Who Exercises and When? The Effects of Intra- and Inter-Individual Variation on the Likelihood and Duration of Exercise

By

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Abstract

The current study examined the ability of inter- and intra-individual characteristics to predict the likelihood and duration of exercise as well as mood. One hundred forty-nine undergraduates (mean age = 19.11; 53% women; 79.19% White) participated in a six-day study. Online surveys measured participants' self-reported exercise duration, emotion-regulation ability, hostility, depressive symptoms, sleep quality, anger, and mood. Higher depressive symptoms predicted higher odds of exercise. Higher hostility predicted lower odds of exercise but, on days when participants did exercise, higher duration of exercise. Higher anger predicted lower odds of exercise. Better sleep quality predicted higher positive and lower negative mood but only for older participants. Higher depressive symptoms predicted higher negative and lower positive mood. Results suggest an indirect relationship between hostility and heart disease may exist, via the relationship of hostility to exercise. Further research should investigate causality and the effectiveness of exercise interventions that foster exercise-conducive environments.

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One-third of American adults have at least one form of heart disease (Lloyd-Jones et al., 2008). The economic impact of heart disease-related healthcare costs and lost productivity from heart disease morbidity and mortality totaled $475.3 billion in the U.S. in 2009 (Lloyd-Jones et al.). Individuals with heart disease often have lower health-related quality of life than do individuals without heart disease (Ford et al., 2008; Hayes, Denny, Keenan, Croft, & Greenlund, 2008). Therefore, is it is important to develop our understanding of the relationships among risk factors to improve heart disease prevention. Identifying risk factors is only the first step; understanding the relationships between risk factors may guide researchers and clinicians in developing better interventions that could be tailored to individuals' needs.

Heart disease prevention efforts benefit from research on well-known behavioral risk factors, such as smoking/tobacco use, sedentary lifestyle, and high-calorie, high-fat diets (Lloyd-Jones et al., 2008). In addition, over the last 30 years, hostility has emerged as a psychological risk factor for heart disease (Diamond, 1982; Matthews, 1982). More recently, a relationship between sleep and heart disease also has been detected (e.g., Buxton & Marcelli, 2010), although the nature of this relationship is not well-established. The next step in improving intervention efforts is to understand the inter-relations among both well-established and newly-investigated risk factors. For example, though the causal, or at least temporal, directions of the relationships remains unclear, hostility and sleep have both been associated with exercise (e.g., Brand et al., 2010; Hassmén, Koivula, & Uutela, 2000. Although there is extensive research on each of these risk factors, the utility of the research is limited by methodology. Specifically, studies of cardiovascular risk factors examine relationships at the aggregate, inter-individual level. Although risk factors are undoubtedly important in the aggregate, upstream risk factors may be modifiable, exerting influence on daily decisions about risky health behaviors. In particular, there is evidence to suggest that two factors, hostility and sleep quality, are related to heart disease both directly and possibly through an upstream relationship with health behaviors – specifically, smoking and exercise.

Hostility and Heart Disease

Hostility is a multi-faceted personality trait that is generally characterized by angry emotional reactions (Jackson & Finney, 2002). It can be expressed behaviorally, either directly (i.e., physical violence against others, oppositional behavior, verbal aggression) or indirectly through roundabout aggression (e.g., gossip, pranks) or undirected aggression (e.g., temper tantrums, slamming doors); cognitively, either by resentment or suspicion; and emotionally, through irritability (Buss & Durkee, 1957). Individuals who are high in trait-level hostility also tend to have more frequent and more intense anger than do individuals who are low in trait hostility (Eckhardt, Norlander, & Deffenbacher, 2004).

Evidence of the relationship between hostility and heart disease emerged from research on Type A personality and occupational stress (Rosenman & Friedman, 1958). Briefly summarized, Friedman and Rosenman (1959) theorized that individuals had three distinct behavior partterns. The "Type A" behavior pattern (Friedman & Rosenman) was exemplifed by "competitiveness, time urgency, speed and impatience, and potential for hostility" (Diamond, 1982, p. 425). The "Type B" behavior pattern was exemplified by a "relative absence of drive, ambition, sense of urgency, desire to compete, or involvement in deadlines" (Friedman & Rosenman, p. 1286). "Type C" had similar characteristics to Type B but also included chronic anxiety or insecuity. These behavioral styles were found to predict heart health outcomes. Friedman and Rosenman found that 28% of men with the Type A behavior pattern had coronary heart disease (CHD), whereas only 3.6% of men with Type B behavior pattern, and only 4.3% of men with Type C behavior pattern had CHD. This difference could not be explained by the number of work hours, diet, or use of tobacco products. The Type A behavior pattern, therefore, was an independent predictor of CHD (Friedman & Rosenman).

As research on the link between Type A and heart disease progressed, it became apparent that hostility drove the relationship (Matthews, 1982). For example, among individuals with a family history of CHD, high hostility was associated with increased likelihood of personal history of heart-related medical procedures (e.g., coronary bypass surgery, angioplasty; Knox et al., 1998). Results of other studies suggest that higher hostility is associated with greater risk of heart disease (Haukkala, Kontinen, Laatikainen, Kawachi, & Uutela, 2010; Siegman, Townsend, Civelek, & Blumenthal, 2000) and heart disease-related mortality (Everson et al., 1997).

Efforts to understand the mechanism linking hostility to cardiovascular disease have often focused on stress-reactivity. Individuals with higher hostility have been shown to exhibit greater cardiovascular reactivity to both social and nonsocial stressors than individuals with lower hositility have been, even after controlling for age, body mass index, smoking status, medication status, and baseline cardiophysiological variables (Brydon et al., 2010). Individuals with high trait hostility have been shown to exhibit higher systolic blood pressure (SBP) during negative social interactions than during nonsocial activities, whereas individuals with low trait hostility were not shown to exhibit this pattern (Brondolo et al., 2009). The implication of this finding is that individuals with high hostility may be more sensitive to unpleasant social interaction and also exhibit cardiovascular characteristics that put them at greater risk for heart disease (Brondolo et al.). Even when seeking social support, individuals with high hostility have been found to experience more cardiovascular stress than individuals with lower hostility have been (Holt-Lunstad, Smith, & Uchino, 2008). Furthermore, individuals with high hostility may not receive the cardiac benefits that intimacy can provide (Vella, Kamarck, & Shiffman, 2008).

Therefore, it is possible to conceptualize hostility as a pervasive personality characteristic that is associated with heart disease, in part, through its association with cardiovascular stress in both interpersonal and solitary situations.

Hostility and Health Behavior

Hostility is an important personality characteristic to investigate because of its well-established connection with heart disease and because of its relatively newly-discovered, indirect association with heart disease, via hostility’s relationship with health behaviors, such as smoking and exercise. Results from a recent path analysis from a longitudinal study of older adults suggested that cognitive vulnerability, defined in the study as anger and hostlity, precedes CHD via psychological distress (including sleep problems), poor health habits, and metabolic syndrome (Vitaliano et al., 2002). There is robust evidence to suggest that individuals who are higher in hostility tend to smoke more (Calhoun, Bosworth, Siegler, & Bastian, 2001; Scherwitz et al., 1992; Siegler et al., 2003). In a study of cariovascular health and hostility among young people, Scherwitz et al. found that smoking was associated with higher hostility, but higher hostility was not associated wih higher blood pressure. Thus, it appears that hostility may be related to heart disease through its relationship to cardiovascular risk behaviors, and the relationship may strengthen with age.

Whreas there is robust support for the existence of a relationship between smoking and hostility, the support for a relationship between exercise and hostility is still being established; no consisistent relationship has been observed. In cross-sectional studies, results have sugested that higher hostility is associated with less-frequent exercise (Hassmén et al., 2000), more-frequent exercise (Allen, Markovitz, Jacobs, & Knox, 2001), or neither (Calhoun et al., 2001; Everson et al., 1997; Scherwitz et al., 1992).

Although various relationships between hostility and exercise have been found in cross-sectional studies, results from cardiac rehabilitation studies have shown that exercise interventions for individuals with heart disease help to reduce hostility (Lavie & Milani, 1999; Lavie & Milani, 2005; Silberman et al., 2010), suggesting that exercise may be upstream of changes in hostility. However, the opposite may also be true; results of a 30-year longitudinal study suggest that, from college to mid-life, an increase in hostility predicted avoidance of exercise (Siegler et al., 2003). Together, these data suggest that the relationship between hostility and exercise is complex, possibly bidirectional, and may be related to other, unmeasured variables. Thus, in addition to being unable to determine whether exercise is associated with higher or lower hostility, we also are unable to discern if there is a causal relationsip – and in which direction – when a relationship between exercise and hostility is observed. Given the inconsistency among cross-sectional and longitudinal studies, as well as the varying conceptualizations of the relationship between exercise and hostility, it is not possible distinguish a general trend in the relationship between hostility and exercise.

Health Behaviors and Mood Regulation

We know from empirical evidence that people use health behaviors to regulate emotion (e.g., Pritchard, Wilson, & Yamnitz, 2007). According to Robert Thayer's theory, mood is associated with the body's level of physical arousal, and mood regulation involves behaviors that change both energy level and tension (Thayer, Newman, & McClain, 1994). Therefore, the relationship between hostility and health behaviors might be most apparent during times of high negative affect, high tension, and low energy.

Related to this theory, Hamilton and colleagues (2008) have suggested that sleep is a biobehavioral resource and that higher quality sleep predicts lower next-day negative affect and fatigue and higher next-day positive affect; therefore, because sleep predicts mood and energy levels, sleep may play an upstream role in mood regulation. It is also possible that optimal mood and energy may vary according to individual characteristics, such as hostility or degree to which a person engages in Type A behavior (Thayer et al., 1994), and thus trait hostility may influence individuals' choices of mood-regulatory behaviors. For example, there is evidence to suggest that individuals with high hostility are more likely than others to smoke (e.g., Allen et al., 2001; Calhoun et al., 2001; Scherwitz et al., 1992; Siegler et al., 2003). The synergistic effect of sleep and hostility on health behaviors has yet to be studied at the daily, intra-individual level; therefore, whether poor-quality sleep precedes higher levels of negative affect, particularly anger, and, thus, more risky choice of health behaviors, remains unknown.

Hostility and Sleep

As with exercise and hostility, there is limited research on the relationship between sleep and hostility. Because the association between sleep and hostility has been relatively uninvestigated, the end goal of much of the extant research on sleep and hostility has been to find an association between hostility and specific physiological parameters, not to establish temporal precedence. For example, a current focus of research on the sleep-hostility relationship is nocturnal blood pressure. Associated with lower risk of both hypertension (Loredo, Nelesen, Ancoli-Israel, & Dimsdale, 2004) and cardiovascular mortality (Ohkubo et al., 2002), nocturnal dipping (the normative reduction of blood pressure during sleep) is traditionally considered a sign of good cardiovascular health. In addition, there is evidence to show that nocturnal dipping is associated with sleep quality. For example, greater nocturnal blood pressure dipping has been associated with objective measures of sleep quality, including more time spent in Stage 4 sleep (Loredo et al., 2004), less time spent awake after sleep onset (Loredo et al.), shorter sleep onset latency (Mezick et al., 2010), and less sleep fragmentation (Mezick et al.). Hostility has been associated with a higher sleep-wake mean arterial pressure ratio, indicating that people who were more hostile had less nocturnal BP dipping (Mezick et al.; Shapiro, Goldstein, & Jamner, 1996). Hostility, therefore, is cross-sectionally associated with lower objective sleep quality.

A potential problem with cross-sectional research in any area is that researchers often make an assumption about the direction of the relationship. Even though researchers have acknwoledged the temporal limitation of cross-sectional research, the language of authors' interpretations and construction of analyses show implicit assumptions about the causal direction. In terms of sleep and hostility, it is assumed that hostility causes poor sleep quality rather than vice versa (Granö, Vahtera, Virtanen, Keltikengas-Järvinen, & Kivimäki, 2008; Ireland & Culpin, 2006). However, sleep quality could also predict hostility. The direction of the relationship between hostility and sleep, therefore, remains unkown.

In addition to the existence of unilateral trend in the cross-sectional research, there is also tendency toward analysis at the level of inter-individual variation. To our knowledge, there is no extant research on the intra-individual relationship between daily sleep quality and daily anger levels. Although individuals may have general sleep patterns and an overall level of trait hostility, it is likely that there are daily fluctuations in both sleep and anger. It is possible that hostile thoughts and anger may disturb sleep; however, it is also possible that disrupted sleep decreases the ability to regulate emotion, reducing ability to manage anger. Consistent with that assumption are multiple studies showing that, after nights of disturbed sleep, individuals report decreases in emotional and cognitive functioning (Killgore et al., 2008). Because anger and sleep have not been studied at a daily level, whether a night of restorative sleep is associated with less anger during the following day – or vice versa – remains unknown.

Sleep and Health Behavior

Like hostility, sleep also has been associated with smoking and exercise. Insomnia symptoms have been reported more often among adults and adolescents who are current smokers than among those who are not (Nakata et al., 2008; Siomos, Avagianou, Theodorou, & Angelopoulos, 2010). However, smoking cessation has been associated with decreases in sleep quality (Aubin, Luthringer, Demazières, Dupont, & Lagrue, 2006; Moreno-Coutiño, Calderón-Ezquerro, & Drucker-Colín, 2007; Prosise, Bonnett, Berry, & Dickel, 1994). One possible explanation for the increased waking after sleep onset and difficulty initiating sleep is the effect that nicotine has on alertness (Takahashi et al., 2005). On the other hand, it is also possible that smokers use nicotine to manage depressive symptoms and sleep disturbance, which may have preceded nicotine use (Moreno- Coutiño et al.). Although there is no clear explanation for the relationship between sleep and smoking, there is ample evidence to support the existence of a relationship between the two.

