

THE ROLE OF SLEEP IN LINKS BETWEEN SOCIAL THREAT AND CARDIOVASCULAR
RISK IN ADOLESCENCE

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ABSTRACT

Melissa Grimes: The role of sleep in links between social threat and cardiovascular risk in adolescence
(Under the direction of Lilly Shanahan)

Experiences of social threat in adolescence are common. During adulthood, such experiences are associated with both sleep problems and cardiovascular risk factors such as obesity and hypertension. Less is known about these associations during adolescence. The current study (N=152) tested whether social threat predicts cardiovascular risk during adolescence, and whether these linkages are mediated by sleep problems. Social threat was assessed via measures of peer victimization/bullying and loneliness. Sleep problems were assessed via sleep duration and disturbance. Cardiovascular risk was assessed via BMI and systolic blood pressure. Experiencing increased social threat at age 15 predicted pre-/hypertension by age 16. Additionally, cumulative sleep problems predicted higher BMI. No social threat→sleep problems→cardiovascular risk mediational pathway emerged. The findings support select linkages among social threat, sleep problems, and cardiovascular risk in mid-adolescence. Further research is needed to better understand the mechanisms by which earlier social threat is translated into later cardiovascular risk.

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Introduction

Cardiovascular disease (CVD) is the leading cause of death in the United States (Mozaffarian et al., 2016). Clinical endpoints of CVD typically do not manifest themselves until mid or late adulthood. However, many factors that initiate and maintain disease processes that eventually lead to later cardiovascular disease—here also referred to as cardiovascular risk—emerge earlier in the life course (Mozaffarian et al., 2016; Twig et al., 2016). For example, national studies suggest that approximately one in five adolescents aged 12-19 in the United States meet criteria for obesity status ($\text{BMI} \geq 95\text{th percentile}$) and approximately one in three meet criteria for overweight status ($\geq 85\text{th percentile}$) (Ogden, Carroll, Kit, & Flegal, 2014). Furthermore, hypertension is increasingly common among young people in the United States (Freedman, 2002; Gidding, Bao, Srinivasan, & Berenson, 1995; Kirk et al., 2005; Miller, Kaylor, Johannsson, Bay, & Churilla, 2014; Nguyen et al., 2011; Skinner, Perrin, Moss, & Skelton, 2015).

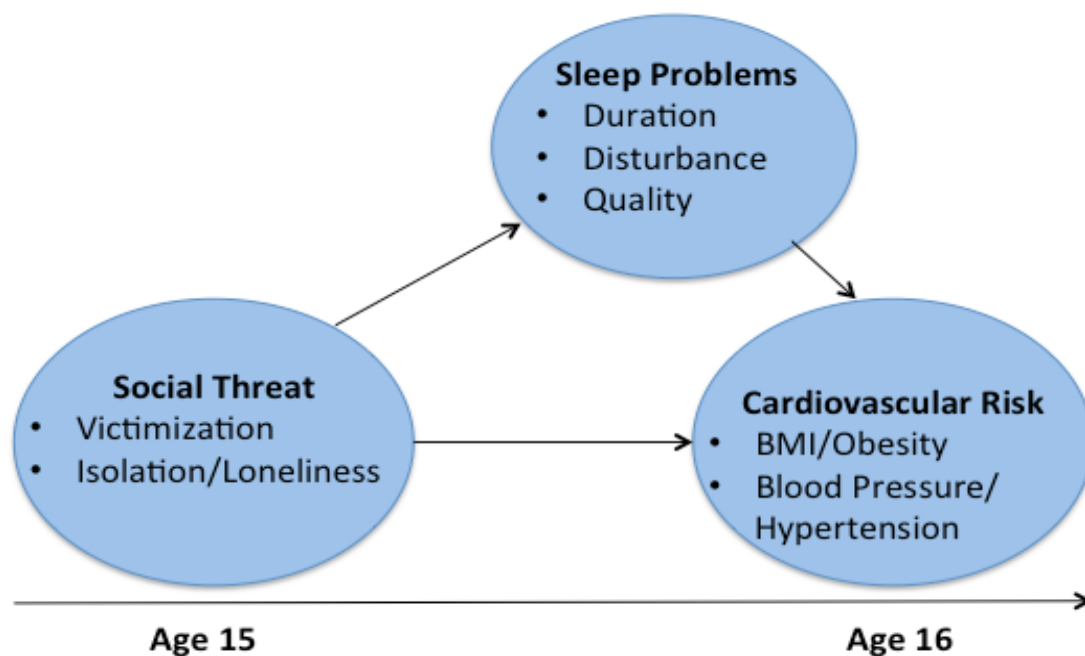
Obesity and hypertension are cardiovascular risk factors that are involved in the initiation and maintenance of chronic disease processes and predict later morbidity and mortality (Hartiala et al., 2012; Janssen et al., 2005; Juonala et al., 2011; Llewellyn, Simmonds, Owen, & Woolacott, 2016; Reilly et al., 2003; Reilly & Kelly, 2011). In the face of rising rates of cardiovascular risk factors during the early life course, many adolescents begin to notice declines in their health from this period onwards (Bauldry, Shanahan, Boardman, Miech, & Macmillan, 2012; Cui & Zack, 2013). Yet, despite mounting evidence that declines in cardiovascular health often begin before adulthood, the developmental origins of cardiovascular risk factors are rarely

examined in studies that begin assessing participants before adulthood (for some exceptions, see Doom, Gunnar, & Clark, 2016; Ruiz & Brondolo, 2016).

Work on adults suggests that influences on the development of cardiovascular risk are manifold, ranging from psychosocial influences to health behaviors to family history and molecular physiological factors. In the psychosocial domain, perceived threat in one's social environment (henceforth referred to as "social threat") has recently emerged as an important predictor of cardiovascular disease risk in adults. The role of social threat in cardiovascular risk is less well-understood during adolescence, however. Yet, during mid to late adolescence—the high school years—youth spend most of their time in frequent interactions with others across multiple social contexts (Giordano, 2003). Adolescents spend long days at school with their peers and teachers. They also spend much of their free time interacting with their peers (Larson & Verma, 1999; Steinberg & Sheffield Morris, 2001). Indeed, during this developmental period, youth typically spend more time with their peers than with their family, and many adolescents are exposed to social threat in the forms of peer victimization/bullying and social isolation (Copeland, Wolke, Angold, & Costello, 2013; Heinrich & Gullone, 2006).

Therefore, the current study examined whether social threat during adolescence—especially in the peer context—predicts cardiovascular risk during this developmental period. In addition, this study added to existing research by testing whether sleep problems—which are associated with both social threat and cardiovascular risk among adults—partially mediate this association. Figure 1 provides a conceptual overview over the current study.

