}{0.8} + \{10 \times MR \times (DDP + TPB)\} \times \frac{TBW}{0.8}$$

In this formula, alcohol dose was assessed in grams, BAL in g/100 ml (i.e., 0.01 gram per 100 ml), DDP and TPB in hours, and TBW in liters. The average metabolism was fixed to 0.015 g/100 ml/h for all participants. It was assumed that the TPB would be reached in 0.5hr after cessation of the alcohol beverage. Sex-specific regression models were used to estimate TBW:

Men:

$$TBW(l) = 2.447 - 0.09516 \times age(years) + 0.1074 \times height(cm) + 0.3362 \times weight(kg)$$

Women:

$$TBW(l) = -2.097 + 0.1069 \times height(cm) + 0.2466 \times weight(kg)$$

In the present study, alcohol dose was converted to grams to milliliters (mls) by the density of alcohol at 24 °C, 0.7861 g/ml. This resulted in increased accuracy and decreased variability in observed peak BALs as compared with those reported in alcohol challenge studies.

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The Alcohol Use Disorders Identification Test (AUDIT; Babor et al. 2001; Saunders et al. 1993b) was used to identify a subgroup of individuals in our sample that would fall under the classification of “at risk drinkers.” The AUDIT includes 10 questions that ask about alcohol use, symptoms of dependence, and negative consequences. The major strength of the AUDIT is that it was specifically designed to detect hazardous and harmful drinking rather than to detect established dependence or abuse (Saunders et al. 1993b; Allen et al. 1997; Bohn et al. 1995). The scale has been reported to have high reliability (Cronbach's α between .75 and .97) and validity (Reinert and Allen 2007). Prior research has suggested different cut-off scores to be used for men and women in identifying potential problem drinkers (Reinert and Allen 2002, 2007). The current study therefore used the cutoff score of eight for men and five for women to classify at risk and low risk drinkers as recommended (Reinert and Allen 2007).

The Biphasic Alcohol Effects Scale (BAES; Martin et al. 1993) was used to assess subjective influences of alcohol. The BAES is developed to measure stimulant and sedative effects of alcohol (Rueger et al. 2009). The Stimulant subscale includes items such as elated, energized, excited, stimulated, talkative, up, and vigorous. The Sedative subscale includes items such as difficulty concentrating, down, heavy head, inactive, sedated, slow thoughts, and sluggish. Each item has a range from 0 (Not at all) to 10 (Extremely). Internal consistency of the scale has been established with individuals with and without alcohol consumption (Chronbach's α between .85 to .94; Martin et al. 1993).

A modified version of the Subjective States Questionnaire (Lundberg & Frankenhaeuser, 1980) was used to assess mood states and levels of physical symptoms in response to alcohol consumption and stress. The scale has been shown to reliably track changes in these constructs (al'Absi et al. 1998). Distress consisted of items such as anxiety, irritability, impatience, and restlessness. Positive affect included items of cheerfulness, contentedness, calmness, controllability, and interest. Physical symptoms included headache, sweating, tremor, stomachache, drowsiness, fatigue, and coughing. Each item had a 8-point scale anchored by the end points, “Not at All = 0” and “Very Strong = 7.”

Participants also completed forms on demographic information, the State–Trait Anxiety Inventory (Trait-Form; STAI; Spielberger et al. 1983), the Spielberger's State-Trait Anger Expression Inventory (STAXI; Spielberger et al. 1985), the Perceived Stress Scale (PSS; Cohen et al. 1983), and mood disturbance (i.e., sum of scores on subscales of tension, depression, anger, vigor, fatigue, confusion with vigor weighted negatively as measured by the Profile of Mood State questionnaire [POMS]; McNair et al. 1992) during the onsite-screening. The Family Tree Questionnaire (Mann et al., 1985; Vogel-Sprott et al., 1985) was used to assess family history of alcoholism.

Procedure

In the current study, participants completed two laboratory sessions (alcohol, no alcohol). The two sessions took place at least a week apart for the majority of participants. The order of the alcohol administration was counterbalanced. To minimize confounds of circadian fluctuation in cortisol levels, all sessions were started between 11am and 1:15pm. The maximum time difference between the sessions was 1 hr, and 89% of the participants started the two laboratory sessions at the same time. The starting time of the two sessions did not vary by two groups (p=.94). Each session started with instrumentation and orientation of approximately 30 minutes, which was followed by a baseline period (30 min), absorption period (30 min), stress tasks (30 min), and recovery period (45 min). The session started with placement of a catheter and a blood pressure (BP) cuff. The participant sat and watched a neutral content video clip while systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) were recorded every 5 minutes. At the end of this initial period,

