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Energy Drinks and Binge Drinking Predict College Students' Sleep Quantity, Quality, and Tiredness

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Abstract

This study examines whether energy drink use and binge drinking predict sleep quantity, sleep quality, and next-day tiredness among college students. Web-based daily data on substance use and sleep were collected across four semesters in 2009 and 2010 from 667 individuals for up to 56 days each, yielding information on 25,616 person-days. Controlling for average levels of energy drink use and binge drinking (i.e., 4+ drinks for women, 5+ drinks for men), on days when students consumed energy drinks, they reported lower sleep quantity and quality that night, and greater next-day tiredness, compared to days they did not use energy drinks. Similarly, on days when students binge drank, they reported lower sleep quantity and quality that night, and greater next-day tiredness, compared to days they did not binge drink. There was no significant interaction effect between binge drinking and energy drink use on the outcomes.

Inadequate sleep yields impairments of alertness (Herscovitch & Broughton, 1981), motor performance (Pilcher & Huffcutt, 1996), and executive functions (Horne, 1985), as well as subjective reports of anxiety, depression, and impulsivity (Anderson & Platten, 2011; Barnes & Meldrum, 2015; Dinges et al., 1997; Galambos, Dalton, & Maggs, 2009; Minkel et al., 2012). Evidence-based standards for adequate sleep in young adults converge on 7 to 9 hours of total sleep per 24 hours (Kaneita et al., 2007; Van Dongen, Maislin, Mullington, & Dinges, 2003; Wehr et al., 1993). Epidemiological studies indicate that young adults do not get enough sleep (Eaton et al., 2010; Leger, Beck, Richard, & Godeau, 2012; Maslowsky & Ozer, 2014; National Sleep Foundation, 2006); 25% of college students obtain less than 6.5 hours a night (Lund, Reider, Whiting, & Prichard, 2010) and 43% of students meet the less-than-5-hour threshold for partial sleep deprivation (Pilcher & Huffcutt, 1996) at least once per week (Taylor & Bramoweth, 2010). Managing academic and social demands may contribute to irregular sleep schedules, sleep deprivation, and daytime somnolence (Hershner & Chervin, 2014; Kenney, LaBrie, Hummer, & Pham, 2012).

Sleeping longer on weekends may compensate for sleep debt accruing during the week (Eliasson, Lettieri, & Eliasson, 2010; Galambos et al., 2009; Lund et al., 2010; Noland, Price, Dake, & Telljohann, 2009; Pallesen et al., 2011; Tsai & Li, 2004) but creates

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variability in sleep-wake patterns associated with poor subjective sleep quality (Lemola, Ledermann, & Friedman, 2013; Mezick et al., 2009). Daytime somnolence is reported as a major problem by 50% of college students, compared to 36% of adults (Oginska & Pokorski, 2006). Understanding the impact of alcohol and caffeine use on sleep may identify modifiable risks to be targeted in interventions for college well-being.

Alcohol and Sleep

Laboratory studies indicate both sedative and stimulant effects of alcohol on sleep (Roehrs & Roth, 2001). In healthy adults, alcohol exposure is associated with reduced sleep latency, increased slow-wave sleep (deep sleep), and decreased rapid eye movement (REM) during the first half of the night, plus an increase in waking or stage 1 (light) sleep during the second half (Ebrahim, Shapiro, Williams, & Fenwick, 2013). Significant alcohol use is reported by more than 1/3 of college students in the U.S.; 35% report binge drinking (5+ drinks in a row) in the prior 2 weeks (Johnston, O'Malley, Bachman, Schulenberg, & Miech, 2014). Counterintuitively, alcohol increases cortical arousal (Chan, Trinder, Andrewes, Colrain, & Nicholas, 2013; Chan, Trinder, Colrain, & Nicholas, 2015) and wakefulness during the night (Chan et al., 2013), contributing to diminished sleep quality.

These outcomes are not well documented in studies of real-world effects of alcohol on sleep. Among university students, research has shown lower sleep quantity and quality on nights (Galambos et al., 2009) and during months (Galambos, Vargas Lascano, Howard, & Maggs, 2013) students consumed more alcohol. Additional research on the real-world effects of consuming alcohol on sleep is needed.