Figure 1. Conceptual model of associations among social threat, sleep problems, and cardiovascular risk during adolescence



Social Threat During Adolescence

Human lives are intertwined, and a key characteristic of the human condition is that it is inherently social. Supportive social connections have been imperative for survival for millions of years. In turn, threats in one's environment have endangered survival. In historical contexts, the predominant environmental threats were physical in nature (e.g., exposure to dangerous predatory animals). During modern times, however, many forms of environmental threat are social in nature. Such social threats include victimization/bullying and also social isolation/the lack of social connection (defined in more detail in the next section). These two forms of social threat—whether observable/"real," perceived/imagined, or anticipated—have been shown to have a strong impact on cardiovascular health among adults (Slavich & Irwin, 2014).

Research suggests that social threats can initiate and maintain the body's "fight or flight" response. This response involves the mobilization of the body's resources to address imminent threat. For example, epinephrine and norepinephrine are released, resulting in increased blood flow and heart rate. These functions serve to keep an individual alert and to free up energetic resources to be able to address a threat (Padgett & Glaser, 2003). However, they also result in increased blood pressure. Thus, the physiological reactions involved in the fight or flight response are typically highly adaptive in the short term until the threat is removed. However, if activated repeatedly or continually—as is often the case among victimized or lonely individuals—these responses can become maladaptive and result in a long-term dysregulation of physiological systems associated with stress responses (Biebl, DiLalla, Davis, Lynch, & Shinn, 2011; Cohen et al., 1998). Ultimately, a progressive dysregulation of the body's stress response systems confers an increased risk of for chronic disease, including cardiovascular disease (Cohen et al., 1998; McEwen & Stellar, 1993; Miller & Chen, 2010; Slavich & Irwin, 2014). I now define and describe victimization/bullying and social isolation/loneliness, which are the two most common—yet often unavoidable—types of social threat encountered by youth during mid to late adolescence (Brown & Larson, 2009).

Victimization (or bullying) is a salient negative social threat experience that many adolescents face in their social networks (Brown & Larson, 2009). Peer victimization (and bullying) is defined as intentional and repeated aggression against others that often involves an imbalance of power (Olweus, 1994). Thus, victimization involves unwanted relational or physical aggression by another youth or group of youth (Centers for Disease Control and Prevention, 2016b). Relational victimization includes behaviors such as exclusion or spreading gossip about another person; physical victimization is more overt and involves hitting or pushing

and shoving another person (Wang, Iannotti, & Nansel, 2009). Victimization is common: prevalence rates range from approximately 8% to 41%, depending on the type of victimization (relational, physical, or verbal) and also the timeframe during which victimization was assessed (Copeland et al., 2013; Nansel et al., 2001; Wang et al., 2009). Indeed, victimization is the most common form of social threat that occurs within the school environment (Kubiszewski, Fontaine, Potard, & Gimenes, 2014). Being victimized by one's peers is perceived as a fundamental threat to safety by many youth (Kubiszewski et al., 2014). By definition, victimization typically involves repeated acts, and can readily lead to perceived or imagined threats even in the absence of "actual" social threats. In addition to the direct social threat encompassed by victimization behaviors, many adolescents suffer from social isolation—a different albeit also important type of social threat that has been found to be relevant to health (Laursen & Hartl, 2013).

Social Isolation/Loneliness is defined by the perceived absence of intimate relationships or social connections—negative or positive (Bunker et al., 2003; Cacioppo et al., 2002; Laursen & Hartl, 2013; Tennant, 1999). From an evolutionary perspective, social isolation posed an extreme threat to safety: survival was difficult without a strong social network to help protect and defend against harm (Hawkley & Cacioppo, 2010). Although individuals can thrive on their own in many areas in today's world, feelings of loneliness and perceived social isolation continue to act as a threat to health. Like bullying, loneliness is a common experience during adolescence, and, in fact, its prevalence peaks during this developmental period. Previous studies have found that anywhere from 50-79% of adolescents experience loneliness, depending on the timeframe of assessment (Brennan, 1982; Culp, Clyman, & Culp, 1995; Heinrich & Gullone, 2006; Parlee, 1979).

Links Between Social Threat and Cardiovascular Health

The presence of social threat in an adolescent's life can have significant implications for their health across the lifespan. Research on mostly adults and also animal models (Cruz et al., 2016) suggests that social threat is as important a risk factor for cardiovascular disease as is smoking or obesity (Bunker et al., 2003; Hemingway & Marmot, 1999; Holt-Lunstad, Smith, & Layton, 2010; Rozanski, Blumenthal, & Kaplan, 1999; Yang et al., 2016). Indeed, victimization and social isolation have been identified as particularly harmful social stressors with respect to adults' cardiovascular health (Powell et al., 2013; Slavich & Irwin, 2014).

Less is known about these associations in adolescence. One of the few extant studies on this topic found that positive social relationships during adolescence were protective against obesity in adolescence and also predicted lower risk of cardiovascular disease into young adulthood (Yang et al., 2016). In turn, social isolation during adolescence was associated with higher levels of systemic low-grade inflammation—a risk factor for cardiovascular disease in addition to obesity and hypertension—in young adulthood. In fact, the effect size of the association between social isolation on cardiovascular risk in the form of systemic inflammation was approximately similar in size to that of the association between physical inactivity and cardiovascular risk (Yang et al., 2016). Another recent study examined linkages between bullying and systemic inflammation and also found that child and adolescent victims of bullying had higher levels of inflammation in young adulthood (Copeland et al., 2014).

Despite their strengths, these two recent studies focused either on social isolation *or* on victimization, but not on both of these forms of social threat simultaneously. In addition, the assessment of social threat constructs was somewhat limited (e.g., via few items only). Yet, research on the impact of psychosocial risk or threat on development has emphasized the benefit

of analyzing risk cumulatively, noting that multiple risk factors in one's environment typically have greater influence on various outcomes than individual factors alone (Evans, Li, & Whipple, 2013). Additionally, previous studies of adolescents were not informative about potential mechanism by which social threat predicts cardiovascular risk. The current study focuses on sleep problems as a potential mediator of this association. Before describing preliminary evidence for separate social threat–sleep problems and sleep problems–cardiovascular risk associations, I next describe two dimensions of sleep problems that may each play a role in our conceptual model.

Pathways from Social Threat to Cardiovascular Links Via Sleep Problems

Little is known about the pathways that link social threat with cardiovascular risk before adulthood. The current study focuses on sleep problems as a potential mediator in this link. There is some support for separate social threat-sleep problems and also sleep problems-cardiovascular risk associations; thus providing preliminary support for our conceptual model. However, no study during adolescence has comprehensively tested this overall mediational model, with several indicators of each, social threat, sleep problems, and cardiovascular risk. I now review the literature on each of these separate links.

The Multiple Facets of Sleep

Sleep is a multifaceted construct, and an individual's sleep problems can be characterized along both quantitative and qualitative dimensions. In the current study, I focus on sleep duration as an index of quantity and sleep disturbance as an index of quality (Buysse et al., 2008). *Sleep duration* is a quantitative index of the amount of time that a person spends asleep each night. It is commonly assessed via self-report of the minutes or hours spent asleep. It can also be assessed by objective calculations based on actigraphy information regarding activity during the night.