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blood and saliva samples and the forms of BAES and subjective mood states were collected. Then, the participant consumed a beverage. The drink (alcohol mixed or not mixed) was prepared by a pharmacist before the session and was stored in a refrigerator. The experimenters as well as the participant were not informed as to the content of the beverage. Administration of the drink was separated into two segments (5 min each) with a 5 minute break in between. The participant was asked to relax for an additional 15 minutes after cessation of consumption (absorption period: 30 min). During this period, cardiovascular measures were collected every 3 minutes, and plasma, saliva, and forms of BAES and subjective mood states were obtained at the end of the phase. After the sampling was completed, the participant engaged in the acute stress tasks in the following order: public speaking (4 min preparation and 4 min delivery), mental arithmetic (8 min), and the cold pressor task (CPT; 5 min). A 3 minute period of instruction preceded each task. These tasks have been reported to reliably induce psychophysiological reactivity (al'Absi et al. 1996; al'Absi et al. 1997). Different speech scenarios and math problem numbers were used for each laboratory sessions to minimize habituation in stress response. Cardiovascular measures were assessed every 2 minutes during each period of the tasks. Also, plasma and saliva samples were collected twice: once at the end of the math task and the other post CPT. BAES and subjective mood questionnaire were also completed after the stressors. The participant watched the neutral content video clip during the recovery period. Cardiovascular indices were obtained during this resting period, and plasma and saliva samples and BAES and mood form were collected at the end of the period. The participants were thoroughly debriefed after the second study session and were compensated for participation.

Data Analysis

For each period, mean values were obtained for SBP, DBP, and HR, and total scores were calculated for subscales of BAES (Stimulation and Sedation) and subjective state questionnaire (positive affect, distress, physical symptoms). For cortisol, values obtained from each period were used for the analysis except that 2 measures collected during the stress protocol were averaged. Each of these measures was analyzed using a 2 (Group: at risk and low risk) × 2 (Session: alcohol, no alcohol) × 4 (Time: baseline, absorption, stress, recovery) multivariate analysis of covariance (MANCOVA). Because preliminary analysis found that the order of alcohol session (alcohol first or second) was not associated with stress response, it was included as a covariate. We also controlled for sex due to the lack of power associated with the small sample size. To calculate whether blood alcohol reached its expected level, BAC was analyzed by a 2 (Group: at risk and low risk) × 4 (Time: baseline, absorption, stress, recovery) MANCOVA adjusting for sex and the order of alcohol session. Wilk's criterion was applied for the tests and cortisol levels were log transformed to meet the assumption of normality required by the statistical analysis. Finally, a series of one-way ANOVA analyses, using Group as a between-subject factor, and chi-square tests were conducted for demographic variables and PSS, STAXI, STAI, and mood disturbance (POMS).

Results

Participant characteristics

Seventeen participants (8 women) were classified as at risk drinkers and the remaining 27 (11 women) were identified as low risk drinkers. The AUDIT scores ranged from 1 to 7 in low risk drinkers and 5 to 14 in at risk drinkers, and the means of the two groups were significantly different ($F(1, 42) = 53.5$, $p < .001$, $\eta^2 = .56$; see Table 1). Reported numbers of alcohol drinks consumed per drinking day was five or six in at risk drinkers and one or two among low risk drinkers. The two groups did not differ in age, length of education,

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hours of sleep, amount of exercise, levels of psychosocial stress (PSS), or trait anger (STAXI; ps > .05). More than 95% of the sample consisted of Caucasians. The number of female participants who reported using oral contraceptives, smokers, and individuals with positive family history of alcoholism were comparable between the groups (ps > .05). At risk drinkers reported higher levels of anxiety (STAI; $F(1, 42) = 4.62$, $p < .05$, $\eta^2 = .10$) and mood disturbance (POMS; $F(1, 42) = 6.47$, $p < .05$, $\eta^2 = .13$) than the low risk drinkers (see Table 1).

Manipulation check of alcohol drink

All participants had a BAC value of 0 during the pre-drink baseline period (see Table 2). There were significant changes over time ($F(3, 38) = 717$, $p < .001$, $\eta^2 = .98$). Multiple comparisons with Bonferroni corrections indicated that BAC peaked during the alcohol absorption period followed by decrease for the rest of the experiment ($ps < .001$; see Figure 1). The mean BAC of the absorption period for the entire sample was 0.05% showing that the mathematical model for calculating individual-specific alcohol dosage met our expectation. There were no group differences, indicating that changes in BAC were comparable between at risk and low risk drinkers.

Effects of stress following alcohol consumption

Self-report measures—Reported levels of distress ($F(3, 38) = 12.0$, $p < .001$, $\eta^2 = .49$), positive affect ($F(3, 38) = 30.0$, $p < .001$, $\eta^2 = .70$), and physical symptoms ($F(3, 38) = 11.6$, $p < .001$, $\eta^2 = .48$) changed over time (see Table 2). Multiple comparison tests with Bonferroni adjustments revealed that distress increased from baseline to stress while positive affect and physical symptoms decreased during this period ($ps < .001$), indicating that acute stress was associated with increase in negative affect. At risk drinkers reported greater distress ($F(1, 40) = 5.28$, $p < .05$, $\eta^2 = .12$) and physical symptoms ($F(1, 40) = 5.30$, $p < .05$, $\eta^2 = .12$) than low risk drinkers as revealed by significant group effects. Consumption of alcohol was associated with increase in physical symptoms ($F(1, 40) = 6.17$, $p < .05$, $\eta^2 = .13$) as indicated by a significant effect of session. No interaction effect was observed in any of these measures.