As with the evidence from research on sleep and smoking, the research from sleep and exercise allows us to come to the conclusion that a relationship between the two variables likely exists; however, whether the relationship is bidirectional (i.e., exercise improves sleep and sleep increases exercise frequency/duration) or unidirectional (i.e., exercise improves sleep) remains unknown. Results from a longitudinal, observational study suggested that individuals who exercise more have better subjective sleep (Brand et al., 2010). As with the relationship between exercise and hostility, most studies on sleep and exercise have conceptualized exercise as an intervention resource; exercise interventions have been shown to successfully improve both objective and subjective sleep parameters (Buman, Hekler, Bliwise, & King, 2010; King et al., 2008; Kubitz, Landers, Petruzzello, & Han, 1996; Youngstedt, O'Connor, & Dishman, 1997). Although exercise can improve sleep, there has not been research on whether better sleep quality precedes more-frequent exercise or longer exercise duration.

Upstream Role of Sleep

Whereas various groups of researchers have conceptualized sleep problems as being downstream – cross-sectionally (Granö et al., 2008), cross-sectionally and retrospectively (Ireland & Culpin, 2006), and temporally (Vitaliano et al., 2002) – it is also possible that sleep is upstream of daily anger, health behaviors, and heart disease. For example, Hamilton, Catley, and Karlson (2007) conceptualized adequate restorative sleep as a biobehavioral resource that can help people cope with chronic pain. They found that individuals who reported having poor sleep quality also had more negative affect and less positive affect in the presence of pain than did individuals who reported having restorative sleep. Hamilton et al. (2008) found that restorative sleep preceded lower negative affect and fatigue as well as higher positive affect. To our knowledge, this conceptualization of sleep has not been applied to the study of hostility, health behaviors, and heart disease.

Summary

Although health behaviors such as smoking and exercise have been conceptualized as emotion regulation strategies (e.g., Thayer et al., 1994), to our knowledge, sleep and hostility have not been modeled as existing upstream of the relationship between health behaviors and emotion regulation, nor have these relationships been studied at the intraindividual (i.e., daily) level.

Study 1: Exploratory Factor Analysis of Health Behaviors as Emotion Regulation Strategies

Before conducting the current study, we conducted a pilot test of a measure of emotion regulation strategies (Thayer et al., 1994). The main goals for collecting pilot data were 1) to replicate Thayer et al.'s findings that people use health behaviors to regulate emotion, 2) to determine whether it was useful to ask about the frequency of those behaviors, as opposed to using a *yes/no* format, 3) to determine whether there were discernable patterns of health behaviors, using exploratory factor analysis (EFA), a statistical improvement over principal component analysis (Costello & Osborne, 2005; Snook & Gorsuch, 1989), which Thayer et al. used with their Mood Regulation Questionnaire, and 4) to assess whether engagement in various health behaviors varied according to people's hostility and sleep quality.

Method

The current study was part of a larger study to investigate the cross-sectional, retrospective relationship among sleep quality, trait hostility, and health behaviors. Participants completed all questionnaires online, remotely.

Participants. The study included 146 men (M age = 20.2, SD = 2.1) and 93 women (M age = 19.5, SD = 1.4). Participants were White (83.1%), Asian/Pacific Islander (6.7%), of mixed ethnicity (5.1%), Black/African American (3.1%), Middle Eastern (1.8%), Native American (.4%), Latino (.4%).

Materials.

Health behavior/emotion regulation strategies. Participants completed a modified version of the Mood Regulation Questionnaire (Thayer et al., 1994). Participants indicated how many times they had engaged in various behaviors (e.g., smoking cigarettes, exercising, listening to music) to improve a bad mood (27 items), increase energy (13 items), and reduce anxiety (19 items). Two modifications were made to the orginial questionnaire. First, participants were asked about the frequency of behaviors instead of whether they had engaged in various behaviors. In other words, we collected frequency data rather than dichotomous (i.e., *yes/no*) data. Second, participants were asked about their engagement in behaviors "today," "yesterday," and "in the last week" (as opposed to being asked about behaviors at a single time point). These modifications were designed to provide a rough indication about the daily variablity in these behaviors, a necessary component of daily process research.

Trait hostility. Trait hostility was measured with an abbreviated (20-item) version of the Cook-Medley hostility scale (Barefoot, Dodge, Peterson, Dahlstrom, & William, 1989; Cook & Medley, 1954), a subscale of the Minnesota Multiphasic Personality Inventory-2 (MMPI-2; Butcher & Megargee, 2001).

Results

Goals 1 and 2. The first goal was to confirm that people use health behaviors to regulate emotion. The second goal was to determine whether it would be more useful to ask about behavior frequency than to ask only whether people engaged in the various behaviors. Descriptive statstics presented in Tables 1-3 were used to inform Goals 1 and 2. As can be seen in Tables 1-3, participants endorsed a wide variety of strategies for regulating emotions. Importantly, at least some participants reported using health behaviors such as smoking cigarettes and exercising, our behaviors of interest, as a means of reducing negative mood, increasing energy, and decreasing anxiety. We found that the modal frequency for each behavior was zero: for behaviors used to change a bad mood, on average, 76.1% (SD = 12.4%) of participants reported not engaging in each behavior; for behaviors used to increase energy, on average, 74.7% (SD = 12.2%) of participants reported not engaging in each behavior; and for behaviors used to reduce anxiety, on average, 81.4% (SD = 8.0%) of participants reported not engaging in each behavior. Because of the large proportion of zeroes for behavior frequency, we would not lose much information from using either a dichotomous response or ordinal response (0, 1, 2, >2 times) option.

Table 1

Frequencies and Ranges for Strategies to Change a Bad Mood

Item	*N*	*n* (*f* = 0)	*n* (*f* = 1)	*n* (*f* = 2)	Upper Bound
Call, talk to, or be with someone	232	129	59	28	5
Try to be alone	232	164	48	10	10
Control thoughts	232	112	63	25	20
Evaluate/analyze situation	232	145	49	23	20
Try to put feelings into perspective	231	140	54	17	34
Exercise: Frequency	232	194	23	7	120
Exercise: Minutes	232	194	—	—	120
Listen to music	232	135	33	27	40
Rest, take a nap, close eyes	232	186	33	4	30
Engage in religious/spiritual activity	232	206	14	5	15
Engage in emotional activity	232	212	8	6	5
Change location	232	175	30	15	8
Tend to chores	232	176	36	14	6
Engage in hobby	232	172	34	12	23
Engage in pleasant/fun activities	232	136	51	18	8
Avoid thing/person causing mood	232	161	51	12	5
Watch TV/movie	232	166	42	11	15
Use humor	232	148	40	17	30
Engage in self-gratification	232	190	27	7	12
Go shopping	232	215	13	1	12
Use relaxation techniques	231	189	20	11	20
Eat something	231	171	36	12	10
Drink coffee/caffeinated beverage	231	203	16	6	7
Smoke cigarettes: Frequency	232	209	10	3	8
Smoke cigarettes: Number	232	209	6	2	8
Read or write	232	205	15	7	20
Have sex	232	211	12	3	10
Engage in stress management	232	179	25	15	20
Take shower/bath, splash water on face	232	188	29	10	7

Table 2

Frequencies and Ranges for Strategies to Increase Energy and Alertness

Item	*N*	*n* (*f* = 0)	*n* (*f* = 1)	*n* (*f* = 2)	Upper Bound
Rest, take nap, close eyes	231	146	70	10	15
Drink coffee/caffeinated beverage	231	151	55	14	8
Listen to music	231	132	51	20	15
Evaluate/analyze situation	231	190	25	8	5
Eat something	231	133	54	19	6
Control thoughts	231	183	28	10	25
Change location	231	180	31	13	4
Smoke cigarettes: Frequency	231	213	8	4	5
Smoke cigarettes: Number	231	213	6	5	5
Use relaxation techniques	231	194	20	9	10
Call, talk to, or be with someone	231	174	26	18	5
Go outside	231	152	43	22	15
Watch TV/movie	231	203	16	3	5
Do something to keep busy	231	152	34	24	7

Table 3

Frequencies and Ranges for Strategies to Reduce Anxiety and Tension

Item	*N*	*n* (*f* = 0)	*n* (*f* = 1)	*n* (*f* = 1)	Upper Bound
Call, talk to, or be with someone	231	155	35	17	10
Exercise: Frequency	231	177	40	5	14
Exercise: Minutes	231	174	—	—	180
Use relaxation techniques	231	184	23	12	20
Rest, take a nap, close eyes	231	186	33	3	4
Listen to music	231	149	38	24	20
Control thoughts	231	172	25	16	15
Eat something	231	194	18	6	6
Tend to chores	231	190	21	9	4
Engage in hobby	231	180	28	9	5
Engage in emotional activity	231	208	13	3	8
Engage in nervous behavior	231	173	21	18	60
Go shopping	231	216	8	2	7
Watch TV/movies	231	186	22	12	8
Engage in stress management	231	179	31	13	6
Read or write	231	208	12	7	5
Take shower/bath/Jacuzzi, splash water on face	231	185	35	5	5
Smoke cigarettes: Frequency	231	205	11	5	8
Smoke cigarettes: Number	231	205	6	7	8
Have sex	231	215	9	5	5
Engage in religious/spiritual activity	231	208	10	9	9

Goal 3. The third goal was to explore whether an EFA (as opposed to a principal component analysis) with our data would yield a different factor structure from Thayer and colleagues'. After reviewing behavior frequencies, we collapsed participants' response data into ordinal categories (0, 1, 2, >2 times). We used Mplus 6.1 (L.K. Muthén & Muthén, 2010) to conduct an EFA (Table 4) with the mean-adjusted weighted least-squares estimator WLSM and promax (i.e., oblique) rotation. We did not find interpretable factors for strategies to change a bad mood, increase energy, or decrease anxiety.

Table 4

Factor Loadings for Exploratory Factor Analysis with Promax Rotation of Thayer's Strategies to Improve a Bad Mood

	Factor				
Item	1	2	3	4	5
Control thoughts	***0.55***	0.02	0.29	0.22	0.24
Evaluate or analyze the situation	***0.59***	0.34	0.18	-0.34	-0.08
Try to put feelings in perspective	***0.88***	0.09	-0.02	-0.29	-0.09
Try to be alone	-0.03	***0.39***	0.05	-0.09	0.03
Engage in religious/spiritual activity	0.26	***0.45***	-0.02	-0.08	0.28
Avoid thing (person) causing the bad mood	0.32	***0.40***	-0.01	-0.39	0.19
Call, talk to, or be with someone	0.22	0.26	***0.61***	0.34	0.10
Listen to music	0.04	-0.07	***0.43***	-0.20	0.13
Engage in emotional activity (e.g., cry, scream)	-0.05	**0.44**	***0.79***	-0.06	0.10
Change location	-0.05	-0.10	***0.47***	-0.04	**0.44**
Engage in hobby	0.07	0.14	***0.76***	-0.35	-0.25
Engage in pleasant (fun) activities	0.09	-0.28	***0.46***	-0.24	0.08
Take shower/bath or splash water on face	-0.13	0.28	***0.41***	-0.27	0.04
Exercise	0.24	0.06	0.11	***-0.62***	-0.10
Rest, take a nap, close eyes, or sleep	0.04	0.20	-0.02	***-0.62***	0.16
Watch TV (movie)	-0.05	-0.03	0.35	***-0.59***	-0.07
Go shopping	0.19	0.20	-0.10	***-0.75***	0.14
Drink coffee or other caffeinated beverage	-0.17	0.21	0.03	***-0.58***	**0.44**
Read or write	0.12	0.03	-0.01	***-0.44***	0.23
Tend to chores	0.05	-0.08	-0.08	**-0.44**	***0.53***
Engage in self-gratification (e.g., pamper oneself)	0.01	0.28	0.00	-0.32	***0.55***
Use relaxation techniques	0.04	**0.36**	0.09	0.13	***0.86***
Eat something	0.10	0.23	-0.05	-0.18	***0.56***
Smoke cigarettes	-0.27	0.07	0.08	**-0.37**	***0.48***
Have sex	-0.17	0.27	0.12	-0.04	***0.68***
Engage in stress management activities (e.g., get organized)	0.24	-0.22	-0.16	-0.12	***0.62***
Use humor	0.21	-0.04	0.22	-0.16	0.34

Note. Factor loadings > |.35| are in boldface. Primary loadings are in italics. 1 = Emotional/Cognitive, 2 = Solitary/Avoidant, 3 = Social/Fun, 4 = Active/Passive/Distracting, 5 = Self-Soothing/Stress Management

Goal 4. To examine cross sectional relationships among health behaviors of interest (i.e., smoking and exercise), hostility, and sleep quality, we first built a simple path diagram (Figure 1) in which our manifest variables shared a latent variable with variance fixed at 1. We modeled sex as a categorical outcome and both exercise minutes and cigarettes smoked as count variables (using a zero-inflated negative binomial distribution, discussed later). We then used tracing rules to calculate correlations among our variables of interest. Factor loadings are in Table 5, and a variance-covariance matrix is in Table 6.