Caffeine and Sleep

Numerous laboratory studies indicate that caffeine exposure reduces total sleep time, increases latency to sleep, and reduces slow-wave (deep) sleep in a dose-related manner (Roehrs & Roth, 2008). Energy drinks contain 50 to 505 mg of caffeine per serving, more than sodas (35–50 mg) and some coffee (77–150 mg) (Reissig, Strain, & Griffiths, 2009). Energy drinks are used by 40-51% of college students (Malinauskas, Aeby, Overton, Carpenter-Aeby, & Barber-Heidal, 2007; Patrick & Maggs, 2014; Woolsey et al., 2015). People are generally motivated to use energy drinks to increase wakefulness and energy, and to enhance the experience of alcohol intoxication (Ishak, Ugochukwu, Bagot, Khalili, & Zaky, 2012; Malinauskas et al., 2007). However, cross-sectional surveys of college students indicate that energy drink usage is associated with decreased sleep duration and poor sleep quality (Lohsoonthorn et al., 2013; Reid et al., 2015; Sanchez et al., 2013). The effects of energy drink use on sleep quantity, quality, and next-day tiredness have not been documented in real-world settings using data from the same individuals over time.

Combination of Alcohol and Energy Drinks

Among college students, 15–34% report using alcohol and energy drinks together in the past 30 days (Brache & Stockwell, 2011; Cobb, Nasim, Jentink, & Blank, 2015; O'Brien, McCoy, Rhodes, Wagoner, & Wolfson, 2008; Patrick, Macuada, & Maggs, 2016; Velazquez,

Poulos, Latimer, & Pasch, 2012). In an online UK sample, 45% university students report combining alcohol and energy drinks to get drunk (Johnson, Alford, Verster, & Stewart, 2016). In addition to combined use of alcohol and energy drinks being associated with more negative alcohol consequences (Brache & Stockwell, 2011; Malinauskas et al., 2007; Miller, 2008; O'Brien et al., 2008; Patrick & Maggs, 2014; Patrick, Evans-Polce, & Maggs, 2014; Pennay et al., 2015; Woolsey et al., 2015), combining alcohol and energy drinks may also be particularly detrimental for sleep. Cross-sectional studies evaluating self-reported outcomes of combining alcohol and caffeine, compared with using alcohol alone, indicate greater sleep difficulties (Peacock, Bruno, & Martin, 2012) and decreased sleep quality (Woolsey, Waigandt, & Beck, 2010). However, others have found no differences in self-reported sleep time or next day tiredness in a study of the hangover experience, based on one drinking session (Penning, De Haan, & Verster, 2011) and no differences in sleep duration or morning somnolence between subjects randomly assigned to exposure of a combination of caffeine and alcohol or to alcohol alone in a laboratory (Rohsenow et al., 2014). Longitudinal research in naturally occurring settings has not examined whether the combination of binge drinking and energy drinks on the same day is particularly detrimental to sleep.

The Current Study

The current study uses daily data from the same individuals over time to examine the effects of alcohol and energy drink use on sleep quantity and quality and next-day tiredness. The aims are to examine (1) the extent to which energy drink use is associated with sleep quantity, sleep quality, and next-day tiredness; (2) whether binge drinking (i.e., 4+ drinks for women, 5+ drinks for men) explains additional variance in these sleep-related outcomes; and (3) whether the effects of energy drink use on sleep are moderated by binge drinking.

Methods

The University Life Study (Howard, Patrick, & Maggs, 2015; Patrick & Maggs, 2011; Patrick, Maggs, & Lefkowitz, 2014) used a measurement-burst design, surveying college students once daily for 14 consecutive days each semester. Eligible participants were first-year, full-time students; U.S. citizens or permanent residents; under age 21; and residing within 25 miles of the main campus. The study included assessments each semester from Fall of first year in college (2007) through Fall of fourth year (2010). However, data on energy drinks, alcohol, and sleep were included for only four semesters (i.e., four 14-day bursts of daily surveys [56 days total]), from spring of students' second year (Spring 2009) to fall of their fourth year (Fall 2010). All procedures were approved by the Institutional Review Board.