For subjective response to alcohol assessed by BAES, there was a significant Group × Session × Time interaction in the Stimulation subscale ($F(3, 38) = 3.56$, $p < .05$, $\eta^2 = .22$; see Table 2). To explore this effect, we calculated change scores (the score during baseline was subtracted from the score during alcohol/no alcohol absorption period) and conducted a 2 group × 2 session AVOVA, including sex and session order in the model where appropriate. A significant Group × Session interaction ($F(1, 42) = 6.05$, $p < .05$, $\eta^2 = .13$) was found, indicating that at risk drinkers reported enhanced levels of stimulation during the absorption period on the alcohol day relative to the no alcohol day ($p = .001$) while this was not the case with the low risk drinkers ($p = .29$; see Figure 2). A significant Group × Session × Time effect was also found in the Sedation subscale ($F(3, 38) = 3.54$, $p < .05$, $\eta^2 = .22$). Analysis of change scores (the value during alcohol/no alcohol absorption period was subtracted from the value post stress) revealed a significant Group × Session effect ($F(1, 42) = 7.44$, $p < .01$, $\eta^2 = .15$), reflecting that at risk drinkers reported increased sedation immediately after stress on the alcohol day as compared with the no alcohol day ($p = .02$), whereas this difference was not found among the low risk drinkers ($p = .84$; see Figure 3).

Physiological measures—SBP ($F(3, 38) = 91.4$, $p < .001$, $\eta^2 = .88$), DBP ($F(3, 38) = 102$, $p < .001$, $\eta^2 = .89$), and HR ($F(3, 38) = 101$, $p < .001$, $\eta^2 = .89$) changed over time (see Table 2). Multiple comparison tests indicated that these measures increased from baseline to stress period ($ps < .001$) as well as from alcohol absorption to stress period ($ps < .001$). However, the DBP and HR findings were qualified by significant Session × Time

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interactions (DBP ($F(3, 38) = 4.82$, $p <. 01$, $\eta^2 = .28$); HR ($F(3, 38) = 15.4$, $p <. 001$, $\eta^2 = .55$). Analysis of change scores (the value during baseline was subtracted from the value during stress) revealed that the level of increase in DBP was greater on the no alcohol day than the alcohol day ($F(1, 42) = 7.35$, $p < .05$, $\eta^2 = .15$). In contrast, the same change score analysis found that the degree of HR response was greater on the alcohol day than the no alcohol day ($F(1, 42) = 19.9$, $p < .001$, $\eta^2 = .32$).

Regarding salivary cortisol concentrations, there was a significant Group × Session × Time interaction ($F(3, 38) = 3.07$, $p < .05$, $\eta^2 = .20$; see Table 2). Analysis of change scores (the value during alcohol/no alcohol absorption period was subtracted from the value post stress) found a significant Group × Session interaction ($F(1, 41) = 5.39$, $p < .05$, $\eta^2 = .12$). This indicates that while low risk drinkers tended to exhibit enhanced cortisol response on the no alcohol day but attenuated cortisol reaction on the alcohol day (i.e., stress dampening effects on cortisol; $p = .04$), at risk drinkers did not show this pattern ($p = .31$; see Figure 4).

Finally, since stress response is related to psychosocial factors such as chronic stress and smoking, trait mood measures that showed significant group differences (i.e., STAI, POMS) and smoking status were included in the model. The Group × Session × Time effects found in the Stimulation and Sedation subscales of the BAES remained statistically significant after controlling for these variables (ps < .05). A trend of the 3-way interaction was also found in cortisol ($p < .07$).

Discussion

The major finding of the present study is that moderate alcohol consumption was associated with increased subjective response and altered hormonal sensitivity to stress in social drinkers who have the potential of becoming problem drinkers. While expected stress dampening effects on cortisol were found among low risk drinkers, this was not the case among at risk drinkers. Attenuated HPA response to stress on the no alcohol day found in high risk drinkers is consistent with previous studies with alcoholics (Errico et al. 1993; Bernardy et al. 1996; Lovallo et al. 2000) and in subjects with a family history of alcoholism (Dawes et al. 1999; Sorocco et al. 2006). These observations were generally in agreement with previous work examining individual differences in hormonal stress response following alcohol intake (Dai et al. 2007; Croissant et al. 2008). A growing body of evidence supports the role of HPA axis in the relationship between stress and substance use (Lovallo 2006); Sinha 2008; Uhart and Wand 2008). Stress-induced activation of HPA may also mediate the shift in neurocognitive circuits from goal-directed to habit behavior (Schwabe et al. 2011). It is possible that the maladaptive stress response observed among the high risk drinkers reflect potential alterations in the HPA axis that may mediate the link between stress and alcohol use. The finding that the low risk group showed the anticipated cortisol reactivity during both alcohol and no alcohol sessions further supports this hypothesis (see Figure 2).

This study also found differences in subjective effects of alcohol between at risk low risk drinkers. Increased levels of stimulation after consumption of alcohol and sedation after subsequent stress tasks were observed only among the at risk drinker group. This is consistent with studies reporting individual differences in effects of alcohol following stress (Childs et al. 2011) and positive linkages between reported positive drinking consequences and levels of hazardous drinking (Capron and Schmidt 2012). The present finding that at risk drinkers reported greater distress and physical discomfort during the laboratory sessions than the low risk group further suggests that high risk individuals may be more vulnerable to stress and therefore seek psychological benefits of alcohol.