Figure 1

Structural Equation Model of Manifest Variables in Pilot Study

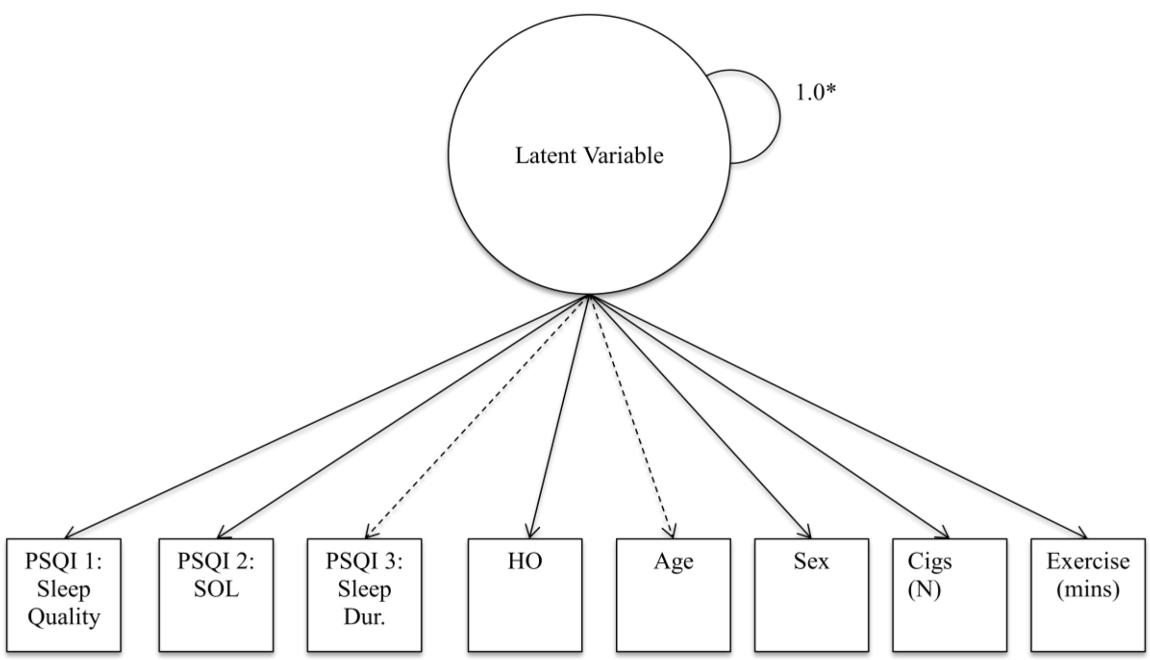


Table 5

Factor Loadings for Structural Equation Model in Study 1

Variable	λ	*p*
PSQI 1: Subjective Sleep Quality/Sleep Disturbance	.415	<.000
PSQI 2: Sleep Onset Latency	-.592	<.000
PSQI 3: Sleep Duration	-.276	.070
Hostility	.753	.002
Age	-.072	.679
Sex	.142	<.000
Exercise (minutes)	.180	.230
Cigarettes (number)	-.488	.014

Table 6

Variance-Covariance Matrix for Manifest Variables in Study 1

	1	2	3	4	5	6	7	8
1. Subjective Sleep Quality	0.17*							
2. Sleep Onset Latency	-0.25*	0.35*						
3. Sleep Duration	-0.11	0.16	0.08					
4. Hostility	0.31*	-0.45*	-0.21	0.57*				
5. Age	-0.03	0.04	0.02	-0.05	0.01			
6. Sex	0.06*	-0.08*	-0.04	0.11*	-0.01	0.02		
7. Exercise (mins)	0.07	-0.11	-0.05	0.14	-0.01	0.03	0.03	
8. Cigarettes (#)	-0.20*	0.29*	0.13	-0.37*	0.04	-0.07*	-0.09	0.24*

Note. *$p < .05$

Sleep parameters. As expected, subjective sleep quality was negatively correlated with sleep onset latency ($r = -.25$, $p < .05$). Sleep disturbance was unrelated to sleep duration.

Exercise. Exercise had a nonsignificant loading; therefore, we inferred that exercise was not associated with any of the other variables.

Sex and hostility. In a 2 (Sex) x 2 (Exercise Status, i.e., exercised at least 1 minute yesterday) analysis of variance (ANOVA) on hostility, there was a conditional main effect for sex [$F(1, 235) = 4.94$, $p = .03$], with women reporting higher hostility than men did.

Exercise and smoking. Minutes spent exericing and number of cigarettes smoked were not correlated.

Smoking and sleep. Better sleep quality was associated with smoking fewer cigarettes ($r = -.20$, $p < .05$).

Smoking and hostility. Higher hostility was associated with smoking fewer cigarettes ($r = -.37$, $p < .05$).

Sex and smoking. Women smoked fewer cigarettes than men did ($r = -.07$, $p < .05$).

Discussion

The results of the preliminary study suggest that some undergraduates do use health behaviors such as smoking and exercise as a way to change a bad mood. An EFA with our data, which are newer than those Thayer et al. published in 1994, did not show a difference in factors, which potentially could have been due to time or methodology (i.e., using exploratory factor analysis instead of principal component analysis). It is possible that gathering additional data or daily data may help to clarify the nature of strategies used to change a bad mood, increase energy, and decrease anxiety. Moreover, it would likely be useful to expand emotion regulation goals to include anger regulation, given that we consider trait hostility to exist upstream of health behavior tendencies.

Current Study

To our knowledge, no study has explored the relationships among hostility, sleep quality, and health behaviors at both the inter- and intra-individual levels (i.e., with multilevel/random effects modeling). Health behaviors such as smoking and exercise are likely to have daily variability and may be used as methods of emotion regulation. It is possible that emotions may become dysregulated following nights of poor sleep quality, and thus sleep and health behaviors might be related via health behaviors' use in emotion regulation. The purpose of the current study was to examine health behaviors' possible antecedents – trait hostility, state anger, and sleep quality – at the level of daily process.

Multilevel modeling can be used to disentangle the effects of interindividual variance (between person effects, or the "who") with intraindividual variance (within person effects, or the "when") and perhaps most interestingly, the intersection of the "who" and "when." Consistent with extant research and theories of emotion regulation, the current study was designed to test the following multilevel hypotheses:

Daily Process: Mood (High- and Low-Arousal Positive and Negative)

The first set of hypotheses was designed to test whether nightly sleep problems had an effect on daily mood that might necessitate mood regulation. In addition, these hypotheses tested whether people who were higher in dispositional hostility were more prone to sleep-related mood disruption.

Cross-level interactions. Our first hypothesis for mood was that a sleep-by-trait hostility interaction would qualify the relationship between sleep and mood, whereby individuals with higher levels of trait hostility would have greater mood disruption following nights of poor sleep. In other words, worse sleep would be followed by higher NEGHI and NEGLO and lower POSHI and POSLO, and the effect would be greater for individuals with higher levels of hostility.

Additional hypotheses were that the effect of sleep quality on the four mood outcomes would depend on sex, depressive symptoms, age, and emotion-regulation ability. Because women have been found to have more negative affect (Diener, Sandvik, & Larsen, 1985; Fujita, Diener, & Sandvik, 1991); because worse sleep quality is associated with lower positive affect (Steptoe, O'Donnell, Marmot, & Wardle, 2008) and higher negative affect (Sonnentag, Binnewies, & Mojza, 2008); and because, according to the circumplex model of affect (Russell, 1980), pleasure and displeasure are two poles of the emotional valence spectrum (*r* = -.71; Russell, 1979); we hypothesized that the effect of sleep on mood would depend on sex. Specifically, after nights of worse sleep quality, women would have particularly high NEGHI and NEGLO and particularly low POSHI and POSLO.

Because depressive symptoms are associated with sleep complaints (e.g., Buysse et al., 2007) – in fact, sleep disturbance is a diagnostic symptom of depression (American Psychiatric Association, 2000) – we hypothesized that mood would be particularly disrupted (i.e., NEGHI and NEGLO would be higher, and POSHI and POSLO would be lower) for individuals with higher depressive symptoms on days following worse sleep quality.

Because the results on the effect of age and mood are mixed, we did not have a prediction about the specific nature of the Sleep Quality-by-Age interaction. Because there is limited research on emotion regulation, we do not have a prediction about the specific nature of the potential Sleep Quality-by-Emotion Amplification and Sleep Quality-by-Emotion Reduction interactions.

Level 2: Does trait hostility predict mood? Individual differences in trait hostility were hypothesized to predict mood. Specifically, we proposed that higher hostility would predict higher NEGHI and NEGLO and lower POSHI and POSLO.

Level 2: Do other person-level covariates predict mood? In addition to our primary Level-2 hypothesis, we also hypothesized that sex, depressive symptoms, emotion-regulation ability (amplification and reduction; Hamilton et al., 2009), and age would predict POSHI, POSLO, NEGHI, and NEGLO.

Women in the U.S. have been found to experience emotion more intensely than men do (Diener et al., 1985; Fujita et al., 1991); therefore, we predicted that women would have higher levels of POSHI, POSLO, NEGHI, and NEGLO than men would.

There is ample evidence showing that people who have depression have worse mood; in fact, negative mood is a cornerstone of the American Psychiatric Association's (2000) criteria. Therefore, we predicted that higher levels of depressive symptoms would be associated with higher NEGHI and NEGLO and lower POSHI and POSLO.

There is limited research on the relationships of emotion amplification and reduction to mood (Hamilton et al., 2009). Therefore, our hypothesis was exploratory; we did not predict a specific direction for the association between emotion-regulation ability and any of the four mood outcomes.

Results of longitudinal and multicohort longitudinal studies have shown mixed results on the effect of age on positive and negative affect (PA and NA, respectively). Results of some longitudinal studies that include young adults in their samples – studies of particular relevance to the current investigation – have shown that NA decreases over time (Charles, Reynolds, & Gatz, 2001; Vaidya, Gray, Haig, Mroczek, & Watson, 2008; Watson & Walker, 1996). However, when the effect of age on mood was analyzed separately for men and women in a study that included young adults, age was not found to significantly affect NA for women. For men, the effect of age on NA depended on level of extraversion and marital status (Mroczek & Kolarz, 1998). Therefore, it appears that NA may decrease with age, but age may interact with other variables to influence NA.

Results of studies on the effect of age on PA have been even less consistent than the results of studies on age and NA. Results of one study showed the existence of a U-shaped relationship between age and PA for women (Mroczek & Kolarz, 1998). Results of another study showed a positive, linear relationship between age and PA, aggregated across the sexes for young adults (Vaidya et al., 2008). However, other studies have shown that, among young adults, PA does not change over time (Charles et al., 2001; Watson & Walker, 1996). Given the inconclusive findings on the effect of age on NA and PA, age was included as a predictor of POSHI, POSLO, NEGHI, and NEGLO, but we had no specific hypotheses about the directions of the possible associations.

Level 1: Does sleep quality predict mood? With regard to mood valence (i.e., positive or negative), research has shown that people have worse mood after nights of poor subjective sleep quality (Harvey, Stinson, Whitaker, Moskovitz, & Virk, 2008; Sonnentag et al., 2008) and better mood after nights of good subjective sleep quality (Harvey et al.; Steptoe et al., 2008). It appears as though sleep is more closely related to emotional valence than to emotional arousal (i.e., high or low); better sleep quality has been found to predict more high- (β = .196, p < .001) and low-arousal positive affect (β = .162, p < .01) and less high- (β = -.199, p < .001) and low-arousal negative affect (β = -.36, p < .001; Sonnentag et al., 2008). Therefore, we hypothesized that low-quality sleep "last night" would predict lower levels of high- and low-arousal positive mood (POSHI and POSLO, respectively) and higher levels of high- and low-arousal negative mood (NEGHI and NEGLO, respectively) "today." There is limited research on the relationship between sleep and low-arousal emotions, perhaps because high-arousal emotions are more distinct from each other than low-arousal emotions are (Zautra, Smith, Affleck, & Tennen, 2001). Therefore, we included four mood outcomes, POSHI, POSLO, NEGHI, and NEGLO, instead of collapsing the positive and negative moods, to contribute more information to the literature on low-arousal moods.

In addition to sleep quality, we also entered day of week into the model as a day-level covariate because evidence has shown that both mood (Cranford et al., 2006; Larsen & Kasimatis, 1990) and sleep quality (Tsai & Li, 2004) are better on weekend days than they are during the week. We tested the contribution of a dichotomous predictor of weekend (defined as Friday, Saturday, and Sunday; 1 = *yes*, 0 = *no*) to mood. We defined weekend as Friday through

Sunday because mood has been found to be best on Friday and Saturday (Larsen & Kasimatis; McFarlane, Martin, & Williams, 1988) and Friday afternoon through Sunday morning (Ryan, Bernstein, & Brown, 2010).

Daily Process: Exercise

Because results of the pilot study showed that only 9.9% of participants smoked cigarettes, we only investigated exercise as a health-behavior outcome in the current study. This set of hypotheses was designed to test whether "last night's" sleep disruption and "today's" anger would predict "today's" exercise duration, even after controlling for between-person differences in dispositional hostility. Additional between-person covariates we examined are age, sex, depressive symptoms, and emotion-regulation ability (amplification and reduction).

Level 2: Does hostility predict exercise? Our primary between-person hypothesis was that hostility would predict exercise. Because of the inconsistent findings in the literature (Allen et al., 2001; Calhoun et al., 2001; Hassmén et al., 2000), we did not have a prediction for the direction of the association (i.e., positive or negative) between hostility and exercise.

Level 2: Do other person-level covariates predict exercise? Additional between-person covariates we suspected might predict exercise were sex, age, depressive symptoms, and emotion-regulation ability. Consistent with previous findings on sex and physical activity (Lloyd-Jones et al., 2008; Schoenborn & Adams, 2010), we predicted that men would exercise more than women would. Research has shown that older people exercise less than younger people (Lloyd-Jones et al.; Schoenborn & Adams). We do not know if the same relationship between age and exercise applies among young people so we entered age as a predictor as well. Research has shown that people with more depressive symptoms exercise less (Brand et al., 2010; Hassmén et al., 2000); therefore, we predicted that higher levels of depressive symptoms would be associated with lower exercise duration. Because of limited research on emotion-regulation ability, we exploreed the relationship between exercise and both amplification and reduction, but we did not have a hypothesis about the direction – positive or negative – of these relationships.

Level 1: Do sleep quality and anger predict exercise? Our primary hypotheses were that "last night's" sleep quality and "today's" anger would predict "today's" exercise duration. Specifically, low-quality sleep would predict less exercise. Although we predicted that there would be a relationship between anger and exercise, results of previous studies have been inconsistent and, thus, we could not specify a direction of this relationship.

Level 1: Does day of week predict exercise? As with the predictions for mood, we entered weekend/weekday as a covariate, as participants' schedules likely varied between the week and weekend days and, thus, time spent exercising may have varied as a function of day type.