Sleep disturbances are occurrences during the night that make it difficult for a person to fall or stay asleep (Bruni et al., 1996). Examples include emotional disturbances such as worrisome thoughts, or physical disturbances such as having to use the restroom, and trouble breathing. Sleep disturbances are more common in adolescents than in adults, possibly due to hormonal changes and increased social stressors, and can negatively influence daytime functioning (Pagel, Forister, & Kwiatkowski, 2007).

Social Threat → Sleep Problems Link

Social threat endangers a fundamental prerequisite for sleep: feeling safe and secure (Dahl & Lewin, 2002). Previous research on adults has demonstrated that perceiving one's physical environment as safe is a necessity for attaining high-quality sleep (Hawkley, Preacher, & Cacioppo, 2010; Troxel, Cyranowski, Hall, Frank, & Buysse, 2007). The ability to fall and stay asleep requires a person to cease responding to her/his external environment. Thus, the person must feel safe enough to stop responding to any potential dangers. This safety prerequisite also extends to the social environment: when safety/security in social relationships is amiss, optimal sleep patterns are threatened (Sladek & Doane, 2015).

Some evidence for the link between social threat and poor sleep comes from work on parent-child relationships—in younger children. For example, research on elementary school children shows that emotional insecurity in the parent-child relationship predicts later sleep problems, including shorter sleep duration, greater disturbances, and poorer sleep quality (Keller & El-Sheikh, 2011). In addition, a family context characterized by anger and hostility—either in the parent-child or in the marital relationship—is also associated with sleep problems in children (Belisio, Louzada, & de Azevedo, 2010; El-Sheikh, Buckhalt, Mize, & Acebo, 2006; Hicks &

Diamond, 2011). However, much of this research was based on younger children and is not informative about social threat in the peer domain during adolescence.

A new body of literature on social threat and sleep is beginning to emerge; the current study will contribute to this work. Beginning with peer victimization, one study of adolescents aged 12-17 years old found that adolescents who had been bullied by classmates had poorer sleep than their peers (Smaldone, Honig, & Byrne, 2007). This study assessed sleep via parent reports, however, which is not an ideal method for assessing sleep in adolescents. In addition, only one dimension of sleep was assessed—whether children got “enough sleep”—which was subject to parental interpretation. Additional studies have also revealed that being the victim of bullying is associated with poor sleep quality and also with sleep disturbances, in particular with difficulties falling asleep and waking up/staying awake (Sansone & Sansone, 2008; Tu, Erath, & El-Sheikh, 2015). In fact, the authors of one recent meta-analysis suggested that the presence of sleep problems could be viewed as a potential marker of bullying exposure (van Geel, Goemans, & Vedder, 2016). However, all of the studies that this meta-analysis was based on were cross-sectional. Most of these studies also did not differentiate between the two main types of victimization (relational and physical). Studying associations between victimization and sleep problems longitudinally and differentiating between the different types of social threat (relational and physical victimization/bullying and social isolation/loneliness) and sleep problems in one study would provide us with a more comprehensive understanding of this association.

With respect to the links between social isolation and sleep problems, work on adults supports this association. A common finding among prior studies is that lonely adults report an overall poorer sleep quality (Cacioppo et al., 2002; Segrin & Domschke, 2011). However, many

of these studies were limited by their cross-sectional designs. Furthermore, much less is known about loneliness-sleep problems associations during adolescence.

One study with adolescents aged 12-17 years, however, revealed that loneliness was significantly correlated with more sleep disturbances (Mahon, 1994). While social connectedness fosters feelings of safety and security that can aid in sleeping, a lack of social support (i.e. loneliness) can increase risk of an array of sleep problems (Sladek & Doane, 2015). The current study extends upon the findings of the current literature by examining the association between social threat at one time point and sleep problems one year later. Testing these associations longitudinally will enable us to analyze whether social threat is a marker for sleep problems one year later in addition to understanding the role of sleep problems in our conceptual mediational model.

Sleep Problems→ Cardiovascular Risk Link

Sleep behaviors during adolescence constitute an important foundation for subsequent sleep behaviors (Dahl & Lewin, 2002), and can have both short- and long-term effects on health. In one study, adults who reported a sleep duration of 5 hours or less had a 500% increase in risk for hypertension compared to those who slept 6 or more hours each night (Vgontzas, Liao, Bixler, Chrousos, & Vela-Bueno, 2009). In addition, in a study of adult women, researchers found that sleeping less than the recommended 8 hours each night put participants at increased risk for coronary heart disease 10 years later (Ayas et al., 2003).

Although the majority of the work on sleep problems and cardiovascular risk has been conducted on adult samples, the number of studies examining this linkage during earlier developmental periods is rising, and is primarily focused on inadequate sleep *duration*. For example, studies have shown that healthy adolescents who do not sleep an adequate amount of

time each night, and/or who have late bedtimes are at increased risk for becoming overweight or obese and developing hypertension during adolescence and into young adulthood (Hart, Cairns, & Jelalian, 2011; Meldrum & Restivo, 2014; Peach, Gaultney, & Reeve, 2015). Reversely, adolescents sleeping an adequate amount each night appear to be protected against becoming obese (Chen, Wang, & Jeng, 2006). However, this study defined “adequate sleep” as attaining 6-8 hours of sleep on four or more weekdays during the week, which does not match the Center for Disease Control’s recommendation for 8-10 hours of sleep for this age group.

Only few studies have examined sleep *disturbance* and cardiovascular risk in adolescence. In one of the few studies, healthy adolescents who experienced a high number of sleep disturbances were at greater risk for higher blood pressure and hypertension and also for higher BMI than their peers (Narang et al., 2012). This study was also one of the few to use the sleep disturbances scale on the Pittsburgh Sleep Quality Index (PSQI), which is also used in the current study. It is clear from the extant literature that suffering from sleep problems puts individuals at increased risk for cardiovascular disease. However, it is necessary to examine this link using multiple dimensions of sleep problems to fully assess how these variables are related.

Taken together, research on mostly adults has suggested that social threat (i.e. victimization and loneliness) is a key psychological construct associated with cardiovascular risk, and that sleep problems could play an important role in these pathways (Cacioppo et al., 2002; Harris, Qualter, & Robinson, 2013; Miller & Chen, 2010; Segrin & Domschke, 2011). Although there is preliminary evidence for several of these separate associations during adolescence, comprehensive tests of mediational pathways in our conceptual model during this developmental period are scant. To my knowledge, the current study is the first to test such a mediational model. In addition, the current study extends previous work with its simultaneous

assessments of a) multiple aspects of social threat, b) multiple aspects of sleep problems, and c) multiple aspects of cardiovascular risk. Finally, the current study examines sex differences in all of the conceptual model's associations, which may be important for the reasons outlined below.