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In contrast, the current findings appear to be inconsistent with studies showing that lower sensitivity to alcohol intake is associated with the risk for alcohol use disorder (Schuckit et al. 2011) or does fully support the model which proposes that increased stimulation during the ascending limb of the BAC curve and decreased sedation during the descending limb of the BAC curve may be linked to alcohol use disorder (Newlin and Thompson 1990). Differences in sample characteristics and methodology such as inclusion of acute stress tasks and timing of the assessment of subjective responses to alcohol may be responsible for the results. More research is clearly needed to identify which characteristics of at risk drinkers may be associated with future alcohol-related problems.

In the current study, moderate alcohol consumption was associated with a cardiovascular stress response. Stress-induced changes in DBP were greater on the no alcohol day than the alcohol day, while HR stress reactions were greater on the alcohol day than the no alcohol day. These findings confirm previous work showing dose-dependent biphasic responses in blood pressure following alcohol consumption (Abe et al. 1994; Bau et al. 2005; Rosito et al. 1999) and a lack of alcohol-related dampening effect in HR when low dose of alcohol was consumed (Levenson et al. 1980; Sayette 1993). The fact that at risk and low risk drinkers exhibited comparable cardiovascular profile suggests that harmful drinking style per se may be less linked to the cardiovascular response to stress.

The results of the current study have important implications for the use of the AUDIT questionnaire. Social drinkers classified as potential hazardous drinkers showed subjectively and physiologically different reactions to alcohol intake and acute stress than the low risk social drinkers. These findings may add further validity to the use of the scale in identifying those who are at risk for alcohol abuse. It may also be useful in research investigating psychobiological mechanisms of stress and alcohol use and/or abuse. In addition the AUDIT may be important for early detection of problematic drinking, with all its clinical implications (Saunders and Lee 2000; Conigrave et al. 1995).

The results of this study should be considered preliminary due to the small sample size. Related to this issue, we were not able to carefully examine the role of sex in the link between potential harmful drinking and stress response following alcohol consumption. Contraceptive use and menstrual cycle should be controlled since they are associated with hormonal responses to stress (Kirschbaum et al. 1999). The use of tobacco products should be also controlled as studies have suggested associations between nicotine intake and neuroendocrine activity (Steptoe and Ussher, 2006). It is important to note, however, that in the experiments reported here the rate of contraceptive or tobacco use was comparable across groups, suggesting minimal associated confounds. In addition, although we note that the number of individuals with a positive family history of alcoholism was the same between at risk and low risk social drinking groups, future research should include equal numbers of individuals with and without family history, and test its mediating role in the link between drinking style and stress response. Collecting additional measures regarding current or previous history of alcohol use/abuse (e.g., quantity, frequency) should help improving the current results as well. Structured or semi-structured interviews should be employed to screen alcohol use disorder. Studies have shown habituation effects with repeated exposure to stress. To minimize potential confounds with the effects of alcohol, we provided participants with different scenarios (public speaking) and the number to start with (mental arithmetic). The order of alcohol session was also counterbalanced. Our preliminary analysis found that the order of alcohol session was not associated with stress response, suggesting that habituation effect was minimal in the current study. Future research should examine the role of hazardous drinking in the stress response following a high dose of alcohol. Finally, the current results should be treated with caution as multiple statistical tests may inflate the possibility of Type I error. Nonetheless, this study included multi-level

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assessments of subjective and objective measures and a well-controlled experimental design (alcohol and no alcohol control sessions) with reliable stressors to examine the role of hazardous drinking on subjective, cardiovascular, and HPA responses to stress following moderate alcohol consumption.

In summary, the current study found that individuals who were classified as potential problem drinkers reported greater levels of stimulation immediately after drinking alcohol and sedation during a subsequent stress period than social drinkers. While low risk drinkers exhibited expected stress dampening effects in cortisol, at risk drinking groups did not show such a pattern. These results suggest the risk of a maladaptive stress-alcohol relationship that could be predictive of substance use disorders.

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Highlights

- We examined if reported alcohol intake behavior is linked to stress response.
- Participants were classified into high and low hazardous drinkers.
- They completed two laboratory stress sessions (with and without alcohol).
- At risk group reported increased subjective responses to alcohol consumption.
- At risk group showed altered hormonal response to stress following alcohol intake.