Method

Participants

Participants were 149 students (53% female) from the psychology participant pool at a large, public, Midwestern university. They ranged in age from 18 to 25 (M = 19.11, SD = 1.34). Most participants (79.19%) were White; 4.03% were of more than one ethnicity; 2.68% were Hispanic/Latino; 2.01% were Black; 1.34% were East Asian/Middle Eastern; and 10.74% did not report ethnicity.

Materials

Background information. Participants were asked to provide their sex, age, ethnicity, year in school, and parents' highest level of education.

Trait hostility. Trait hostility was measured with a modified version of the Cook-Medley hostility scale (Barefoot et al., 1989; Cook & Medley, 1954), a subscale of the

Minnesota Multiphasic Personality Inventory-2 (MMPI-2; Butcher & Megargee, 2001). The 20-item version used in the current study included the Cynicism, Hostile Affect, and Aggressive Responding subscales of the Cook-Medley hostility scale because these three scales were found to relate to coronary heart disease survival, whereas the other Cook-Medley subscales were not (Barefoot et al.). Chronbach's α was .753 for the 20-item Cook-Medley in Study 1. Four-year test-retest reliability has been high (r = .84; Shekelle, Gale, Ostfeld, & Paul, 1983).

State anger. Anger was measured with the well-established State Anger Scale (SAS; Spielberger, Jacobs, Russel, & Crane, 1983). The SAS includes 10 statements about anger as an emotional state. The intensity of anger associated with each statement is measured on a 4-point Likert-type scale from 1 (*not at all*) to 4 (*very much*). Test-retest reliability for a 7-10-day interval was low (r = .02, n.s.).

Mood. Participants indicated on a 7-point scale (0 = *none*, 2 = *slightly*, 4 = *moderately*, and 6 = *extremely*) the degree to which they felt 16 emotions "today," (e.g., *active, blue, calm, nervous).* The Mood Checklist in the current study is a combination of words from Larsen and Diener's (1992, as cited in Zautra et al., 2001) 16-item Mood Adjective Checklist and an abbreviated mood checklist that Hamilton et al. (2008) used. Two additional words, *passive* and *quiet*, were added to the current list. *Quiet* falls under the "deactivated" category in the circumplex model (Feldman Barrett & Russell, 1998). *Passive* was added because it is the opposite of *active*. One criticism of affect measures, such as the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988), is that they sometimes do not include word opposites. For example, PA and NA were relatively uncorrelated on the PANAS (Watson et al.), perhaps because opposite pairs of words were not included (e.g., *active* but no *passive* on the PANAS; Russell & Carroll, 1999).

The correlation for the fatigue adjectives (*tired, drowsy*) was moderate (*r* = .61; Hamilton et al., 2008). Test-retest reliability over a one-week interval was .73 for positive affect and .70 for negative affect (Hamilton et al., 2008; Zautra et al., 2001). In the aforementioned studies, the adjectives described affect, which can be considered a more general trend of inner experience, but in the current study, the adjectives are describing mood, which can be considered general feelings over the course of a day.

Health behavior/emotion regulation strategies. Participants completed a modified version of the Mood Regulation Questionnaire (Thayer et al., 1994), which was modified after Study 1. Because results from Study 1 indicated that the overwhelming majority of participants engaged in each behavior zero times each day, participants in the current study were asked whether they engaged in the various behaviors in a dichotomous fashion. Questions about anxiety-reducing health behaviors will be removed because of the problems encountered with the EFA in Study 1. Furthermore, results of Study 1 indicated that anxiety may not be relevant to the study of hostility and anger. Consistent with the decision to remove anxiety-reducing health behaviors was the decision to add questions about anger-reducing health behaviors. In the current study, the list of anger-reducing strategies was the same as the list of bad mood-improving strategies. In addition to adding anger-reducing strategies, we also asked participants if they engaged in each of the behaviors because it was “fun” or if they engaged in each of the behaviors without an emotional reason. It is possible that the interpreteablity of the factors in Study 1 was hampered by reporting problems. For instance, the endorsement of items such as “doing chores” might reflect the demand characteristics of the study, rather than an accurate report of behaviors used to regulate emotion. To reduce participant burden, we also changed the organization of the questionnaire so that, rather than asking participants about a list of strategies for each purpose, we provided a list of all strategies and ask participants to indicate all of the reasons they engaged in the behaviors.

Daily sleep quality and duration. Participants completed a daily sleep diary that included information about the previous night's sleep. Parameters measured were bedtime, wake time, sleep onset latency, number of nighttime awakenings, minutes of wake after sleep onset, time awake before rising from bed, nap time, and overall sleep quality. In addition, participants recorded alcohol or medication they used to help with sleep as well as any stimulants they used to increase energy and alertness. Sleep diaries like the one in the present study are used often (e.g., Taylor & Bramoweth, 2010).

Because the daily diary was dated, we were able to create a dichotomous variable, Weekend (Friday, Saturday, Sunday; 1 = *yes*, 0 = *no*).

Depressive symptoms. Participants completed the 21-item Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977), which measures depressive symptoms through questions about affect, somatic complaints, and interactions with others. The CES-D asks about the frequency of symptoms, using a scale from 0 (*Rarely or none of the time [<1 day]*) to 3 (*Most or all of the time [5-7 days]*). While using the CES-D's cutoff score may overestimate the prevalence of depression in a college student population, the measure has more discriminability in assessing the severity of symptoms, especially in students who report mild symptoms, than does the Beck Depression Inventory (Santor, Zuroff, Ramsay, Cervantes, & Palacios, 1995). The items on the CES-D have high internal consistency reliability (Chronbach's $\alpha = .88$; Orme, Reis, & Herz, 1986).

Emotion-regulation ability. Emotion regulation, the ability to change the trajectory of an emotional response over time (Gross, 1998), was measured with the Emotion Amplification and Reduction Scales (TEARS; Hamilton et al., 2009), a scale with two factors, Amplification (9 items, e.g., “I can deepen the feeling of an existing emotion”) and Reduction (9 items, e.g., “When the need arises, I can cut short an emotional response). Responses are on a 4-point, Likert-type scale (1 = *not at all true for me* to 4 = *very true for me*). Amplification and Reduction are separate factors whose items cannot be combined to obtain an overall score on the measure. Higher scores indicate better ability to amplify or reduce emotion.

Procedure

Cohorts of up to 20 participants came to a campus computer lab at 8:00 p.m. on a Monday, Tuesday, Wednesday, or Thursday to complete the first night’s questionnaires. Participants were first given instructions on accessing the study website and choosing a time at which they would like to complete the study on the following five nights. Options for times ranged from 8:00 p.m. to 11:45 p.m., spaced at 15-minute intervals. On the first night, participants completed all of the questionnaires included in the study on computers in the lab. On subsequent nights, participants were emailed a link to a newer version of the study, which only included the questions about anger, mood, sleep quality, and alertness. The URL to the study changed each night, for data organization purposes, and students were emailed a reminder in the afternoon.

Many participants were fully adherent, completing six consecutive nights. Some participants missed nights. Other participants missed nights but asked if they could add nights to the end of the study. Although we intended to collect six consecutive nights of data, for some individuals, those six nights were spread over more than a six-day period. It is important to note, though, that because data were only collected once per day, each time participants completed the survey, regardless of the number of days between observations, we had data about the current day’s mood and alertness and the previous night’s sleep.

Results

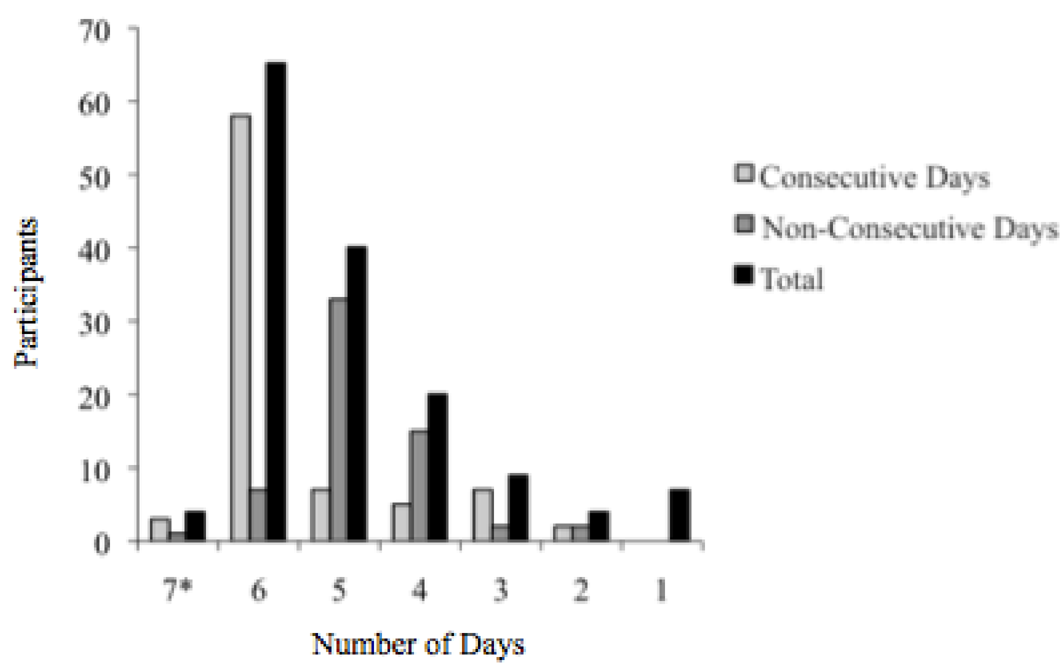
Data Analytic Plan

We used Mplus 6.1 (L.K. Muthén & Muthén, 2010) to analyze data.

Missing data. We obtained a total of 768 person-days. We excluded from analysis participants who completed their survey more than four hours before or after their designated time, resulting in 740 person-days' and all 149 participants' inclusion in the analyses. After excluding 28 person-days, the median number of person-days was 5, and the modal number of person-days was 6, as can be seen in Figure 2. All analyses ultimately included 706 person-days (142 participants), because Mplus used listwise deletion to exclude 34 person-days (7 participants). Five of the seven excluded participants (23 person-days) were the first five participants in the study. They were excluded because we failed to include a measure in their surveys. The other two participants were excluded because they did not report their ages.

Figure 2

Frequency of Person-Days



Note. Four participants accidentally completed a seventh day of questionnaires.

Hostility. We chose to separate the Cook-Medley-20 into its three factors for two reasons. First, Cynicism, Hostile Affect, and Aggressive Responding measure cognition, affect, and behavior, respectively; therefore, it was possible that they may have differed in their ability to predict emotion and exercise. The evidence of the relationship between hostility and exercise is mixed (e.g., Allen et al., 2001; Calhoun et al., 2001; Hassmén et al., 2000); therefore, we analyzed the three factors of Barefoot et al.'s (1989) 20-item Cook-Medley to investigate whether separate factors might elucidate the relationship better than the scale total.

Descriptive Statistics

In general, we observed responses across the entire range of each measure we used, as can be seen in Table 7.

Table 7

Descriptive Statistics for Longitudinal Study

Variable	Possible Range	Observed Range	Grand Mean of Unweighted Person Means	Grand Mean of Weighted Person Means	SD of Unweighted Person Means from Grand Mean	Grand Mean of Unweighted Within-Person SDs	Grand Mean of Weighted Within-Person SDs	SD of Unweighted Within-Person SDs
Baseline Measures								
RED	9-36	10-36	23.51	23.56	6.05	--	--	--
AGGR	0-9	1-8	4.38	4.40	1.51	--	--	--
HOAFF	0-5	0-4	1.75	1.73	1.19	--	--	--
CYN	0-6	0-6	3.57	3.54	1.61	--	--	--
DEP	0-60	1-54	14.90	14.60	9.36	--	--	--
Daily Measures								
SLEEPQ	1-10	0-8	4.50	4.52	1.52	1.58	1.60	0.80
ANGER	10-40	10-40	13.73	13.41	3.92	3.17	3.01	3.17
POSHI	0-36	0-36	17.07	16.95	5.36	4.73	4.74	2.35
POSLO	0-12	0-12	6.05	6.07	1.95	1.84	1.84	0.85
NEGHI	0-12	0-12	3.76	3.60	2.33	2.09	2.10	1.18
NEGLO	0-24	0-24	7.62	7.39	3.47	3.47	3.47	1.70
EXMINS	0-180+	0-180+	24.86	28.49	29.96	20.25	18.47	19.01

Sleep quality. Over the course of cleaning data for analysis, the scale's original range, 1 (*light sleep*) to 10 (*deep sleep*), was recoded as 0 to 9. Across all person-days, the observed range of responses was 0 to 8, 90% of the total scale. Participants reported mediocre sleep: 4.50 on a scale of 1 to 10 (SD = 1.52).

Daily anger. Participants experienced very little anger. The possible range of scores was 10 to 40. Although we observed scores across the entire range, average anger was toward the bottom of the scale (M = 13.73, SD = 3.92).

Depressive symptoms. The possible range of scores was 0 to 60. Participants endorsed responses over 89% of the range (1 to 54); however, overall, participants reported low levels of depressive symptoms (M = 14.9, SD = 9.36). Using a cutoff score of 34 to classify participants as "depressed," which has been done previously (Santor et al., 1995), fewer than 2.3% (+2 SD) of participants reached the cutoff score.

Hostility. Participants endorsed Cynicism scores across the entire range (0 to 6) and, on average, reported a moderate amount of Cynicism (M = 3.57, SD = 1.61). Participants endorsed most of the range of scores for Hostile Affect (observed: 0 to 4, possible: 0 to 5) and reported a moderate amount of Hostile Affect, on average (M = 1.75, SD = 1.91). Participants endorsed most of the range of scores for Aggressive Responding (observed: 1 to 8, possible: 0 to 9), and, on average, participants reported a moderate amount of Aggressive Responding (M = 4.38, SD = 1.51).