Sex Differences

The associations predicted by our conceptual model may differ by sex for several reasons. First, the prevalence of the study's key constructs is sex-differentiated. With respect to type of victimization, females are more likely than males to be victims of relational aggression. In turn, males are more likely than females to be victims of physical aggression (Wang et al., 2009). Sex differences in loneliness are not consistently found, but select studies have reported that male adolescents report feelings of loneliness more often than female adolescents (Koenig & Abrams, 1999). The prevalence of sleep problems is also typically sex-differentiated. Sleep duration has been found to be shorter for females than for males during adolescence, but this sex difference reverses during adulthood (Burgard & Ailshire, 2013; Maslowsky & Ozer, 2014). Female adolescents are also more likely to present with sleep disturbances than their male counterparts (Buboltz, Brown, & Soper, 2001; Maume, 2013). Finally, several cardiovascular risk factors including obesity and elevated systolic blood pressure are more common in adolescent males than females (Dasgupta et al., 2006; Ogden et al., 2014; Shanahan, Schorpp, Volpe, Linthicum, & Freeman, 2016).

Second, the pathways in our conceptual model may differ by sex. For example, associations between social threat and sleep problems may be stronger in females than in males considering that adolescent females tend to ruminate more about social threat than males (van Geel et al., 2016). Studies that test sex differences in select links of our conceptual model are rare, and results are inconclusive to date. For example, one study of European youth found that

short sleep duration was associated with higher BMI in both sexes (Hitze et al., 2009). In contrast, a study of Australian adolescents reported that this association was found in male but not in female participants (Eisenmann, Ekkekakis, & Holmes, 2006). Given evidence of sex-differentiated prevalence of key construct in our model and select evidence for sex-differentiated associations, the current study aims to further explore sex differences in our conceptual model.

Current Study

The current study examined associations among social threat, sleep problems, and cardiovascular risk in adolescence in a community sample of adolescents at approximately ages 15.5 and 16.5 years old. The primary outcome of the current study was cardiovascular risk—that is factors that could initiate and maintain disease processes that eventually lead to later cardiovascular disease. I specifically examined two cardiovascular risk indices—both of which can be assessed continually and also with clinically meaningful cutoffs that result in categorical variables. First, I examined body mass index (BMI), which is calculated using an individual's height and weight. In turn, BMI can then be used to place the person into a weight category, ranging from underweight to obese (Centers for Disease Control and Prevention [CDC], 2015). Previous research has shown that elevated BMI in childhood and adolescence predicts lifelong cardiovascular morbidity (Skinner et al., 2015). Second, I focused on blood pressure, which is a measure of the strength with which the blood pushes against the artery walls (National Library of Medicine [NLM], 2015). Systolic blood pressure indicates the pressure when the heart is active (NLM, 2015). Blood pressure that is between a normal and high threshold is indicative of pre-hypertension, a condition that, if not treated, can result in hypertension. Obesity and hypertension are both thought of as indices of the overall underlying construct of cardiovascular risk. Nevertheless, research has shown that, during adolescence, BMI and systolic blood pressure

are only moderately correlated (Hahn, Heath, & Chang, 1994). Therefore, it will be important to examine them as separate outcomes.

Taken together, I propose to test a model that examines whether social threat manifests itself in cardiovascular risk (e.g., overweight/obesity and pre-/hypertension) during adolescence via sleep problems, and whether these associations differ by sex.

Hypotheses

- 1) The presence of social threat (victimization/loneliness) will be associated with increased cardiovascular risk, as characterized by higher BMI / a classification as overweight/obesity, and higher systolic blood pressure / a classification as pre-/hypertensive status.
- 2) The presence of social threat (victimization/loneliness) will be associated with increased sleep problems in the form of shorter duration and more disturbances.
- 3) Participants who present with sleep problems will be at increased risk for higher BMI / a classification as overweight/obesity, and higher systolic blood pressure / a classification as pre-/hypertensive status.
- 4) Sleep problems will mediate the association between presence of social threat and cardiovascular risk outcomes.
- 5) Sex differences in all associations will be tested. Given limited evidence from the extant literature, there are no specific hypotheses.

Methods

Participants

Participants came from the RIGHT (Research Investigating Growth and Health Trajectories) Track project, an ongoing prospective-longitudinal community study spanning 12+ years, which was approved by the governing Institutional Review Board. Four hundred and forty seven participants were initially recruited at 2 years of age through childcare centers, the County Health Department, and the local Women, Infants, and Children program. Additional details about sample recruitment may be found elsewhere (Smith, Calkins, Keane, Anastopoulos, & Shelton, 2004). The recruitment sample was diverse, with 67% of the children classified as European American, 27% African American, 4% biracial, and 2% Hispanic. Families were also economically diverse: Hollingshead scores that take into account parental educational level and occupation (Hollingshead, 1975) ranged from 14 to 66 ($M = 39.56$). Hollingshead scores from 40 to 54 are typically representative of the middle class.

When participants were approximately 16 years old, a new study component was added for a subset of participants. This “health component” focused on adolescents’ health behaviors and cardiometabolic health. The current study draws on data from this health component and examines $N = 152$ participants (females = 58%) with complete data on adolescent social threat, sleep problems, and cardiovascular risk. Attrition analyses revealed that participation at the second time point was unrelated to sex ($p = .12$), race ($p = .58$), and SES ($p = .63$).

Analytic Strategy

I began by testing each separate link in the model. Models predicting continuous outcomes such as BMI and systolic blood pressure were estimated using separate ordinary least squares linear regression models. Models predicting dichotomous outcomes such as overweight/obesity and pre-/hypertension were estimated using separate logistic regression models. The outcome variables were 1) first regressed on the covariates, 2) then on the cumulative index adjusted for the covariates, 3) then on each predictor one at a time, adjusted for the covariates, and 4) finally on all individual predictors in each domain and covariates simultaneously. In a final step, mediation was tested using Baron and Kenny's (1986) method for examining mediation through regression. I tested three separate pathways: 1) social threat → cardiovascular risk 2) social threat → sleep 3) sleep → cardiovascular risk. I then regressed cardiovascular risk on social threat, controlling for the role of sleep. Full mediation would be supported if the social threat variable was no longer significant in the fourth regression step.

With respect to missing data, the analytic techniques used here employed listwise deletion. A more ideal method, primarily available with more advanced techniques such as structural equation modeling, would have been the use of a full information maximum likelihood estimator—which uses all available data values (Enders & Bandalos, 2001). Previous analyses with the current sample showed, however, that results generally did not differ when using listwise deletion versus full information maximum likelihood estimators (Janssen et al., 2017). Thus, at least in past analyses with this sample, the use of the listwise deletion method for missing data did not bias the results.

Procedures

At approximately ages 15.5 and 16.5, adolescents were invited for laboratory visits. During the age 15 assessment, adolescents visited the RIGHT Track laboratory at the University of North Carolina at Greensboro and reported on social threat. During the age 16 assessment, adolescents visited the Exercise Physiology Laboratory at the University of North Carolina at Greensboro and reported on their sleep problems. In addition, trained interviewers assessed adolescents' weight and height and measured adolescents' blood pressure. Adolescents provided assent and were given \$50 gift cards for their participation. At least one parent attended the visit to the research laboratory with their child and provided consent. All study protocols were approved by the governing Institutional Review Boards.