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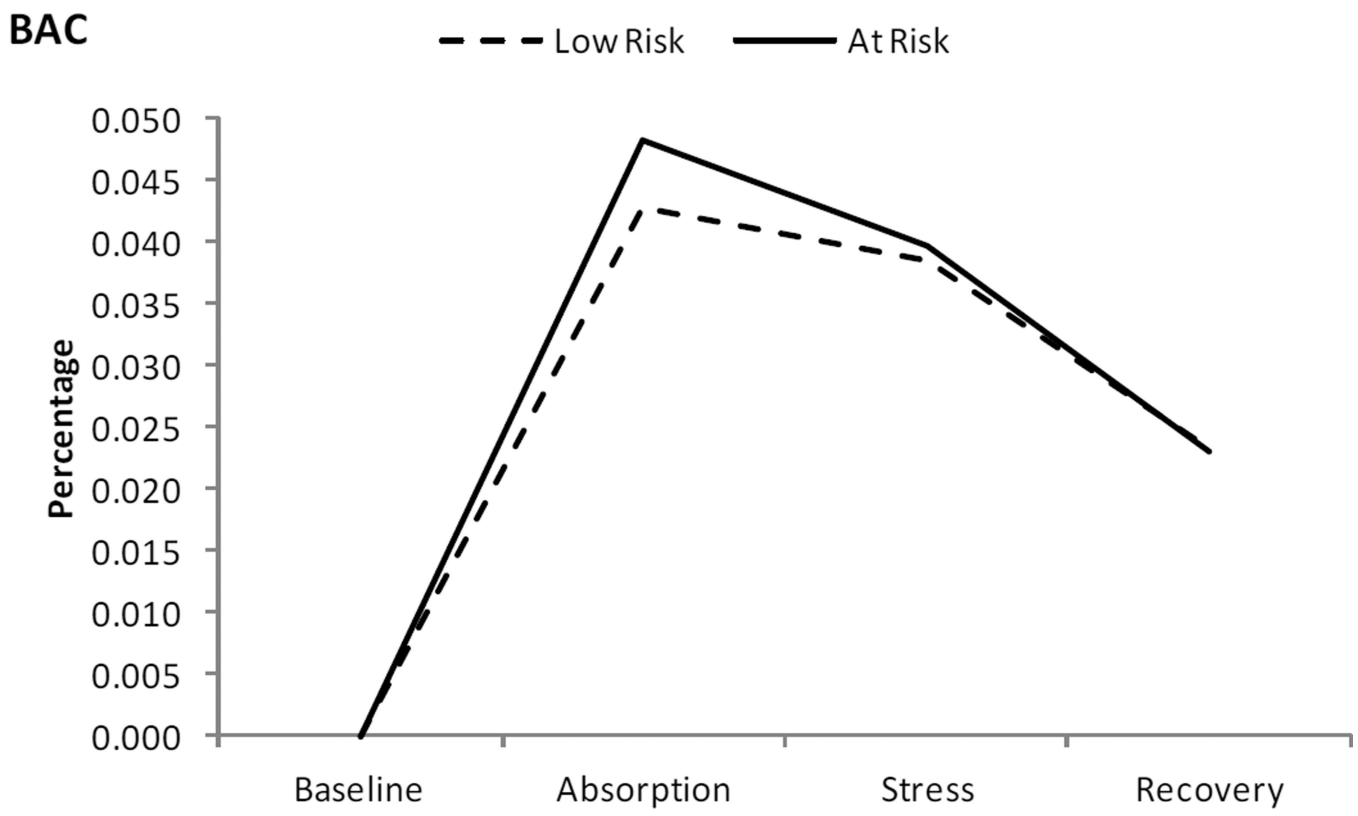

Figure 1.
Changes in blood alcohol concentration (BAC) following alcohol administration.

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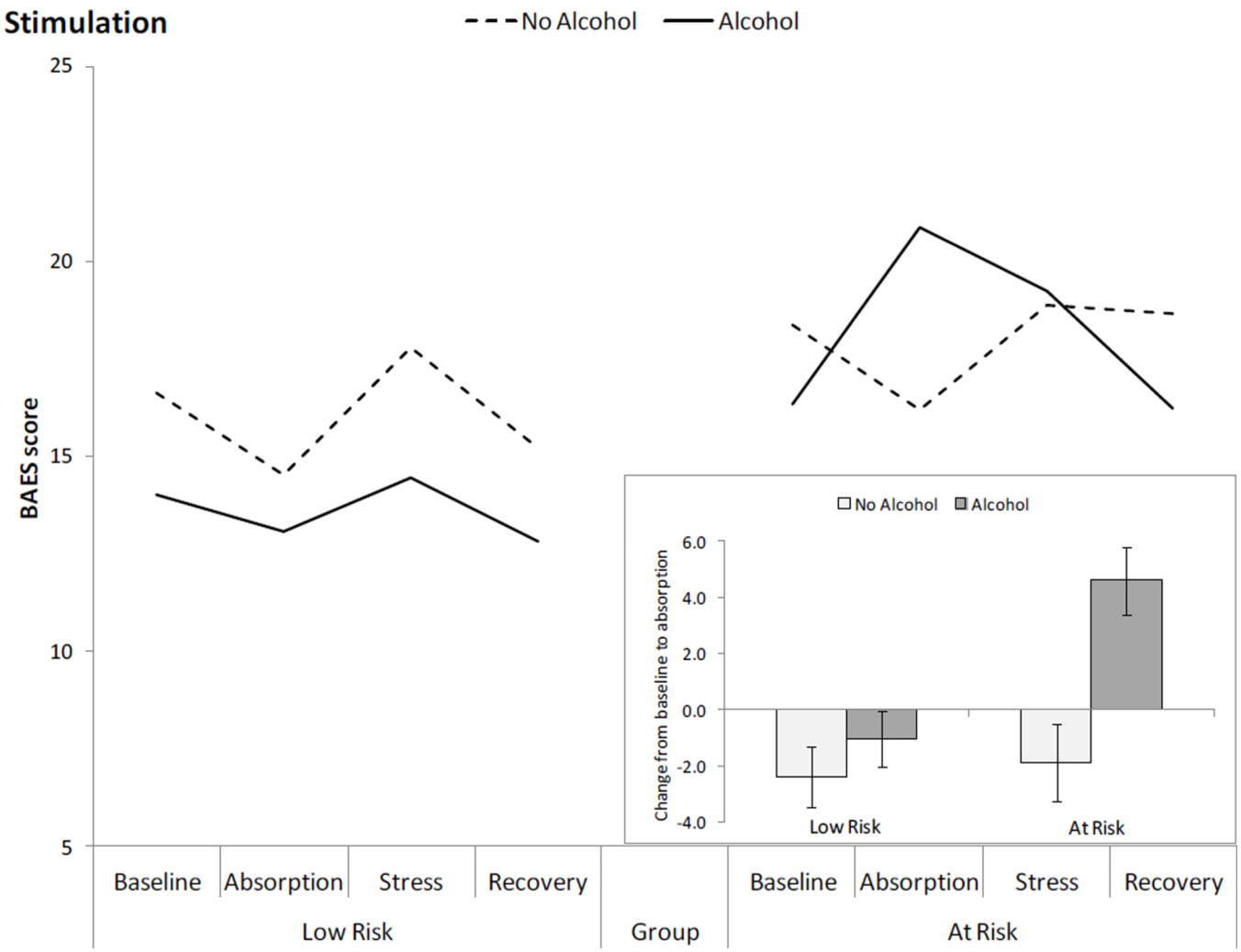