In total, 744 students (65.6%) completed the baseline survey in Fall 2007 and provided informed consent. A stratified random sampling procedure was used to achieve a diverse sample by gender and race/ethnicity (25.2% were Hispanic/Latino, 27.3% White non-Hispanic [NH], 23.0% Asian American/Pacific Islander NH, 15.6% Black/African American NH, and 8.7% multiple races NH). Of the 744 students, 686 (92.2%) completed at least one daily survey relevant to this study (out of a possible 56 daily surveys). For the current analyses, a survey-day was included if it contained complete data for all three key variables.

Of the 686 students, 667 (97%) were included because they reported their energy drink use, alcohol use, *and* sleep. The analytic sample includes three levels of data: Level 1, also called the *daily level*, included 25,616 total days across all semesters and people (out of a possible 37,352 days [i.e., 56 days × 667 people]); Level 2, also called the *semester level*, included 2,354 semesters across all people (out of a possible 2,668 semesters [i.e., 4 semesters × 667 people); and Level 3, also called the *person level*, included the 667 participants.

Measures

Daily Level Covariates (Level 1)

Sleep: Each day participants were asked questions about the previous day, including what time they woke up and went to sleep later that day. Sleep quantity (hours of sleep) was calculated from going-to-sleep time on day *t* (e.g., Tuesday) and wake time on day *t*+1 (e.g., Wednesday). Sleep quality derived from the daily question, “How well did you sleep?” (referring to sleep from day *t* to the morning of day *t*+1, e.g., Tuesday night's sleep), with response options from *Awful* coded as 1 to *Great* coded as 7 (Pilcher & Ott, 1998). Next-day tiredness referred to how tired a student was the day after possible energy drink or alcohol use. Thus it was reported on day *t*+2 (e.g., Thursday), referring to tiredness on day *t*+1 (e.g., Wednesday), with the question, “Think back over [yesterday's day of the week] (from the time you woke up until you went to sleep). To what extent did you feel tired?” Response options ranged from *Very slightly or not at all* (1) to *Extremely* (5).

Substance Use: Each day, students were asked about their previous-day (day *t*) substance use. Energy drink use, i.e., consuming “high energy (caffeinated) drinks like Red Bull,” was coded as Yes if any energy drink use (1) or No if no energy drink use (0). Binge drinking (“4 or more drinks containing any kind of alcohol within a two-hour period” for women, 5+ for men) was coded as Yes (1) or No (0); no alcohol use was coded as (0).

Weekend nights: Thursday, Friday, and Saturday were coded as 1 and weeknights (Sunday through Wednesday) as 0, reflecting substance use patterns of US college students (Del Boca, Darkes, Greenbaum, & Goldman, 2004; Hartzler & Fromme, 2003; O'Connor & Colder, 2005).

Semester-level covariates (Level 2)—Semester-mean sleep quantity was calculated as the average of the respective daily-level continuous measures for each person during each 14-day period in each semester. For example, the semester-mean sleep quantity scores for a person who provided 13 daily reports of sleep quantity in a given semester would be the average of those 13 daily ratings. Semester-mean energy drink use and binge drinking behaviors were calculated as the average of the respective daily-level dichotomous indicators for each person during each sampling period in each semester. These means reflect the proportion of assessed days each semester on which a student consumed energy drinks or binge drank, respectively. The four consecutive semesters included in these analyses were coded 0, 1, 2, and 3.

Person-level covariates (Level 3)—Person-mean sleep quantity was calculated using the respective daily-level continuous measures across all available days. For example,

person-mean sleep quantity for a person who provided 50 daily reports of sleep quantity across the 56 days of data collection would be the average of those 50 daily ratings. Person-mean energy drink use and binge drinking behavior were calculated as the average of the respective daily-level dichotomous indicators across all available days. These means reflect the proportion of all reported days on which a student consumed energy drinks or binge drank, respectively. Gender was self-reported as male (1) or female (0).