Emotion reduction. Participants endorsed responses across 96% of the Emotion Reduction scale (observed range: 10-36, possible range: 9-36). On average, participants reported moderate ability to reduce emotions (M = 23.51, SD = 6.05).

Mood. Participants endorsed responses across the entire range of the POSHI scale (0 to 36). On average, participants reported experiencing a moderate amount of POSHI (M = 17.07, SD = 3.58). The same was true for POSLO as well (observed and possible range: 0 to 12; M = 6.05, SD = 1.95).

Whereas participants reported experiencing moderate levels of positive moods, they reported experiencing low levels of negative moods. Although participants endorsed responses across the entire range of NEGHI (0 to 12), on average, NEGHI was relatively low (M = 3.76, SD = 2.33). The same was true for NEGLO (observed and possible range: 0 to 24, M = 7.62, SD = 3.47).

Exercise. Participants reported exercising from 0 to more than 180 minutes per day. On average, participants reported exercising 24.86 (SD = 29.96) minutes per day. A substantial portion of students (22.15%) did not report exercising over the course of the six-day study.

Daily Process: Mood

Outcomes. We analyzed four outcomes: POSHI, POSLO, NEGHI, and NEGLO. Outcomes for each day were calculated by summing the day's ratings for each outcome's respective items. POSHI included *active*, *cheerful*, *happy*, *lively*, *peppy*, and *stimulated.* POSLO included *calm* and *relaxed*. NEGHI included *anxious* and *nervous.* NEGLO included *blue, drowsy*, *sad,* and *tired.* Although *passive* is the opposite of *active*, whether *passive* could be considered a component of low-arousal negative affect was unclear, as Russell and Carroll (1999) proposed its inclusion in a measure of affect but did not present supporting empirical evidence. Therefore, although it was included in the Mood Checklist, *passive* was not included in any of the four outcomes. *Quiet* was also excluded from the outcomes because it had no clear valence.

Distribution. Mood is often measured on a Likert-type scale (e.g., Watson et al., 1988). Although clearly ordinal, data from Likert-type scales can be analyzed with parametric statistics because of the central limit theorem (e.g., Atkins & Gallop, 2007; Norman, 2010); therefore, traditional multilevel regression analyses were performed. Parameter estimates were linear.

Alpha level. We analyzed four outcomes, POSHI, POSLO, NEGHI, and NEGLO. The model for each outcome had 96 free parameters, for a total of 384 parameters. To correct for the possible inflation in Type I error, we used a Bonferroni correction (Abdi, 2007; Wolfram MathWorld, 2012). The most conservative corrections would have been to set the α level at .05/384 = .00013 or to correct for the total number of tests done for the entire study (α = .05/420 = .00011). Two less-conservative approaches would have been to correct for the number of tests within a family (α = .05/96 [96 tests per outcome]) or to correct for the number of tests for each parameter (α = .05/4 = .0125 [each parameter tested four times, once for each outcome]). As a compromise between the least-conservative approach (i.e., α = .05 for each test) and the most-conservative approaches (i.e., correcting for the total number of tests for mood-outcome data or the entire study), we used α = .0125.

Analysis type. The intraclass correlation coefficient (ICC; e.g., Peugh, 2010; Snijders & Bosker, 2012) is a calculation of the proportion of variance due to variability at the level of grouping (in a two-level model). ICC is calculated with the following formula: $ICC = \frac{\hat{\tau}_{00}}{\hat{\tau}_{00}+\sigma_e^2}$, where $\hat{\tau}_{00}$ is the group-level variance, σ_e^2 is the individual-level variance, and the sum of $\hat{\tau}_{00}$ and σ_e^2 is the total unexplained variance.

ICC is often used to determine whether MLM, rather than aggregated or disaggregated ordinary least-squares (OLS) regression, is the appropriate analysis technique. ICC values close to 0 would indicate that disaggregated OLS regression may be appropriate, given that almost no unexplained variance is due to group-level differences, whereas ICC values close to 1 would indicate that aggregated OLS regression may be appropriate, given that almost all unexplained variance is due to group-level differences. ICC calculations for the four outcomes, POSHI, POSLO, NEGHI, and NEGLO, described below, were .457, .448, .409, and .382, respectively. According to ICC for each of the outcomes, MLM was the appropriate regression technique to use.

An ICC between 0 and 1 alone does not mean that aggregated or disaggregated OLS would be inappropriate, however. The design effect (Peugh, 2010, p. 91), which takes into account the average number of units per cluster, is a calculation of the degree of nesting in data, with a higher number of units per group indicating more nesting – and further violation of the assumption of independence inherent in OLS regression. A higher design effect, therefore, indicates greater need for MLM; a design effect of 2.0 or greater is considered the value at which MLM is necessary. The design effect is calculated with the following formula:

$Design\ Effect = 1 + ICC\,(n_c - 1)$, where n_c is the average number of units per cluster.

Results of the design effects calculations indicated that MLM was the appropriate technique for analysis of the current data. Of the 142 people included in the current analysis – 7 were excluded because they were missing covariate values – the average cluster size (i.e., average number of daily surveys that participants completed) was 4.972. The design effects for our outcomes, POSHI, POSLO, NEGHI, and NEGLO, were 2.82, 2.78, 2.62, and 2.52, respectively – above the 2.0 threshold that is used as an indicator of MLM's appropriateness.

Covariates. Known and suspected predictors of mood – weekend/weekday, sleep quality, sex, age, hostility, depression, and emotion reduction – were entered into the model as covariates.

Centering. Level 1 covariate weekend/weekday was not centered because it is dichotomous. The other Level 1 covariate, sleep quality, was centered within-person (i.e., centered within-group; CWG), and the within-person mean (i.e., mean within-group; MWG) was added as a covariate at Level 2. Level 2 covariates age, depression, cynicism, hostile affect, aggressive responding, and reduction were grand mean-centered (CGM). Sex was not centered because it is a dichotomous predictor.

Effect of person-level variables on mood. At the inter-individual level, we hypothesized that person-level sleep quality, sex, age, the three factors of the Cook-Medley-20 hostility scale (Cynicism, Hostile Affect, Aggressive Responding), CES-D score (referred to for the remainder of the paper as “depression”, “depression score”, or “depressive symptoms”), and Emotion Reduction (referred to throughout the paper as “Reduction”) would predict daily mood. Although a model with both Emotion Amplification and Reduction fit better than the model with Reduction only did [$\chi^2(1) = 6.396$, $p = .011$], we excluded Amplification from the model because of concerns of multicollinearity. We included Reduction rather than Amplification because reduction has been found to behave with variables in expected directions, whereas Amplification has not. For example, Amplification was positively associated with both positive affect and fatigue, the latter inconsistent with expectations, and was unrelated to negative affect, whereas Reduction was associated positively with positive affect and negatively with both negative affect and fatigue (Hamilton et al., 2009).

Effect of day-level variables on mood. At the intra-individual level, we hypothesized that sleep quality “last night” would predict mood “today.” To be specific, we predicted that, within-person (i.e., at Level 1), lower-than-average sleep quality would predict worse mood (i.e., lower positive moods, higher negative moods). We also tested the contribution of weekend (Friday, Saturday, Sunday; 1 = *yes*, 0 = *no*), to daily mood.

Random effects. Each of the four outcomes was modeled with a random intercept. The effect of weekend/weekday was included as a fixed predictor, which has been done previously (Cranford et al., 2006). We were unsure of whether to include sleep as a fixed or random covariate; therefore, we performed a nested model comparison to determine which model would result in better fit. The model with a random slope of sleep quality – the more-complex model – did not fit significantly better than the model with a fixed slope of sleep quality, as can be seen in Table 8. Therefore, we chose the more-parsimonious model, the one with the fixed slope of sleep quality.

Table 8

Deviance Test for Model with Fixed vs. Model with Random Slope of Sleep Quality

Model	-2*Log Likelihood	*df*	χ^2	*p*
H_0: Fixed Slope	14,462.346	92	—	—
H_1: Random Slope	14,432.924	118	—	—
H_0 vs. H_1		26	29.422	.292

Note. Deviance test is a comparison of -2*Log Likelihood of two nested models. The difference in Deviance scores follows a χ^2 distribution, with degrees of freedom equal to the difference in free parameters between the two models. The calculation for the Deviance test is $D_0 - D_1 \sim \chi^2(df = q_1 - q_0)$, where D_0 is the Deviance (i.e., -2*Log Likelihood) of the nested (less-complex) model; D_1 is the Deviance score of the parent (more-complex) model; q_1 is the degrees of freedom of the parent model; and q_0 is the degrees of freedom of the nested model.

Equations. The following equations were used to model each of the four mood outcomes:

$$(MOOD)_{ij} = \beta_{0j} + \beta_{1j}(WKEND)_{ij} + \beta_{2j}(SLEEPQ_{CWG})_{ij} + e_{ij} \quad (1)$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(SLEEPQ_{MWG})_j + \gamma_{02}(SEX)_j + \gamma_{03}(AGE_{CGM})_j + \gamma_{04}(DEP_{CGM})_j$$

$$+ \gamma_{05}(CYN_{CGM})_j + \gamma_{06}(HOAFF_{CGM})_j + \gamma_{07}(AGGR_{CGM})_j + \gamma_{08}(RED_{CGM})_j + u_{0j} \quad (2)$$

$$\beta_{1j} = \gamma_{10} \quad (3)$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}(SEX)_j + \gamma_{22}(AGE_{CGM})_j + \gamma_{23}(DEP_{CGM})_j + \gamma_{24}(CYN_{CGM})_j$$

$$+ \gamma_{25}(HOAFF_{CGM})_j + \gamma_{26}(AGGR_{CGM})_j + \gamma_{27}(RED_{CGM})_j \quad (4)$$

$$z_{ij} = d_{POSHI}(equation_{POSHI}) + d_{POSLO}(equation_{POSLO}) + d_{NEGHI}(equation_{NEGHI}) +$$

$$d_{NEGLO}(equation_{NEGLO}),$$

where each term in the equation represents Equations 1-4 for each of the mood outcomes. When one d = 1, the other ds = 0. Therefore, z_{ij} only ever = one set of equations; the rest of the equations are multiplied by a d that = 0.

Cross-level interactions: Level-1, person-centered sleep quality-by-hostility. We hypothesized that the effect of sleep quality on mood would depend on level of Cynicism, Hostile Affect, and Aggressive Responding. There were no significant sleep quality-by-Cynicism, sleep quality-by-Hostile Affect, or sleep quality-by-Aggressive Responding effects on any of the four outcomes (Tables 9-12).

Table 9

Predictors of POSHI

Parameter	β
Intercept	13.803*
Level 1	
WKEND	-1.239*
SLEEPQ	.456
Level 2	
SLEEPQ	.458
SEX	1.144
AGE	.156
DEP	-.168*
CYN	.263
HOAFF	-.404
AGGR	.373
RED	.029
Cross-Level Interactions with SLEEPQ	
SEX	.171
AGE	.315*
DEP	-.018
CYN	.092
HOAFF	.038
AGGR	-.145
RED	-.006

Note. $*p < .025$

Table 10

Predictors of POSLO

Parameter	β
Intercept	5.134*
Level 1	
WKEND	-.308
SLEEPQ	.157
Level 2	
SLEEPQ	.302*
SEX	-.206
AGE	.048
DEP	-.052*
CYN	.056
HOAFF	-.297
AGGR	.059
RED	-.026
Cross-Level Interactions with SLEEPQ	
SEX	.008
AGE	.018
DEP	-.001
CYN	-.018
HOAFF	-.008
AGGR	-.023
RED	.003

Note. *$p < .025$

Table 11

Predictors of NEGHI

Parameter	β
Intercept	6.398*
Level 1	
WKEND	-1.344*
SLEEPQ	-.083
Level 2	
SLEEPQ	-.196
SEX	-.803
AGE	-.257
DEP	.085*
CYN	.048
HOAFF	.221
AGGR	-.143
RED	-.037
Cross-Level Interactions with SLEEPQ	
SEX	.026
AGE	-.027
DEP	-.005
CYN	.034
HOAFF	.063
AGGR	-.095
RED	-.011

Note. $^*p < .025$

Table 12

Predictors of NEGLO

Parameter	β
Intercept	10.329*
Level 1	
WKEND	-1.371*
SLEEPQ	-.275
Level 2	
SLEEPQ	-.447*
SEX	-.154
AGE	-.310
DEP	.228*
CYN	.016
HOAFF	-.162
AGGR	-.214
RED	.055
Cross-Level Interactions with SLEEPQ	
SEX	-.223
AGE	-.194*
DEP	-.005
CYN	.006
HOAFF	-.001
AGGR	.061
RED	.009

Note. *$p < .025$

Cross-level interactions: Level-1, person-centered sleep quality-by-other level-2 covariates. We explored whether the effect of Sleep Quality on the four mood outcomes depended on sex, age, depression, or reduction (Tables 9-12). We predicted that women would have particularly disturbed mood (i.e., higher NEGHI and NEGLO, lower POSHI and POSLO) after nights of worse sleep quality. We predicted that individuals with higher depression scores would have particularly disturbed mood after nights of worse sleep quality. We specified no direction for the potential age-by-sleep quality or emotion reduction-by-sleep quality interactions.

Sex. There was no significant sleep quality-by-sex effect on any of the four mood outcomes.

Age. The effect of sleep quality on POSHI depended on participants' age (Table 9). According to Preacher, Curran, and Bauer's (2006) online utility, which we used to plot and probe the interaction, the region of significance for the effect of sleep quality on POSHI was significant for participants at least 1.37 years older than the mean age of 19.11 (Figure 3). As can be seen in Figure 4 (produced with Preacher et al.'s utility), for older participants, POSHI was higher after better sleep, whereas for younger or average-aged participants, POSHI was not significantly higher after nights of better sleep.