Figure 2.
Changes in subjective response (stimulation) to stress following alcohol administration.

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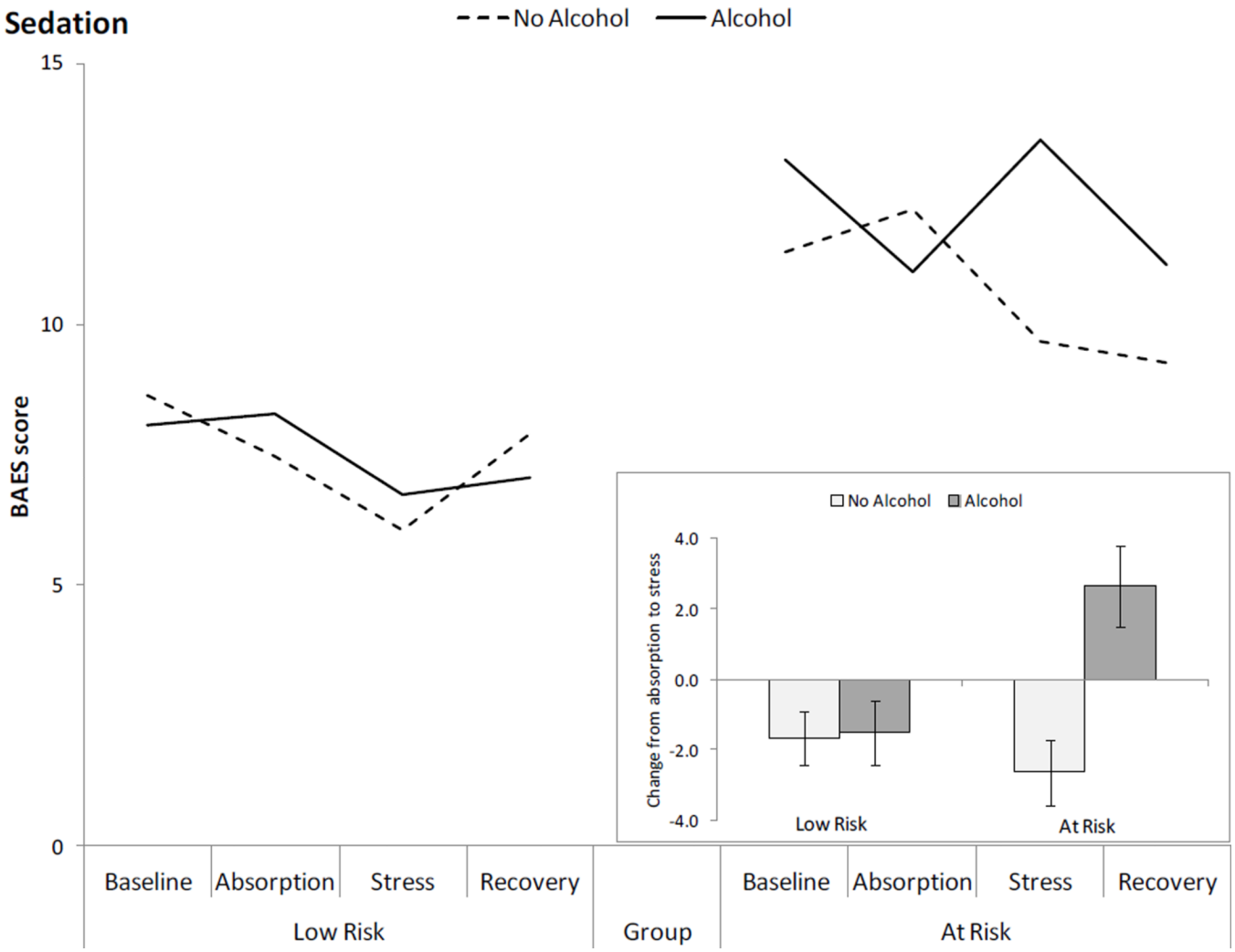

Figure 3.
Changes in subjective response (sedation) to stress following alcohol administration.