Plan of Analysis

To account for the correlation between daily reports from the same person and within semesters, three-level hierarchical linear models (Raudenbush & Bryk, 2002) were estimated using the mixed program in Stata 13 (StataCorp, 2013). Full information maximum likelihood (FIML) estimation was used to handle missing data. Multilevel modeling with FIML estimation offers a flexible and efficient method of addressing missing data (Black, Harel, & Betsy McCoach, 2011; Mazza, Enders, & Ruehlman, 2015). For each outcome—i.e., sleep quantity, sleep quality, and next-day tiredness—three models were estimated. To address Aim 1, Model A focused on the daily-level effects of energy drink use on sleep. Model A included daily-level (Level 1) variables of energy drink use and weekend nights, semester-level (Level 2) variables of semester-mean energy drink use and semester, and person-level (Level 3) variables of gender and person-mean energy drink use. To account for any separate effect of sleep quantity on sleep quality and next-day tiredness, sleep quantity was included as a control variable in those models. To address Aim 2, Model B included all Model A variables plus the daily level effects of binge drinking (Level 1), semester-mean binge drinking (Level 2), and person-mean binge drinking (Level 3). Finally, to address Aim 3, Model C included all Model B variables and a daily-level interaction between energy drink use and binge drinking (Level 1). All models included random effects for semester and person.

Results

Descriptives

Descriptive information is provided in Table 1. Energy drink use was reported on 4.5% of all sampled days (n=1,146 days [Level 1]) and binge drinking was reported on 7.2% of all days (n=1,832 days). Students reported both using energy drinks and binge drinking on 0.9% of all sampled days (n=218 days). Binge drinking occurred on 11.0% of days on which energy drinks were used; conversely, energy drink use occurred on 6.9% of days on which binge drinking occurred. At the person level, 46.6% of students (n=311 [Level 3]) reported energy drink use on at least one day, 53.7% (n=358) reported binge drinking on at least one day, and 18.9% (n=126) of students reported both using energy drinks and binge drinking on the same day at least once.

Sleep Quantity

Results regarding sleep quantity are shown in the first two columns of Table 2. Days with energy drink use were associated with lower sleep quantity that night, compared to days without energy drink use (Aim 1, Model A). Students spent more time sleeping on weekend nights. Students who used energy drinks more and semesters in which energy drink use was

higher were not associated with differences in sleep quantity (no effects of person-mean or semester-mean energy drink use). Men reported sleeping longer than women, and sleep quantity decreased slightly across semesters.

Days with binge drinking were associated with lower sleep quantity that night, compared to days without binge drinking (Aim 2, Model B). The daily-level effects of weekends and energy drink use were similar to Model A. Students who binge-drank more and semesters with greater binge drinking did not differ in their quantity of sleep (no effects of person-mean or semester-mean binge drinking). However, semester-mean energy drink use was associated with lower sleep quantity: Controlling for binge drinking, students spent less time sleeping during semesters in which they used more energy drinks.

Sleep Quality

Results regarding sleep quality are shown in the middle two columns of Table 2. Days with energy drink use were associated with lower sleep quality (Aim 1, Model A). Students reported greater sleep quality on weekends and on nights they slept longer. In Model A, person-mean energy drink use and semester-mean sleep quantity were associated with lower sleep quality. That is, among students who used energy drinks more and in semesters with greater energy drink use, sleep quality was lower. There were no differences in sleep quality by gender, person-mean sleep quantity, semester, or semester-mean energy drink use.

Days with binge drinking were associated with lower sleep quality that night (Aim 2, Model B). With binge drinking in the model, the daily-level effects of weekend, sleep quantity, and energy drink use remained. In addition, students who binge-drank more on average evidenced greater sleep quality; there were no effects of semester-mean binge drinking.

Next-Day Tiredness

Results regarding next-day tiredness are shown in the last two columns of Table 2. Days with energy drink use were associated with greater next-day tiredness (Aim 1, Model A). Students reported feeling less tired on weekends and after sleeping longer. In Model A, gender and person-mean energy drink use were associated with greater next-day tiredness. That is, women and students who used more energy drinks than other students reported more tiredness. There were no differences based on person-mean sleep quantity or semester-mean energy drink use. Tiredness increased across semesters and semester-mean sleep quantity was associated with less next-day tiredness. In other words, tiredness was less in semesters during which students slept more hours.

Days with binge drinking were associated with greater next-day tiredness (Aim 2, Model B). With binge drinking in the model, the previously described daily-level effects of weekend, sleep quantity, and energy drink use remained. There were no effects of person-mean or semester-mean binge drinking.

Interactions

Interactions in Model C, to address Aim 3, were not significant and are not shown.