Measures

Cardiovascular risk. *Body mass index (BMI)* was computed using the formula $\text{weight}/(\text{height}^2)$. Height (kg) and weight (m) were measured by trained interviewers during participants' visits to the laboratory at ages 4, 5, 7, 10, 15, and 16, and by participants' self-reports when a laboratory visit was not possible. Height was measured to the nearest 0.1 cm with a wall mounted, calibrated stadiometer (SECA, Chino CA). Weight was measured to the nearest 0.1 kg with a balance-beam scale (Detecto-medic, Brooklyn NY). Age- and sex-adjusted BMI percentiles were assigned according to the Center for Disease Control (CDC) growth charts (Centers for Disease Control and Prevention, 2009). CDC guidelines were also used for computing dichotomous overweight/obesity variables. Specifically, adolescents at $\text{BMI} \geq 85^{\text{th}}$ percentile for their sex and age were coded as being overweight/obese (Centers for Disease Control and Prevention, 2009). Among participants with both laboratory-measured and self-reported BMI, measurements were highly correlated ($r = .97, p < .001$).

Systolic blood pressure (SBP). Upon arrival at the Exercise Physiology Laboratory and after obtaining consent/assent, participants rested quietly for 5 minutes with their arm supported at heart level and feet on the floor, as outlined by the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (National High Blood Pressure Education Program, 2004). Manual cuff blood pressure measurements were repeated two times with at least 5 minutes between measures. The mean of two readings was taken; such averaging has been shown to have high validity (Bauldry, Bollen, & Adair, 2015). Dichotomous pre-/hypertension variables were computed using the age- and sex-adjusted height percentiles provided by the U.S. Department of Health & Human Services guidelines (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004). According to these guidelines, values of SBP ≥ 120 mmHg or $\geq 90^{\text{th}}$ percentile for age, sex, and height indicate pre-/hypertension.

Social threat. *Victimization* was measured using a self-report measure of aggression and social behavior during the past year adapted from Linder, Crick, and Collins (2002). This 24-item questionnaire (full measure shown in Appendix) yielded two subscales of interest for the current study: relational victimization and physical victimization. Participants were asked to rate each statement on a 7-point Likert scale ranging from 1 (“Not at all true”) to 7 (“Very true”). Example items in the relational victimization subscale include “I have a friend who ignores me or gives me the “cold shoulder” when they are angry with me” and “A friend of mine has gone “behind my back” and shared private information about me with other people.” Example items in the physical victimization subscale include “I have been pushed or shoved by people when they are mad at me” and “I have a friend who tries to get their way through physical intimidation.” In

the current study, the reliability coefficient for the 4-item relational victimization subscale is $\alpha=.80$ and $\alpha=.57$ for the 3-item physical victimization subscale.

In addition, the Youth Risk Behavior Survey (YRBS) was administered to participants. The YRBS is a self-report questionnaire that includes 2 items (full items shown in Appendix) assessing victimization behaviors (Centers for Disease Control and Prevention, 2016a). The first item asks participants if they have been bullied on school property in the past 12 months. The second item asks if they have been bullied electronically in the past 12 months. A substantial number of items on the YRBS have kappas ranging from 61-100%, indicating sufficient reliability (Brener, Collins, Kann, Warren, & Williams, 1995).

Social isolation/loneliness was assessed using a 24-item self-report measure of loneliness and social dissatisfaction that was adapted from Asher, Shelley, and Henshaw (1984). The full measure is shown in the Appendix. There are 16 target items and 8 filler items that are rated on a 5-point Likert scale ranging from 1 (“Not at all true”) to 5 (“Always true”). Example target items include “I have nobody to talk to” and “It's hard to get other teens to like me.” Scores from the 16 target items are summed, resulting in a total loneliness score ranging from 16 (low loneliness) to 80 (high loneliness). In the current study, reliability for this measure is high, with $\alpha=.92$.

In addition to the individual social threat variables, I created a cumulative social threat index. I dichotomized the continuous social threat variables (loneliness, relational victimization, and physical victimization), assigning scores of 1 to those scoring in the top 25% for each variable, and 0 for all others. This approach to dichotomizing variables is consistent with previous cumulative risk research (Burchinal, Roberts, Hooper, & Zeisel, 2000; Evans et al., 2013). The two bullying variables were already dichotomized, with 0 indicating “no” and 1

indicating “yes”. These five dichotomous variables were summed to create a cumulative social threat score ranging from 0-5.

Sleep problems. The Pittsburgh Sleep Quality Index (PSQI) was used to measure adolescents’ sleep duration and disturbance. The PSQI is a self-report measure that assesses sleep behaviors over the past 1-month period. Here, I focused on two of the seven subscales of the measure: duration and disturbance. The PSQI has been found to be internally consistent, reliable, and valid ($\alpha = .83$, test-retest reliability of .87) (Backaus, Junganns, Broocks, Riemann, & Hohagen, 2002; Carpenter & Andrykowskia, 1998; Pilcher et al., 1997). The sleep duration subscale assesses participants’ average amount of sleep each night over the past month (in hours). The sleep disturbance subscale is comprised of 10 items asking participants how often during the past month have they had trouble sleeping because of issues including having to use the bathroom, feeling too hot or cold, and having bad dreams. Participants’ responses were scored 0 for “Not during the past month”, 1 for “Less than once a week”, 2 for “Once or twice a week”, and 3 for “Three or more times a week.” For ease of analysis and interpretation, the scores on this subscale were then split into tertiles representing no sleep disturbance (score of 0-1), moderate sleep disturbance (score of 2-8), or severe sleep disturbance (score of 9+). Although the PSQI was designed for adults, it is commonly used with adolescents (Harris et al., 2013).

In addition to the individual sleep variables, I created a cumulative sleep problems index. First, the sleep duration variable was dichotomized into less or greater than 8 hours (1 = sleeping less than 8 hours). Next, for the sleep disturbance variable, those scoring in the highest—most severe—tertile were assigned 1; all others were assigned 0. Furthermore, I used one more item from the PSQI for the cumulative sleep index, the item coding sleep quality. Specifically, this

item asked: “During the past month, how would you rate your overall sleep quality?” with scores ranging from Very Good (0) to Very Bad (3). For inclusion into the cumulative risk index, this score was dichotomized into 0 = “good quality” (score of 0-1) and 1 = “poor quality” (score of 2-3). These three dichotomous variables were summed to create a cumulative sleep problems score ranging from 0-3.

Notably, sleep can be measured in a variety of ways, and objective instruments—such as polysomnography—are often considered “gold standard.” However, due to high participant burden when using polysomnography or actigraphy (Gradisar, Gardner, & Dohnt, 2011), only self-reports of sleep were assessed during adolescence in this study. Self-report scales, such as the Pittsburgh Sleep Quality Index (PSQI), are commonly used and allow one to understand how individuals perceive their own sleep (Lockley, Skene, & Arendt, 1999).