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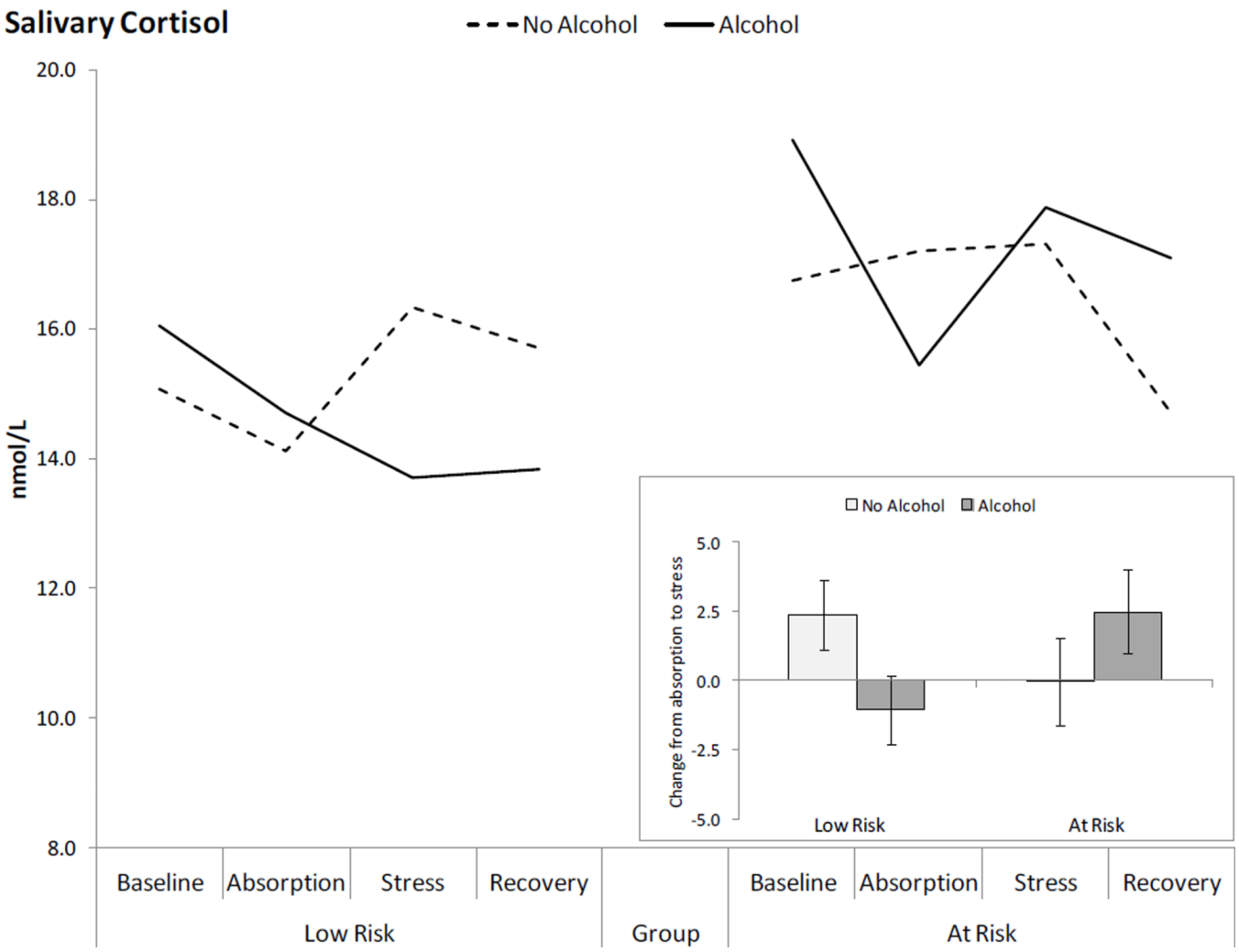

Figure 4.
Changes in salivary cortisol concentrations in response to stress. Scores show raw cortisol values.

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Table 1

Sample characteristics.

	Low Risk (n = 27)	At Risk (n = 17)	*p*
Age (years)	23.0 (0.4)	22.3 (0.5)	ns
Education (years)	15.4 (0.3)	15.8 (0.4)	ns
Sleep (avr. hrs/day)	7.7 (0.1)	7.6 (0.2)	ns
Exercise (avr. hrs/week)	5.5 (0.7)	5.8 (0.8)	ns
AUDIT total score	4.0 (0.4)	8.7 (0.5)	< .001
D/dd (median score)	0	2	--
Stress (PSS)	16.6 (0.6)	17.1 (0.7)	ns
Anger (STAXI)	13.1 (0.5)	14.5 (0.6)	ns
Anxiety (STAI)	28.3 (0.9)	31.4 (1.2)	< .05
Mood disturbance (POMS)	−2.5 (2.5)	7.6 (3.1)	< .05
Caucasians (%)	96	100	ns
Female (%)	41	47	ns
Oral conceptive use (%)	64	43	ns
Smokers (%)	7	18	ns
Family history of alcoholism (%)	11	24	ns

Entries show mean (standard error) except for number of smokers. Note. AUDIT: The Alcohol Use Disorders Identification Test; D/dd: typical drinks per drinking day (from AUDIT; 0 = 1 or 2; 1 = 3 or 4; 2 = 5 or 6; 3 = 7 to 9; 4 = 10 or more); PSS: the Perceived Stress Scale; STAXI: the Spielberger's State-Trait Anger Expression Inventory; STAI: the State–Trait Anxiety Inventory; POMS: the Profile of Mood State questionnaire.