Discussion

These analyses provide a novel window into the naturally occurring ebbs and flows of college students' energy drink use, binge drinking, sleep, and next-day tiredness. Across 25,000+ sampled days (≤56 per person), the average nightly sleep was 7.6 hours, with fewer hours of sleep on weekdays than weekend days, similar to prior research results (Buboltz, Brown, & Soper, 2001; Galambos et al., 2009; Pilcher & Ott, 1998; Trockel, Barnes, & Egget, 2000). Sleep quality was rated as slightly above average (4.45), somewhat lower than but similar to prior results using this measure with students (Hawkins & Shaw, 1992; Pilcher, Lambert, & Huffcutt, 2000; Pilcher & Ott, 1998). Tiredness was a common but by no means ubiquitous experience; students reported being moderately (22%), quite a bit (11%), or extremely (5%) tired on about 38% of days. Almost half the sample reported energy drink use on at least one sampled day across the four semesters and almost 1 in 5 participants reported both energy drink use and binge drinking on at least one day.

This real-world study documents that consumption of energy drinks predicts sleeping fewer hours, lower quality of sleep, and greater next-day tiredness, even after controlling for typical energy drink use for each person as well as between- and within-person levels of binge drinking. Caffeine may contribute to already high levels of sleep debt and, conversely, may be used to combat sleep deprivation and tiredness. This stimulation-sedation loop (Lund et al., 2010; Wong, Robertson, & Dyson, 2015) and expectancies/motives for caffeine exposure (Huntley & Juliano, 2012) require additional research in various populations.

Males reported longer sleep and less tiredness than females, similar to some (Buboltz et al., 2001; Galambos, Howard, & Maggs, 2011) though not all prior research (Carney, Edinger, Meyer, Lindman, & Istre, 2006; Hawkins & Shaw, 1992). Prior research in this sample helps to explain gender differences; women spent more time on academics and employment than men (Greene & Maggs, 2015), and binge drinking increased across the second- through fourth-year periods studied here (Howard et al., 2015).

Observed daily-level and person-level links of energy drink use with sleep quality and next-day tiredness were similar. People who used more energy drinks, on average, reported lower sleep quality and more next-day tiredness in general; this link was observed within-persons across days as well. Days with greater energy drink use were associated with lower sleep quantity, though average energy drink use did not predict sleep quantity on average. For binge drinking, however, results for sleep quality differed across levels of analysis. Persons who binge drank more often reported greater sleep quality on average, but sleep quality was lower on nights after binge drinking than on nights following non-binge drinking days. Differential time use may help to explain these results as lighter drinkers may spend more work, study, or activity time that competes with sleep. We have previously observed differences between levels in associations of academic time use with affect; students report less positive and more negative affect on days and during semesters when they spend more time on academics, but students who spend more time on academics across college report more positive and less negative mood (Greene & Maggs, 2014).

Strengths and Limitations

This study is one of the first and largest studies to examine links of binge drinking and energy drink use with sleep and tiredness. It captures naturally occurring college life experiences over 25,000 days from an ethnically diverse sample of male and female college students followed across four semesters spanning two years. The within-person design across days and semesters controls for all stable between-person differences that plague cross-sectional designs.

Important limitations include, first, the focus on a single college serving primarily traditional-aged full-time students living in a college town. Second, all sleep data are self-reported. Future work could use validated sleep diaries with actigraphy to assess sleep in greater depth. Third, data on other caffeine consumption, exact caffeine content of energy drinks consumed, and exact timing of consumption of energy drinks and their pharmacological overlap would be useful for future analyses. Fourth, no data were available on medication use (e.g., sleep aids, study aids, or medical and non-medical drugs) that may affect sleep or interact with caffeine and/or alcohol. Finally, next-day tiredness may reflect fatigue associated with non-sleep-related conditions (e.g., mental or physical illness), rather than sleepiness due to insufficient sleep or poor quality sleep.

Implications and Future Directions

After consuming energy drinks or binge drinking, college students sleep less and more poorly, and are more tired the next day. Policies to improve student well-being could aim to reduce the availability of energy drinks and improve labeling. Interventions and assessments for well-being could include a greater focus on alcohol, energy drinks, and sleep.