Covariates. Three potential covariates were assessed in the sample: sex, race, and socioeconomic status (SES). Children’s sex and race were reported by parents. SES was assessed using the Hollingshead Index, a weighted average of parental education and employment (Hollingshead, 1975). Scores ranging from 40 to 54 represent middle class professional and technical occupations. Families from a range of socio-economic strata typically captured by this scale are represented in this analysis.

Measures used in sensitivity analyses. Two measures were included to account for potential within-family sources of social threat in follow-up analyses. Parent-child conflict was measured through the hostility scale of the Getting Along with My Parent (Mom) questionnaire (Conger & Ge, 1999). This scale includes 8 questions that assess the frequency with which the mother displays both verbal and nonverbal behaviors, such as criticizing the child’s ideas and pushing, hitting, or grabbing the child. Prior research has found reliability for the hostility scale

to be $\alpha=.79$ (Conger et al., 2002). Adolescent perception of interparental conflict was assessed through five questions regarding the extent to which they have witnessed behaviors in the past year. Items included statements such as “My parents are often angry at each other” and “My parents disagree and argue about my behavior more than once a week”. While this subscale comes from an unpublished measure (Shanahan, 2007), the scale had a high reliability in this sample, with $\alpha=.84$.

Results

Descriptive Statistics

Table 1 displays descriptive statistics [means and standard deviations for continuous variables and N (%) for categorical variables] for all social threat, sleep, and cardiovascular risk variables used in the current study. Consistent with recent work on nationally representative cohorts (e.g., Nguyen et al., 2011; Reither, Olshansky, & Yang, 2011), youth in the analytic sample showed evidence of relatively high BMI and systolic blood pressure. For example, the average BMI was at 24.15, which is close to the BMI = 25 CDC cutoff used to define overweight status (Janssen et al., 2005). Indeed, 32.9% of adolescents in our sample met criteria for overweight and obesity status combined ($\geq 85^{\text{th}}$ percentile), which is consistent with a rate of 32.2% for adolescents that has recently been reported at the U.S. national level (Skinner & Skelton, 2014). The average systolic blood pressure (SBP) for adolescents in our sample was 113 mmHg, which is close to the adult cut-off of 120 mmHg used to define pre-hypertension. Indeed, 21.7 % of our participants met criteria for the combined pre-/hypertension status category. Taken together, a substantial proportion of adolescents in our sample met criteria for cardiovascular risk factors, which is consistent with recent nationally-representative data from young people growing up in the United States.

Social threat was also prevalent in this sample: the cumulative social threat variable indicated that the majority of adolescents in our sample (56.4%) had encountered some form of social threat in the past year. Almost 15% of adolescents reported having been bullied at school within the past year, and 10% reported having been bullied electronically. The possible scores

for the relational and physical victimization measures ranged from 4-28 and 3-21, respectively, and the mean values on these scales in our sample indicate that participants experienced some form of victimization in the past year ($M = 9.19$ and $M = 4.75$ for relational and physical victimization, respectively). With respect to the sleep variables, only 43.2% of adolescents reported not having had a sleep problem in the past month, and 14.8% of adolescents in our sample reported poor sleep quality. The mean sleep duration for adolescents in our sample was below 8 hours, and, thus, fell below the recommended minimum number of hours of nightly sleep for adolescents (Centers for Disease Control and Prevention, 2015).

We also tested sex differences in the mean and prevalence of each study variable. There was a significant difference for relational victimization, $t(142.78) = -2.49, p = .014$, with females experiencing more relational victimization than males. In contrast, males reported more physical victimization at the statistical trend level, $t(147) = 1.78, p = .077$. In addition, there was a significant sex difference for sleep disturbance, $t(144.38) = -2.73, p = .007$, with females suffering from more sleep disturbances than males (Figure 2). Figure 2 indicates that this the sex difference emerged particularly at the level of severe sleep disturbances [$\chi^2(1) = 6.01, p = .01$].

Bivariate Associations Among Study Variables

Table 2 shows Pearson correlations among all continuous study variables. *Correlations within study constructs.* Correlations among the individual social threat variables indicated that loneliness was positively correlated with both relational victimization and physical victimization, meaning that higher levels of loneliness were associated with more relational and physical victimization. Correlations among the sleep variables indicated that adolescents who slept more hours also reported a lower number of sleep disturbances. Correlations between the cardiovascular risk variables indicated that BMI and blood pressure were positively correlated:

those with high BMI also had higher blood pressure. The size of significant correlations within each construct ranged from $r = -.20$ to $r = .47$, supporting low to moderate associations among study variables. Overall, these low to moderate associations did not support the use of factor analyses and factor score models to create overarching summary variables for each of the risk and outcome domains (Burchinal et al., 2000).

Correlations across study constructs indicated that some indicators of social threat were associated with greater sleep disturbance. Specifically, higher levels of loneliness and relational victimization were associated with greater sleep disturbance. Surprisingly, however, there was only one marginal correlation between the cardiovascular risk variables and each, the individual social threat and sleep variables. Specifically, greater levels of loneliness were associated with systolic higher blood pressure at the statistical trend level. In addition, higher numbers of sleep disturbances were associated with higher BMI at the statistical trend level. With respect to the cumulative variables, increased cumulative social threat were marginally correlated with greater cumulative sleep problems and blood pressure, and significantly correlated with increased sleep disturbance. Increased cumulative sleep problems were associated with higher BMI and greater loneliness.

Predicting continuous CVR outcomes. Table 3 displays results from ordinary least squares regression models predicting the continuous BMI and systolic blood pressure outcome variables. The outcome variables were 1) first regressed on the covariates, 2) then on the cumulative index adjusted for the covariates, 3) then on each predictor one at a time, adjusted for the covariates, and 4) finally on all individual predictors in each domain and covariates simultaneously. When interpreting results, we primarily focus on the coefficients of the

cumulative variables, and use caution when interpreting results with individual indicators from each domain given multiple testing.

Race was significantly associated with BMI: being non-White was associated with higher BMI ($\beta = .29, p < .001$). From the domain of social threat, the cumulative social threat variable predicted higher blood pressure at the statistical trend level ($\beta = .16, p < .10$). With respect to the individual social threat variables, only loneliness predicted higher blood pressure at the statistical trend level ($\beta = .16, p < .10$); this association became significant in the multivariate model ($\beta = .21, p < .05$). From the domain of sleep problems, the cumulative sleep problems score was associated with greater BMI ($\beta = .18, p < .05$). In the multivariate model, being electronically bullied was associated with lower BMI ($\beta = -.20, p < .05$). Taken together, cumulative social threat predicted SBP at the statistical trend level and with each additional sleep problem, BMI one year later increased. Next, findings from the continuous outcomes were followed up with clinically meaningful dichotomous CVR variables, using logistic regression models.