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Table 2

Subjective and physiological measures analysis of significance.

	Low Risk (n = 27)		At Risk (n = 17)	
	No Alcohol Day	**Alcohol Day**	**No alcohol Day**	**Alcohol Day**
BAC (%) [a]				
Baseline	n/a	0	n/a	0
Absorption	n/a	0.043 (0.002)	n/a	0.048 (0.003)
Stress	n/a	0.038 (0.002)	n/a	0.040 (0.002)
Recovery	n/a	0.023 (0.002)	n/a	0.023 (0.002)
Distress [ab]				
Baseline	1.7 (0.6)	1.5 (0.6)	3.5 (0.7)	3.7 (0.7)
Absorption	2.8 (0.7)	1.9 (0.7)	3.6 (0.9)	3.6 (0.8)
Stress	4.1 (0.8)	3.1 (0.7)	7.5 (1.0)	5.9 (0.9)
Recovery	4.2 (0.8)	3.1 (0.7)	4.3 (1.0)	5.8 (0.9)
Positive affect [a]				
Baseline	18.4 (1.1)	17.5 (1.2)	17.4 (1.3)	18.3 (1.5)
Absorption	16.8 (1.1)	15.8 (1.1)	15.7 (1.3)	18.6 (1.4)
Stress	12.4 (1.1)	12.6 (1.3)	12.0 (1.4)	13.9 (1.6)
Recovery	14.8 (1.2)	14.4 (1.4)	17.1 (1.5)	15.4 (1.7)
Physical symptoms [abc]				
Baseline	2.8 (0.6)	2.8 (0.5)	3.8 (0.7)	4.5 (0.6)
Absorption	2.2 (0.5)	2.9 (0.6)	4.0 (0.6)	4.5 (0.7)
Stress	1.1 (0.3)	1.7 (0.5)	1.8 (0.4)	3.0 (0.6)
Recovery	1.5 (0.5)	3.0 (0.7)	3.5 (0.7)	4.2 (0.8)
Stimulation [de]				
Baseline	16.6 (1.8)	14.0 (1.6)	18.4 (2.3)	16.4 (1.9)
Absorption	14.5 (1.7)	13.1 (1.8)	16.2 (2.1)	20.9 (2.2)
Stress	17.8 (1.9)	14.5 (1.9)	18.9 (2.3)	19.2 (2.3)
Recovery	15.2 (1.8)	12.8 (1.8)	18.7 (2.3)	16.2 (2.2)
Sedation [abde]				

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	Low Risk (n = 27)		At Risk (n = 17)	
	No Alcohol Day	**Alcohol Day**	**No alcohol Day**	**Alcohol Day**
Baseline	8.6 (1.3)	8.1 (1.5)	11.4 (1.6)	13.2 (1.9)
Absorption	7.5 (1.4)	8.3 (1.4)	12.2 (1.7)	11.0 (1.8)
Stress	6.1 (1.0)	6.7 (1.2)	9.7 (1.3)	13.5 (1.5)
Recovery	7.9 (1.3)	7.1 (1.3)	9.3 (1.6)	11.1 (1.6)
SBP (mmHg) [a]				
Baseline	107.4 (1.6)	108.0 (1.7)	109.5 (2.0)	109.2 (2.1)
Absorption	111.9 (1.9)	111.0 (1.8)	111.7 (2.3)	113.6 (2.2)
Stress	128.1 (2.2)	126.3 (2.3)	126.0 (2.8)	124.3 (2.8)
Recovery	112.3 (1.6)	110.5 (1.7)	112.1 (2.0)	110.6 (2.1)
DBP (mmHg) [acd]				
Baseline	59.0 (1.2)	59.1 (1.4)	58.7 (1.5)	58.5 (1.7)
Absorption	60.8 (1.1)	59.7 (1.1)	58.5 (1.4)	58.5 (1.3)
Stress	71.7 (1.3)	69.5 (1.2)	69.1 (1.6)	66.3 (1.5)
Recovery	62.4 (1.3)	58.6 (1.0)	59.3 (1.6)	57.0 (1.3)
HR (bpm) [acd]				
Baseline	62.2 (1.7)	60.5 (1.8)	59.0 (2.1)	58.7 (2.2)
Absorption	64.0 (1.7)	66.5 (1.9)	58.7 (2.1)	64.6 (2.4)
Stress	77.8 (1.7)	81.5 (2.0)	72.1 (2.1)	75.7 (2.4)
Recovery	64.0 (1.6)	68.6 (1.9)	61.0 (2.0)	64.6 (2.3)
Log Cortisol (nmol/L) [ace]				
Baseline	2.6 (0.1)	2.7 (0.1)	2.7 (0.1)	2.9 (0.1)
Absorption	2.5 (0.1)	2.6 (0.1)	2.7 (0.1)	2.7 (0.1)
Stress	2.7 (0.1)	2.5 (0.1)	2.7 (0.1)	2.7 (0.1)
Recovery	2.6 (0.1)	2.5 (0.1)	2.6 (0.1)	2.7 (0.1)

Entries represent mean and standard error of the mean. Note.

[a] Time effect was significant.

[b] Group effect was significant.

[c] Session effect was significant.

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[d] Session×Time was significant.

[e] Group×Session×Time was significant.