Future daily level research should extend to diverse young adult groups beyond full-time four-year-college attenders. Cross-cultural influences on sleep and on motivations to use alcohol and caffeine need to be understood. Additional outcomes of interest may include the impact of caffeine and alcohol on next-day and longer-term academic performance and health behaviors (e.g., activity level, nutrition). Naturalistic research on the ecology of sleep can then suggest possible innovative avenues for environmental, policy, or individual interventions to promote health and well-being.

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Table 1

Characteristics of the Analytic Sample

	M	SD	Observed range
Level 3: Person-level constructs			
Male gender	0.48	0.50	0-1
Person-mean sleep quantity (hours)	7.55	0.88	5.29-12.25
Person-mean energy drink use	0.05	0.09	0-0.67
Person-mean binge drinking	0.07	0.10	0-0.64
Level 2: Semester-level constructs			
Semester-mean sleep quantity (hours)	7.52	1.11	0-13.33
Semester-mean energy drink use	0.05	0.12	0-1
Semester-mean binge drinking	0.07	0.12	0-0.64
Level 1: Daily-level constructs			
Sleep quantity (hours)	7.50	2.06	0-15.75
Energy drink use	0.04	0.21	0-1
Binge drinking	0.07	0.26	0-1
Sleep quality	4.45	1.33	1-7
Next-day tiredness	2.28	1.16	1-5

Note. Level 3 $N = 667$ people; Level 2 $N = 2,354$ person semesters; Level 1 $N = 25,616$ person days.

Table 2

Multilevel Model Coefficients for Sleep Quantity, Sleep Quality, and Next-Day Tiredness

	Sleep Quantity (hours)		Sleep Quality (1-7)		Next-Day Tiredness (1-5)	
	Model A	Model B	Model A	Model B	Model A	Model B
	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)
Intercept	7.31*** (0.05)	7.28*** (0.05)	4.51*** (0.05)	4.46*** (0.05)	2.32*** (0.04)	2.29*** (0.05)
Level 3: Person-level						
Male gender	0.25*** (0.06)	0.26*** (0.06)	-0.07 (0.06)	-0.07 (0.06)	-0.24*** (0.06)	-0.24*** (0.06)
Person-mean sleep quantity	—	—	-0.02 (0.04)	-0.02 (0.04)	-0.04 (0.04)	-0.04 (0.04)
Person-mean energy drink use	0.44 (0.40)	0.39 (0.40)	-0.91* (0.36)	-1.07** (0.37)	0.95** (0.33)	0.81* (0.33)
Person-mean binge drinking	—	0.66 (0.41)	—	0.74* (0.36)	—	0.38 (0.33)
Level 2: Semester-level						
Semester (linear)	-0.04** (0.01)	-0.04** (0.01)	-0.01 (0.01)	-0.01 (0.01)	0.03** (0.01)	0.03** (0.01)
Semester-mean sleep quantity	—	—	-0.04** (0.02)	-0.04** (0.02)	-0.05** (0.02)	-0.05** (0.02)
Semester-mean energy drink use	-0.39 (0.21)	-0.41* (0.21)	0.21 (0.13)	0.21 (0.13)	-0.16 (0.13)	-0.16 (0.13)
Semester-mean binge drinking	—	-0.17 (0.26)	—	0.04 (0.16)	—	0.17 (0.17)
Level 1: Daily-level						
Weekend day	0.39*** (0.02)	0.43*** (0.02)	0.06*** (0.01)	0.07*** (0.01)	-0.07*** (0.01)	-0.08*** (0.01)
Sleep quantity	—	—	0.12*** (0.003)	0.12*** (0.003)	-0.06*** (0.003)	-0.06*** (0.003)
Energy drink use	-0.40*** (0.07)	-0.37*** (0.07)	-0.10** (0.04)	-0.09* (0.04)	0.11** (0.03)	0.09** (0.03)

	Sleep Quantity (hours)		Sleep Quality (1-7)		Next-Day Tiredness (1-5)	
	Model A	**Model B**	**Model A**	**Model B**	**Model A**	**Model B**
	B (SE)	**B (SE)**	**B (SE)**	**B (SE)**	**B (SE)**	**B (SE)**
Binge drinking	—	-0.32*** (0.05)	—	-0.08** (0.03)	—	0.12*** (0.02)

Note. Level 3 N = 667 people; Level 2 N = 2,354 person semesters; Level 1 N = 25,616 person days.

* p<.05,

** p<.01,

*** p<.001