Predicting categorical CVR outcomes. Table 4 displays results from logistic regression models predicting the categorical overweight/obesity and pre-/hypertension variables. From the domain of social threat, the cumulative social threat variable predicted pre-/hypertension status. Specifically, with each additional social threat encountered by the adolescent, the odds for meeting criteria for pre-/hypertensive status increased by a factor of 1.40 ($p < .05$). None of the individual social threat variables predicted the categorical cardiovascular risk outcomes. From the domain of sleep problems, the cumulative sleep variable was associated with the overweight/obesity outcome at the statistical trend level. Specifically, with each additional sleep problem, the odds for meeting criteria for overweight/obesity status increased by a factor of 1.46

($p < .10$). None of the individual sleep variables predicted the categorical cardiovascular risk outcomes.

Predicting continuous sleep variables. Table 5 displays results from ordinary least squares regression models predicting the continuous sleep duration and sleep disturbance variables, as well as the cumulative sleep problems variable. Similar to the tables above, the outcome variables were first regressed on the covariates, then on each predictor adjusted for the covariates, and finally on all predictors and covariates combined. In terms of the demographic variables, sex was significantly associated with both sleep disturbance ($\beta = .20, p < .05$) and cumulative sleep problems ($\beta = .18, p < .05$), with females reporting greater sleep problems.

The cumulative social threat variable predicted sleep disturbance and cumulative sleep problems at the statistical trend level ($\beta = .16$ and $\beta = .15, p < .10$, respectively). In terms of the individual social threat variables, results from the adjusted bivariate models showed that, relational victimization significantly predicted sleep disturbance ($\beta = .23, p < .01$), while loneliness significantly predicted cumulative sleep problems ($\beta = .19, p < .05$). Relational victimization continued to significantly predict sleep disturbance ($\beta = .22, p < .05$) when all other social threats were adjusted for.

Sex differences in associations. Sex differences were tested in all regression models via moderation analyses. Only one significant interaction emerged, indicating that higher levels of loneliness predicted increased sleep disturbance only in males ($\beta = -.76, p < .05$). However, given the number of interactions tested, this finding could be due to chance.

Mediation Analyses

Based on the results from the regression pathways, I tested four complete mediation models were tested as suggested by Baron and Kenny (1986): cumulative social threat predicting

BMI via cumulative sleep problems, cumulative social threat predicting BMI via sleep disturbance, loneliness predicting BMI via cumulative sleep, and relational victimization predicting BMI via sleep disturbance. While some of the individual pathways in these models were significant, as previously described, the overall mediational pathways were non-significant. Thus, evidence for social threat predicting cardiovascular risk via sleep problems did not emerge.

Sensitivity Analyses

In a first set of sensitivity analyses, all models were rerun, adjusting for within-family sources of social threat (i.e., parent-child hostility and child perception of interparental conflict). These analyses did not result in any meaningful changes in effect size of the results reported here.

In a second set of sensitivity analyses, I attempted to control for cardiovascular risk at age 15. A first finding was that age 15 and 16 BMI were correlated at $r = .90, p < .001$. When age 15 BMI was included in the analyses, the standardized coefficient of cumulative social threat to later BMI was reduced from $\beta = .18$ to $\beta = .03$. A second finding was that age 15 and 16 systolic blood pressure were correlated at $r = .46, p < .001$. When age 15 systolic blood pressure was included in the regression models, the standardized regression coefficient of cumulative social threat predicting later blood pressure was reduced from $\beta = .16$ to $\beta = .14$. When age 15 BMI and systolic blood pressure were included in the analyses predicting age 16 categorical overweight/obesity and pre-/hypertension outcomes, findings did not change, however. Thus, only 1 out of 4 findings changed with the inclusion of the age 15 CVRs. Tables S1 and S2 in the Appendix show the full results of these sensitivity analyses.

The recommended minimum number of hours of nightly sleep for adolescents is 8 hours, and in a number of previous studies, the < 8 hours cut-off had been used to define short sleep duration (e.g. Eisenmann et al., 2006; Seicean et al., 2007). Therefore, my main analyses had focused on whether or not adolescents typically slept 8 hours per night (Centers for Disease Control and Prevention, 2015). In a third set of sensitivity analyses, I tested whether using a different cut-off for “short sleep duration” would change the findings. Descriptive analyses showed that 23% of adolescents typically slept < 7 hours/night, whereas only 6% of adolescents typically slept < 6 hours/night; therefore I used the < 7 hours/night variable for these sensitivity analyses. Results revealed that sleeping less than 7 hours was associated with higher BMI ($\beta = .17, p < .05$) and greater risk of being overweight/obesity ($OR = 2.38, p < .05$). Changing the cumulative sleep problems index to include sleep duration less than 7 hours also changed results. Specifically, the cumulative score including less than 7 hours of sleep/night was associated with both higher BMI ($\beta = .26, p < .01$) and higher blood pressure ($\beta = .20, p < .05$), and also associated with greater risk of being overweight/obese ($OR = 1.68, p < .05$), and of being pre-/hypertensive ($OR = 1.71, p < .05$).

Mediation analyses using this lower threshold for sleep duration yielded non-significant findings, as neither the individual nor the cumulative social threat variables predicted the new cumulative sleep problems variable.

Discussion

Cardiovascular risk—such as elevated BMI and pre-/hypertension—among young people in the United States is at historically high levels and contributes to disease processes that predict subsequent all-cause morbidity and mortality (Mozaffarian et al., 2016). Nevertheless, the origins of cardiovascular risk factors during the early life course remain to be fully understood. The current study was among the first to examine social threat—a putative risk factor from the domain of psychosocial risk—and sleep problems—a putative risk factor from the domain of health behaviors—in the prediction of adolescent cardiovascular risk. Results supported separate direct links from cumulative social threat to later pre-/hypertension and associations between cumulative sleep problems and higher BMI. Support for a full mediational chain from earlier social threat to later sleep problems and cardiovascular risk did not, however, emerge.

Descriptive findings from the current community study were consistent with work from nationally representative studies in that rates of cardiovascular risk among adolescents were high (Ogden et al., 2014; Skinner & Skelton, 2014). Specifically, about one in three adolescents in our sample met criteria for being overweight/obese, and approximately one in five for pre-/hypertension. In addition, our sensitivity analyses showed that adolescent BMI is highly stable over the course of one year and that systolic blood pressure displays moderate stability over this time span. These prevalence rates and stabilities are alarming given the harmful consequences of increased cardiovascular risk, including chronic illness and disability beginning at a young age and also early mortality (Mozaffarian et al., 2016). Given such costly outcomes, it is pertinent to better understand early-life factors that play a role in the development of cardiovascular risk in

adolescence.