Figure 3

Confidence Bands for Significance of the Effect of the Sleep Quality-by-Age Interaction on POSHI

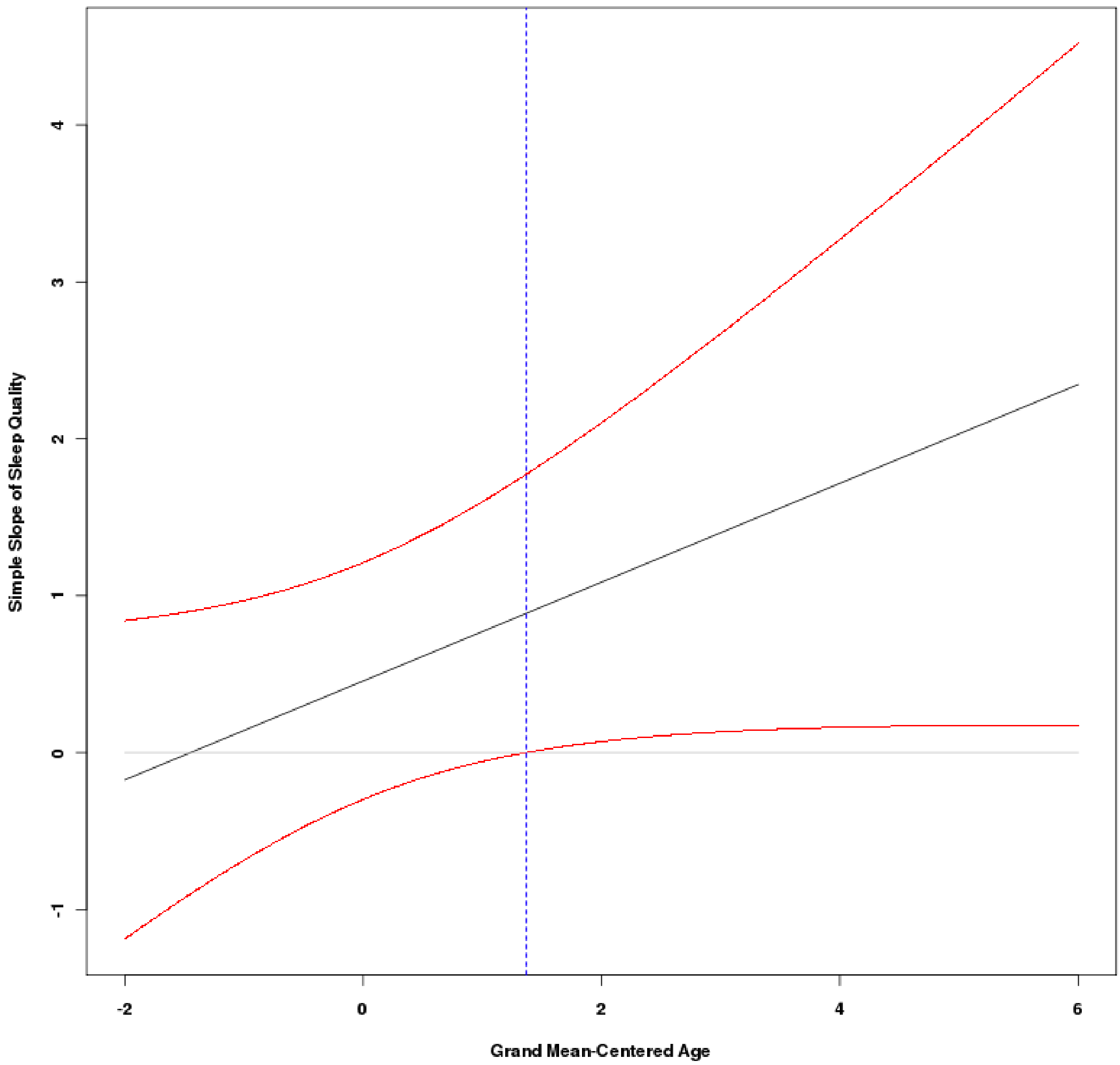


Figure 4

Effect of the Sleep Quality-by-Age Interaction on POSHI

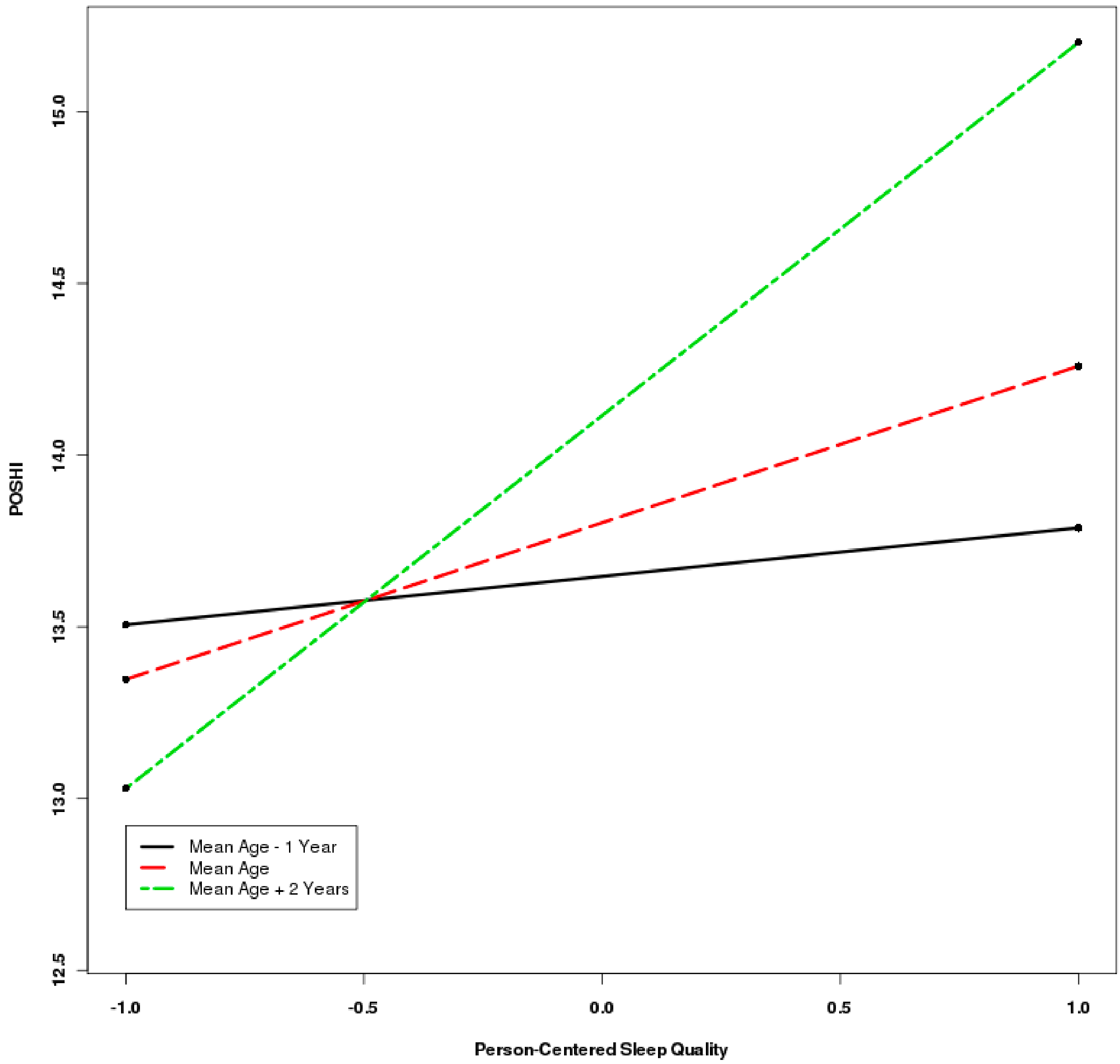
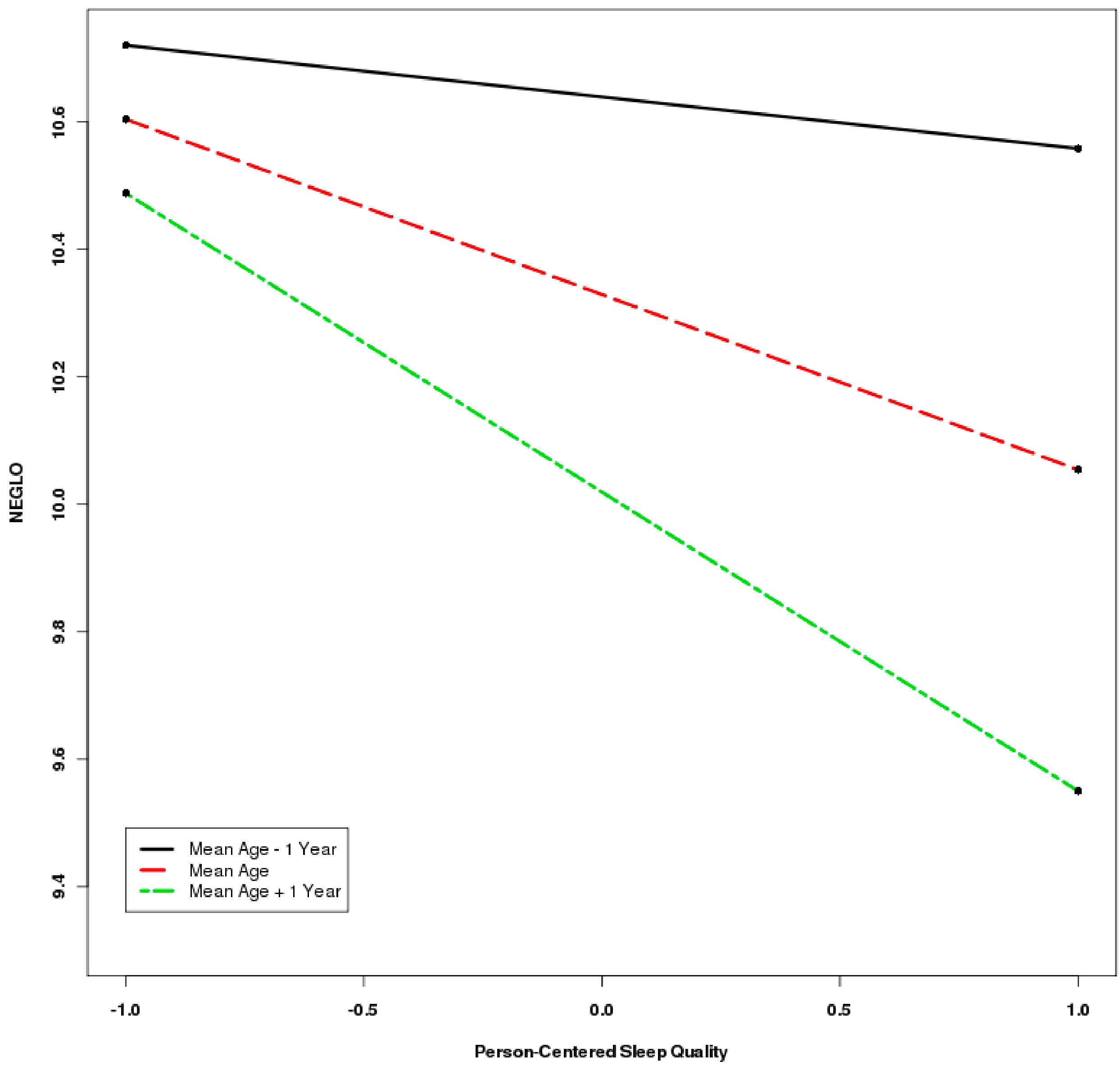


Figure 5

Effect of the Sleep Quality-by-Age Interaction on NEGLO



The effect of sleep quality on NEGLO also depended on participants' age (Table 12). According to Preacher et al.'s (2006) online utility, the simple slope of the effect of sleep quality on NEGLO was not significant at any age; however, the interaction was significant. As can be seen in Figure 5 (produced with Preacher et al.'s utility), the trend appeared to be that, for older participants, NEGLO was lower after nights of better sleep.

For the interactions with age, it is important to note that only 17 participants (11.6%) were older than 20.48 years. Only 15 of those participants were included in the analyses because two participants were missing data. Because of the uneven numbers of participants in the two groups – participants at least 20.48 years of age and participants under 20.48 years – it is important to interpret the age interactions with caution.

Depressive symptoms. There were no significant sleep quality-by-depression effects on any of the four mood outcomes.

Emotion reduction. There were no significant sleep quality-by-regulation effects on any of the four mood outcomes.

Level 2: Hostility as a predictor of mood. The second of our primary hypotheses for mood was that higher Cynicism, Hostile Affect, and Aggressive Responding would predict higher NEGHI and NEGLO and lower POSHI and POSLO. None of the three Hostility factors was a significant predictor of the intercepts of POSHI, POSLO, NEGHI, or NEGLO (Tables 9-12, respectively).

Level 2: Other predictors of mood. We also hypothesized that person-level sleep quality, sex, age, depression, and reduction would predict the four mood outcomes. Parameter estimates are shown in Tables 9-12.

Person-level sleep quality. Higher person-level sleep quality predicted higher POSLO and lower NEGLO. Person-level sleep quality predicted neither POSHI nor NEGHI. In summary, sleep quality predicted low-arousal, but not high-arousal, moods.

Sex. Sex (1 = female, 0 = male) did not predict any of the mood outcomes.

Age. Age predicted POSHI, but its slope cannot be interpreted directly because age was part of an interaction. Age alone did not predict NEGLO, but age was part of an interaction to predict NEGLO. Age did not predict POSLO or NEGHI.

Depressive symptoms. Higher depression predicted lower POSHI and POSLO and higher NEGHI and NEGLO.

Emotion reduction. Reduction did not predict any of the mood outcomes.

Level 1: Sleep quality as a predictor of mood. We hypothesized that worse sleep quality would predict lower levels of POSHI and POSLO and higher levels of NEGHI and NEGLO. Sleep quality alone did not predict POSHI (Table 9), POSLO (Table 10), NEGHI (Table 11), or NEGLO (Table 12).

Level 1: Effects of day of week. We predicted that mood would be better (i.e., positive moods would be higher and negative moods would be lower) on the weekend than during the week. POSHI was significantly lower during the weekend (Table 9). NEGHI was significantly lower during the weekend than it was during the week (Table 11). NEGLO was significantly lower during the weekend than it was during the week (Table 12). POSLO during the weekend did not differ significantly from POSLO during the week (Table 10). To summarize, college students reported lower moods, both positive and negative, during the weekend.

To summarize, both positive and negative moods were lower during the weekend than they were during the week. At Level 1, sleep quality did not predict any of the four moods. At Level 2, the three factors of Hostility did not predict any of the moods. Person-level sleep quality predicted low-arousal moods in the expected direction; better sleep quality predicted higher POSLO and lower NEGLO. Sex did not predict any of the four moods. Depression predicted mood in the expected direction: higher depression predicted higher negative moods and lower positive moods. Emotion reduction did not predict any of the four moods. The effect of daily (i.e., Level-1) sleep quality on the four moods did not depend on any of the hostility factors, sex, depressive symptoms, or emotion-reduction ability. Overall, it appears that mood depended on person-level factors (average sleep quality, level of depressive symptoms) and an interaction between person-level and day-level factors (age and daily sleep quality), with older participants receiving greater benefit from better sleep quality.

Daily Process: Exercise

Data coding. The Centers for Disease Control and Prevention uses 10 minutes as a "cut off" score to define a meaningful bout of exercise (Lloyd-Jones et al., 2008); thus bouts of exercise ranging from 1 to 9 minutes were re-coded as 0 minutes for all analyses. We tried to predict who would report exercising 1 to 9 minutes on at least one day during the study and found that sex was the only significant predictor; females were .729 times less likely to report exercising 1 to 9 minutes as men were [$\beta = -1.307$, $e^{\beta} = .271$, $p = .028$]. It is possible that this trend occurred because, particularly for men, reporting exercise is more socially desirable than reporting no exercise (Lindwall & Ginis, 2010). Age, depressive symptoms, Cynicism, Hostile Affect, Aggressive Responding, and Emotion Reduction did not predict who reported exercising 1 to 9 minutes at least once during the study.

Distribution selection.

Method. We conducted a random-effects analysis of observations (days) nested within individuals. Our analysis was different from traditional multilevel analyses because our outcome was not normally distributed. Furthermore, we could not use the central limit theorem as justification for use of traditional multilevel analysis because we hypothesized that our observations were not sampled from a normal distribution. Count outcomes, such as minutes of exercise, are not normally distributed: count outcomes are integers and have a minimum value of zero. When outcomes are not normally distributed, using OLS regression will result in biased results, with inaccurate standard errors and *p* values (Atkins & Gallop, 2007).

Depending on the shape of the data, analyses can be conducted with a Poisson distribution, which assumes that the mean is equal to the variance; a negative binomial (NB) distribution, which is an overly-dispersed Poisson (i.e., $\mu < \sigma^2$); or a zero-inflated version of either. A zero-inflated Poisson or negative binomial is a distribution with a higher proportion of zeroes than would be expected with either the Poisson or negative binomial distribution (Atkins & Gallop, 2007). Poisson is nested within NB; Poisson dispersion = 1, whereas NB is over-dispersed, and the dispersion is estimated (Atkins & Gallop, p. 732). Parameter estimates are similar in Poisson and NB. The only difference is the variance, meaning that, if the data are over-dispersed, standard errors in the model would be artificially low if the model were assumed to follow a Poisson distribution. The dispersion parameter is asymptotically normally distributed; therefore, to determine if the data are significantly over-dispersed (and, thus, a NB distribution is more appropriate), a Wald statistic can be calculated by dividing the parameter by its standard error and significance can be determined with a one-tailed test. Because the Poisson is nested within NB, a deviance test can also be performed (Atkins & Gallop, p. 732). The deviance test is the difference between the -2*log likelihood values of the two models. The difference between the two values follows a χ^2 distribution, with degrees of freedom equal to the difference in free parameters between the two models.

When the outcome is an uncommon event, a zero-inflated version of Poisson (ZIP) or NB (ZINB) may be more appropriate (Atkins & Gallop, 2007, p. 733). ZIP and ZINB may be advantageous over Poisson and NB because it is possible to analyze a logistic model (zero vs. not-zero) and a count model with different predictors for each, whereas, in Poisson and NB, zero vs. not-zero is not modeled separately; in Poisson and NB, the zeroes are part of the count. Modeling the count and logistic portions separately with the zero-inflated distributions can allow for more-accurate modeling of count data (Atkins & Gallop, p. 734). ZIP is nested within ZINB (when dispersion = 1, ZINB is the simpler ZIP model; Atkins & Gallop, p. 734). You can use a Deviance statistic to determine if ZINB or ZIP fits better.

Determining whether Poisson or NB fits better than a zero-inflated version is more complicated because Poisson and NB are not nested within their respective zero-inflated models; therefore, Deviance testing cannot be used. You can use the Bayesian Information Criterion (BIC; Muthén, 2010; Schwarz, 1978) to compare non-nested models or, if you would like a significance test, you can calculate the Vuong statistic (Atkins & Gallop, 2007; Buis et al., 2009; Clarke, 2001; Vuong, 1989). Sample size is used in the calculation, but from the Vuong formula, it is unclear if *n* refers to Level 1 or Level 2 units. Buis et al. (2009) calculated the Vuong test in a multilevel study with a disaggregated *n*; therefore, in the current study, we calculated the Vuong with Level 1 units (person-days), of which we had 706 in the analyses.

Results. To determine which distribution was appropriate, we ran our model four times, once with each distributional assumption (i.e., Poisson, NB, ZIP, and ZINB). We first compared exercise minutes modeled with a Poisson distribution to exercise minutes modeled with a negative binomial distribution. Because Poisson is nested within negative binomial, we were able to use a Deviance test to determine which distribution fit the data better. The negative binomial distribution fit the data significantly better than the simpler Poisson distribution did, χ^2 (1) = 7,394.01, $p < .0001$.

We then compared the ZIP model and ZINB with a Deviance test. The ZINB distribution fit significantly better than the simpler ZIP distribution, χ^2 (1) = 1,760.66, $p < .0001$. The two better-fitting models, NB and ZINB, are non-nested so we compared them with the BIC. ZINB had a lower BIC than NB. Therefore, the ZINB distribution fit our data better than the NB distribution did. BIC and -2*log likelihood values for the four models are presented in Table 13. Results of the Vuong confirmed the results of the BIC; ZINB fit better than NB. Components needed to calculate the Vuong with Clarke's (2001, p. 735) steps – log likelihood (i.e., likelihood ratio), degrees of freedom, and Level-1 sample size – are included in Table 14.

Table 13

Fit Indices for the Model, Assuming Poisson, Negative Binomial, ZIP, and ZINB Distribution

Model	-2*Log likelihood	*df*	Bayesian Information Criterion
Poisson	11,812.768	14	11,904.603
Negative Binomial	4,418.762	15	4,517.157
Zero-Inflated Poisson	5,663.054	27	5,840.164
Zero-Inflated Negative Binomial	3,902.398	28	4,086.067

Table 14

Components for Calculation of Vuong with Procedure in Clarke (2001, p. 735)

Model	Level-1 *n*	*df*	Log likelihood
Poisson	706	14	-5,906.384
Negative Binomial	706	15	-2,209.381
Zero-Inflated Poisson	706	27	-2,831.527
Zero-Inflated Negative Binomial	706	28	-1,951.199

Covariates. The same covariates were used to model both the logistic model (i.e., did a participant exercise on a given day?) and count model (i.e., if a participant did exercise on a given day, for how long did he or she exercise?). Centering of covariates was the same as in the analyses for mood.

Level 2: What person-level covariates predict exercise? At the person level, we included person means of both sleep quality and anger, sex, and grand mean-centered age, Cynicism, Hostile Affect, Aggressive Responding, depressive symptoms, and Emotion Reduction as predictors of exercise.

Level 1: What day-level covariates predict exercise? At the day level, person mean-centered sleep quality “last night,” person mean-centered anger “today,” and day of the week (weekend vs. weekday; uncentered because it is dichotomous) were hypothesized to predict exercise.

Analysis. Analysis of ZINB models involves a two-step process. The first step is a logistic regression (i.e., predicting whether a response is zero or non-zero). The second step is an analysis of the non-zero, count portion (Atkins & Gallop, 2007; Hilbe, 2007). Both steps of the zero-inflated negative binomial regression were modeled simultaneously with Mplus 6.1 (L.K. Muthén & Muthén, 2010). Alpha level was set at .025 (i.e., .05/2) because each parameter was tested twice, once in the logistic portion of the model and again in the count portion.

Did participants exercise "today"? The first step of our multilevel analysis was a logistic regression. The Level-1 and Level-2 equations are below:

$$\ln(EXERCISED_{Y/N})_{ij} = \beta_{0j} + \beta_{1j}(WKEND)_{ij} + \beta_{2j}(SLEEPQ_{CWG})_{ij} + \beta_{3j}(ANGER_{CWG})_{ij}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(SLEEPQ_{MWG})_j + \gamma_{02}(ANGER_{MWG})_j + \gamma_{03}(SEX)_j$$

$$+ \gamma_{04}(AGE_{CGM})_j + \gamma_{05}(DEP_{CGM})_j + \gamma_{06}(CYN_{CGM})_j + \gamma_{07}(HOAFF_{CGM})_j +$$

$$+ \gamma_{08}(AGGR_{CGM})_j + \gamma_{09}(RED_{CGM})_j$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

Level 2: Person-level predictors of exercise "today." As is shown in Table 15, sleep quality, sex, age, Hostile Affect, Aggressive Responding, and emotion reduction did not predict whether someone exercised on a given day over the course of the study.

Table 15

Level-1 and Level-2 Predictors of Whether Participants Exercised "Today"

Parameter	β	Exp(β)
Intercept	1.255*	3.508*
	Level 1	
WKEND	.504*	1.655*
SLEEPQ	-.011	.989
ANGER	.005	1.005
	Level 2	
SLEEPQ	.025	1.025
ANGER	-.065*	.937*
SEX	-.329	.720
AGE	.042	1.043
CYN	-.147*	.863*
HOAFF	-.056	.946
AGGR	.005	1.005
DEP	.043*	1.044*
RED	-.030	.970

Note. $^*p < .025$

Anger, Cynicism, and depression score did predict whether someone exercised on a given day during the study. For every point higher than all participants' mean anger a particular participant's mean anger was, the odds of that particular participant's exercising on a given day during the study were .063 times lower. For every point higher than the grand mean a person's Cynicism was, the odds of that participant's exercising on a given day during the study were .137 times lower. For every point higher than the grand mean a person's depression score was, the odds of that person's exercising on a given day during the study were .044 times higher.

Level 1: Day-level predictors of exercise "today." As is shown in Table 15, the odds of participants' exercising were .655 times higher on the weekend (Fri, Sat, Sun) than during the week. Neither day-level anger nor day-level sleep quality significantly predicted whether someone exercised on a given day over the course of the study.

For how long did participants exercise on days they did? The second step of our multilevel analysis was the count portion of the analysis. Level-1 and Level-2 equations are below:

$$\ln(EXERCISE_{MINUTES})_{ij} = \beta_{0j} + \beta_{1j}(WKEND)_{ij} + \beta_{2j}(SLEEPQ_{CWG})_{ij} + \beta_{3j}(ANGER_{CWG})_{ij}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(SLEEPQ_{MWG})_j + \gamma_{02}(ANGER_{MWG})_j + \gamma_{03}(SEX)_j$$

$$+ \gamma_{04}(AGE_{CGM})_j + \gamma_{05}(DEP_{CGM})_j + \gamma_{06}(CYN_{CGM})_j + \gamma_{07}(HOAFF_{CGM})_j +$$

$$+ \gamma_{08}(AGGR_{CGM})_j + \gamma_{09}(RED_{CGM})_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

e_{ij} ~ ZINB

$u_{0j} \sim N(0,\tau_{00})$

When interpreting the parameters, it is not possible to use raw output. In a model assuming a ZINB distribution, the natural log of the outcome is used for calculation; therefore, to interpret the parameters more easily (i.e., the effects of the covariates on minutes of exercise, not on natural-log minutes of exercise), the inverse of the parameters is taken through exponentiation (i.e., raising constant *e* to the parameter values).

Level 2: Person-level predictors of exercise duration "today." As is shown in Table 16, sleep quality, anger, sex, age, Hostile Affect, Aggressive Responding, depression score, and emotion reduction did not predict exercise duration. For every point higher than the grand mean of Cynicism a participant's Cynicism score was, that participant exercised 16% more.

Table 16

Level-1 and Level-2 Predictors of Participants' Exercise Duration "Today"

Parameter	β	Exp(β)
Intercept	4.156*	63.816*
	Level 1	
WKEND	-.237*	.789*
SLEEPQ	-.015	.985
ANGER	-.003	.997
	Level 2	
SLEEPQ	-.067	.935
ANGER	.019	1.019
SEX	-.210	.810
AGE	-.080	.923
CYN	.148*	1.160*
HOAFF	-.073	.930
AGGR	-.057	.944
DEP	.017	1.017
RED	.021	1.021

Note. *p < .025

Level 1: Day-level predictors of exercise duration "today." As is shown in Table 16, when participants did exercise, they exercised for 21.1% less time on the weekends than they did during the week. Day-level sleep quality and day-level anger did not significantly predict how much time participants spent exercising.

To summarize, whether participants exercised on a given day – and how much they exercised during the study – depended on both day-level and person-level factors. At Level 1, the odds of exercising were .655 times higher during the weekend than during the week. At Level 2, higher anger was associated with lower odds of exercising; higher Cynicism was associated with lower odds of exercising; and higher levels of depression were associated with greater odds of exercising. How much a participant exercised on a given day depended on the day of the week and level of Cynicism. At Level 1, participants spent less time exercising during the weekends than they did during the week. At Level 2, participants with higher Cynicism spent more time exercising

Discussion

The purposes of this study were to investigate day- and person-level factors that predict mood, whether people exercise, and how much time people spend exercising. Overall, we found that person-level covariates, but not day-level covariates, except day of week, predicted daily mood and exercise. As we anticipated, lower levels of depression and better average sleep quality predicted better mood. Higher Cynicism and higher average anger were both associated with lower odds of exercising. However, higher levels of depressive symptoms were associated with higher odds of exercise. Contrary to our expectations, sleep did not appear to predict worse mood for people with potential mood-related vulnerabilities (e.g., higher depressive symptoms and hostility) than for people with lower levels of depression and hostility. The only day-level covariate that independently predicted mood and exercise was day of week: positive and negative moods were less intense during the weekend than they were during the week, and odds of exercise were higher during the weekend than they were during the week. Nightly sleep quality predicted mood but only for older participants.

Although it appears that day-level covariates may not predict daily mood or exercise, it is possible that we simply did not have enough within-person observations to detect a within-person effect. What we can surmise, however, is that, over a six-day period, person-level covariates and day of the week are better able to predict mood than day-level covariates are – at least for younger participants in the study. Possible clinical implications are that it might take longer than six days to see an improvement in mood and increased odds of exercising if those are goals of sleep treatment for people under a certain age.

Mood

Mood is an important indicator of mental health and is associated with physical health. Based on our six days of mood reports, it appears as though the emerging adults in this study were, in general, more happy than sad on most days. Although we expected to be able to predict day-to-day fluctuation in mood on the basis of health behaviors and personality variables, our data suggested that mood was determined primarily by stable, person-level or environmental factors.

Sleep quality. In general, the sleep quality in this undergraduate population was relatively poor. The average person-weighted sleep quality was 5.5 on a scale from 1 (*light sleep*) to 10 (*deep sleep*). This is consistent with other reports of poor-quality sleep among college students: in another prospective study, college students reported sleep quality of 5.66 on a scale from 1 to 10 (Taylor & Bramoweth, 2010). Taylor and Bramoweth found college students often fall asleep while driving and cause car accidents because of their sleepiness. Therefore, our finding is further evidence that sleep is an important health issue for college students.

In the current study, sleep quality predicted mood in the expected direction. At the person level, better sleep quality predicted higher positive mood and lower negative mood. At the day level, the effect of nightly sleep quality on mood depended on age. For older participants, there was support for our hypothesis that better nightly sleep quality would be associated with higher positive mood and lower negative mood. This finding was consistent with results of other research showing that worse sleep quality is associated with higher negative mood (Pilcher, Ginter, & Sadowsky, 1997; Pilcher & Ott, 1998) and lower positive mood

(Steptoe et al., 2008). However, this finding was surprising, given the restricted age range in our sample (18-25 years). This finding may suggest a broader age-related effect of sleep on mood such that sleep problems do not manifest effects on mood in adults younger than approximately 20.5 years.

Personality variables. We did not find a connection between any of the hostility factors and any of the mood outcomes. Our results are partially consistent with results of a study in which hostility and anger were not associated with positive affect (Harmon-Jones, 2003). Contrary to previous findings (Diener et al., 1985; Fujita et al., 1991; Lloyd-Jones et al., 2008; Kring & Gordon, 1998), female participants did not report more intense moods than males. This could be because of methodological differences in how we measured mood (e.g., with mood adjectives on a Likert-type scale in the current study vs. with questions about experience of mood intensity in Diener et al.'s study). Consistent with our prediction, made on the basis of the diagnostic criteria for major depressive disorder (American Psychiatric Association, 2000), higher depressive symptoms were associated with higher negative mood and lower positive mood. We can consider this association a validation of the results (i.e., participants were reading the questions, not responding randomly).

Day of the week. The general trend was that mood was less intense on the weekend. POSHI, NEGHI, and NEGLO were significantly lower on the weekend than they were during the week. Although the effect of weekday on POSLO was not significant, it appeared that POSLO was lower on the weekend as well. These findings are partially inconsistent with prior research showing that mood is better on the weekend (Cranford et al., 2006; Larsen & Kasimatis, 1990; McFarlane et al., 1988; Ryan et al., 2010). Although positive mood was lower during the weekend, negative mood was lower during the weekend, too. To be more specific, negative mood has been lower and vigor higher (Cranford et al.) and pleasantness and arousal have been highest (McFarlane et al.) during the weekend.

Exercise

Regular exercise is an important predictor of good health (Lloyd-Jones et al., 2008). From our six days of data, it appears as though the emerging adults in this study reported more exercise than college students in other studies have reported. For example, approximately 78% of participants in the current study reported exercising at least once over the six-day observation period, whereas only 55% of college students in another study (Carney, Edinger, Meyer, Lindman, & Istre, 2006) reported exercising at least once per week. It appears that, in general, college students may exercise less-frequently than the general population of people age 18-24: prevalence of physical inactivity over the course of a week has been reported as low as 5.5% among all adults age 18-24 (Lloyd-Jones et al.), which is substantially lower than the rate of inactivity found in the current study (22.1%) and in Carney et al.'s study (45%). Although we expected to be able to predict day-to-day fluctuation in exercise on the basis of sleep and personality variables, our data suggested that exercise was determined by stable, person-level or environmental factors.

Personality variables. Person-level hostility and average daily anger both predicted exercise. Participants with higher Cynicism had lower odds of exercising, but, on days when participants did exercise, participants with higher Cynicism had longer exercise duration. Results are somewhat consistent with the finding that loneliness, which is associated with hostility, has been negatively associated with both exercise frequency and duration, as measured by questionnaire (Hawkley, Thisted, & Cacioppo, 2009). Similar to the result with Cynicism, we found that higher average anger predicted lower odds of exercising during the study. However, Cynicism predicted exercise duration, whereas average daily anger did not.

Depressive symptoms. We hypothesized that higher levels of depressive symptoms would predict lower exercise odds and duration. Contrary to our hypothesis, we found that higher levels of depression predicted higher odds of exercising. Depressive symptoms did not predict exercise duration. It is possible that public psychoeducation on the benefits of exercise have hit the mainstream and been successful. It is also possible that Dr. Steve Ilardi's Therapeutic Lifestyle Change trials have been publicized on campus enough to have an effect on students – an effect that might not be found on other campuses.

Sleep quality. Again, it is important to note that sleep quality in our sample was generally fairly poor, but we did observe endorsement of responses across 90% of the scale's range. Thus it was surprising that we did not find an effect of average nightly sleep quality on either exercise odds or exercise duration. This is inconsistent with prior research in which longer time of disturbed sleep predicted lower daily physical activity. Each hour of sleep disturbance was associated with 3% less daily physical activity (Gupta, Mueller, Chan, & Meininger, 2002).

Demographic differences. We predicted that men would have higher odds of exercising and longer exercise duration than women would. We found no difference in odds or duration between men and women. This is inconsistent with the finding that men exercise more than women, according to both accelerometer (Troiano et al., 2007) and questionnaire (Lloyd-Jones et al., 2008). We hypothesized that age would predict exercise odds and duration, but because literature on age and exercise uses a much larger age range (i.e., young adults versus older adults), we did not know if the trend would hold in our narrow age range of participants. Therefore, we added age as a covariate, but we did not predict the direction of the relationship. Age was not significantly associated with exercise odds or duration. We do not know if this was due to limited power or a methodological issue or if there is actually no effect of age among young adults age 18-25.

Day of the week. The odds of participants' exercising were higher during weekend days than during weekdays. However, when participants did exercise, they spent less time exercising on the weekend than they did during the week. These findings are consistent with results of studies in which physical activity was measured with accelerometers; adolescents were found to spend less time engaged in moderate-to-vigorous physical activity on the weekend than during the week (Dunton, Whalen, Jamner, Henker, & Floro, 2005; Treuth et al., 2007; Trost, Pate, Freedson, Sallis, & Taylor, 2000).

Limitations

A major limitation of the current study was that information on wake time was not collected for this study. Participants were asked about bedtime, sleep onset latency, time spent awake after sleep onset (WASO), but without wake time, sleep duration or sleep efficiency could not be calculated. It is important to note that studies have shown that sleep quality, but not sleep duration, is associated with college students' mood (Pilcher et al., 1997). However, obtaining data about sleep duration and sleep efficiency, another metric of sleep quality, would have provided us with a richer picture about the relationships we studied. Furthermore, there is evidence showing that sleep duration is associated with relevant health outcomes, such as obesity and physical activity. For example, actigraphy-measured WASO has been associated with physical activity in adolescents (Gupta et al., 2002). Sleep duration has been associated with risk of overweight and obesity (Knutson, 2005; Vioque, Torres, & Quiles, 2000), and the association has been stronger for younger adults than for older adults (Hasler et al., 2004).

Attrition was another methodological concern in the current study. Participants were asked to complete questionnaires for six consecutive nights. Only 40.9% of participants completed questionnaires on six consecutive nights. On average, participants completed approximately five (4.97) nights of questionnaires. Many participants completed fewer than six nights (“partial completers”), and some completed six nights, but they were not all consecutive (e.g., six nights of questionnaires over an eight-day period; “irregular completers”). We did not analyze whether participants who completed all six nights as instructed were different from partial completers or irregular completers.

If participants who completed the study as instructed were different from others, then the Level 1 results would have been, at most, slightly biased toward the tendencies of participants who completed the study as instructed because participants who completed the study as instructed accounted for 50.8% of the person-days (Level 1). At Level 2, the results would be biased toward partial or irregular completers (59.1% of participants) because all participants were given equal weight at the person level,

A potential issue we did not examine with the irregular or partial completers was whether attrition was more likely on particular days of the week (e.g., weekend days). We were partially able to attenuate this effect by adding day of the week as a covariate in the model, but the larger issue is that we may have non-randomly missing data if irregular or partial completers were more likely to miss certain days.

Both between- and within-person variability in time of measurement in the current study may have posed unknown statistical issues. Between-person inconsistency was the result of institutional limitations. Our concern was that many participants would complete the first day of the study, but requiring all participants to complete questionnaires at the same time every night would result in mass attrition. Therefore, we had to balance the methodological importance of consistency, which reduces error, with the importance of collecting multiple days of data from each participant – the study’s raison d’être. As a compromise, all participants completed the first night of the study at the same time, but they were allowed to pick a time, within a four-hour window, that would fit their nighttime schedule for the five following nights. Within-person inconsistency occurred because participants frequently failed to complete the nightly questionnaire at the specific time they chose, often resulting in nightly variation of many hours over the course of the study.

It is possible that variability in time of assessment biased our data. There is evidence showing a circadian rhythm of positive affect (Murray, Allen, & Trinder, 2002). Therefore, any variability in mood over the course of the study could have been due to variability in Level 1 predictors or due to variability in time of measurement, the latter because questionnaire responses might have been influenced by current mood. It is also possible that completion later in the night was less accurate because participants' memory for their overall mood for the day potentially declined later in the night. There is evidence showing that the ability to remember specific details of an event declines quicker than the ability to provide gist-level information (Goldsmith, Koriat, & Pansky, 2005). Variability in completion time is potentially problematic because we asked detailed questions (e.g., sleep diary questions about the previous night's sleep) that may have been increasingly difficult to answer as time passed.

Addressing Limitations and Future Research with Current Data

We could address the limitations of the current study both methodologically and statistically. Future studies should examine whether sleep duration is associated with exercise. There is evidence showing that sleep duration is associated with actigraphy-measured physical activity (Gupta et al., 2002), but whether a predictive relationship exists between sleep duration and purposeful, moderate-to-vigorous exercise among young adults remains unknown. Data collection strategies using smart phones could be used to more tightly control the time of assessment, thus reducing error variance in mood caused by diurnal fluctuation. However, it might be more informative to collect multiple mood assessments across the course of the day.

This would serve two purposes: first, it would result in a reduction in memory bias and error, and second, it would enable us to model diurnal change.

Finally, it may be important to consider more complex analyses, over longer time periods. For instance, it may be that the effects of sleep quality aggregate over multiple days. Mood today may be influenced by last night's sleep, which we modeled in the current study, as well as by yesterday's mood and by sleep from the night before last. There is evidence showing that consecutive nights of short sleep duration predict negative affect (Hamilton et al., 2008).

Suggestions for Future Research

Sleep and exercise are important because they are associated with morbidity and mortality (Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002; Lloyd-Jones et al., 2008; Vgontzas, Liao, Bixler, Chrousos, & Vela-Bueno, 2009). Current research suggests that sleep quality and exercise are mostly determined by individual differences and stable environmental characteristics. This suggests that simple educational differences might offer the greatest hope of changing these health behaviors.

Given that exercise, sleep, and mood appeared to remain rather stable within-person, perhaps interventions should focus on developing good stable habits that are resistant to change from the weekday to the weekend. Our results clearly showed that many participants in our study could benefit from sleep treatment; average person-weighted and -unweighted sleep quality were approximately 5.5 on a scale from 1 (*light sleep*) to 10 (*deep sleep*).

In addition to perhaps increasing the odds or duration of exercise, it might also be helpful to explore the use of sleep treatment in reducing the effects of trait hostility. Reductions in emotional and cognitive functioning have been found to occur after nights of disturbed sleep (Killgore et al., 2008). Individuals with higher hostility have also experienced greater cardiovascular reactivity in response to stressful interpersonal interactions (Brondolo et al., 2009). It is possible that sleep treatment for individuals with high trait hostility and poor sleep quality could attenuate the relationship between hostility and cardiovascular reactivity.

In the United States, traditional-age college students are typically considered to be relatively healthy. However, the current study indicates that college students age 18-25 have worse exercise habits than the age population overall. In addition, college students appear to have poor sleep quality. The current study highlights the importance of improving college students' health behaviors to foster long-term behaviors that can improve health and reduce the risk of mortality from heart disease.

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