Social threat and sleep problems have been established as important correlates of cardiovascular risk among adults, but less is known about the role of these two factors in the emergence of cardiovascular risk during adolescence. Both, social threat and sleep problems were common in our sample: more than half of the adolescents in our sample experienced at least one social threat in the past year and more than half of adolescents also exhibited at least one sleep problem in the past month. The high prevalence of social threat is concerning given that previous research indicates that social threat—such as exposure to bullying in adolescence—predicts serious mental and physical health problems into adulthood (Copeland et al., 2013). Thus, social threat experiences in the peer domains cannot simply be viewed as a “normative rites of passage” during adolescence, but give rise to concern. Similarly, sleep problems have also been shown to have both short- and long-term consequences for cognitive, emotional, and behavioral development (Dahl & Lewin, 2002; Shanahan, Copeland, Angold, Bondy, & Costello, 2014), and, once established during adolescence, sleep problems may be stable into adulthood or recur.

In terms of the predictive models, a number of associations deserve attention. First, cumulative social threat was predictive of later pre-/hypertension. One proposed mechanism, supported mainly by extant literature on adult samples, refers to a link from social threat to continued activation of the autonomic nervous system, resulting in increased blood pressure and heart rate (Rozanski et al., 1999). In turn, continued elevation of blood pressure can lead to increased risk of pre-/hypertension at a later time point.

Second, cumulative social threat predicted sleep problems (i.e., sleep disturbance and a greater number of total sleep problems) at the statistical trend level one year later. One result of

exposure to social threat may be that the individual consciously or unconsciously perceives his/her physical environment as unsafe. This perception is detrimental to attaining high-quality sleep (Hawkley, Preacher, & Cacioppo, 2010; Troxel, Cyranowski, Hall, Frank, & Buysse, 2007). Indeed, during evolutionary time, during which frequent imminent threats to survival were the norm, prolonged sleep without awakening was rare (Nunn, Samson, & Krystal, 2016).

Third, cumulative sleep problems were related to increased BMI at the same time point. This is consistent with studies showing links between sleep disturbances, short sleep duration, and higher BMI in adolescents (Hart et al., 2011; Meldrum & Restivo, 2014; Narang et al., 2012; Peach et al., 2015). While the exact mechanism by which these associations occur is not perfectly understood, research in adult samples suggests that poor sleep leads to increased hypothalamic activity, which results in increased appetite (Knutson, 2010) and also in increased impulsivity with respect to eating. If increased appetite and impulsive eating are not supplemented by an increase in physical activity, weight gain and increased BMI can occur. While prior work found similar associations using an individual sleep duration variable, the lack of such findings in the current study is likely due to different definitions of inadequate sleep duration. For example, the associations reported in Meldrum & Restivo (2014) were using less than 5 hours as their cutoff for poor sleep duration.

Finally, although I found support for each link of the mediational model, no single one full mediational chain emerged. Thus, the current study did not identify sleep problems as a mechanism by which social threat is translated into increased cardiovascular risk during adolescence. Sleep may not be the only health behavior via which social threat could have an effect on cardiovascular risk. It is likely, for example, that adolescents who experience social threat may withdraw from group activities such as team sports. Consequently, they may engage

in less physical and more sedentary activities—which ultimately may contribute to an increase in cardiovascular risk.

Notably, it was primarily the cumulative variables, but not the individual social threat or sleep indicators, that were predictive. From a methodological perspective, the use of cumulative measures is encouraged for samples of smaller size (Burchinal et al., 2000). Substantively, cumulative scores may also better capture the co-occurrence of risk commonly found in the real world. Cumulative scores do not parse out small effects of individual variables one-by-one. Rather, they are representative of the overall (social threat or sleep) experience. Indeed, the use of cumulative scores also allows for the possibility that the effects of multiple, individual threats are compounded by one another.

The totality of social threats and sleep problems likely create physiological circumstances conducive to the development of cardiovascular risk. Although the current work focused specifically on social threats from the peer domain, the fact that our main significant findings center around the cumulative scores is consistent with research on other domains of social stress (Suglia, Duarte, Chambers, & Boynton-Jarrett, 2012). With respect to individual indicators, the sole consistent “signal” to both cardiovascular risk and sleep problems was from loneliness. The perceived absence of intimate relationships or social connections is a powerful predictor of health behaviors and health among adults (Hawkey & Cacioppo, 2010). Given the number of statistical tests conducted, this finding should not be over-interpreted, but it may be worthwhile to generate a better understanding of the role of loneliness in adolescents’ health.

Indeed, despite the significant findings discussed above, it should be noted that fewer significant associations emerged than expected, which could be due to several reasons. First, as noted, the effects of individual indicators of social threat or sleep problems may be too small to

impact outcomes. Second, BMI is not the best measure of cardiovascular risk. Indeed, high BMI in adolescence could indicate body fat or high levels of lean muscle mass, and waist circumference could be a more accurate measure of adiposity, and thus, cardiovascular risk (Dobbelsteyn, Joffres, MacLean, & Flowerdew, 2001; Shanahan et al., 2016). Third, statistical power may be another reason for fewer-than-expected significant findings. However, given that the identified effect sizes when using individual risk indicators were generally small, greater power would, at best, have resulted in small effect sizes becoming significant. Finally, from the perspective of study design, it is possible, that social threat → sleep problems → cardiovascular risk mediational chains could take more time to unfold and thus could only be observed with longer timeframes. Our study covered the period of one year only, but more time may be needed to see these processes unfold. Alternatively, and especially with respect to the social threat → sleep link, it is possible that this association fades over time, and that this link is more easily captured in the moment; indeed, the previous studies that had reported associations between select social threat indicators and sleep problems were primarily cross-sectional in nature (e.g. Cacioppo et al., 2002; van Geel et al., 2016).

Previous research had been inconclusive with respect to sex differences in associations. Therefore, a final goal of our study was to examine sex differences. Several sex differences emerged in the prevalence of social threat and sleep variables. Consistent with previous work (Wang et al., 2009), females were more likely to suffer from relational victimization, whereas males were marginally more likely to experience physical victimization. With respect to sleep, sleep disturbances were far more likely among females than males. The animal literature suggests that reproductive hormones lead females to wake up more frequently throughout the night compared to their male counterparts, particularly during periods of ovulation (Fang &

Fishbein, 1996). In addition, adolescent females are more likely than males to suffer from mental health conditions that also be associated with sleep problems (Buboltz et al., 2001; Maume, 2013; Shanahan et al., 2014). Despite these sex differences in prevalence, our predictive models revealed only one sex difference in prediction: loneliness significantly predicted greater sleep disturbance in males but not in females. However, given the number of sex differences tests conducted, this finding should be interpreted with caution.

Strengths and Limitations

The current study is not without its limitations. First, the sample is not nationally representative, as participants came from one region in North Carolina, and findings cannot be generalized to the larger U.S. population. Nevertheless, some of the prevalence estimates (e.g., of cardiovascular risk factors) were consistent with those from nationally representative samples. Second, although the overall model assessed is longitudinal in nature, sleep problems and cardiovascular risk were measured at the same time point. Thus, we cannot draw conclusions regarding the direction of effects between these two variables. However, future data from the overarching study will allow for longitudinal tests of these associations. Third, the sample size was not large; however, even if a larger sample had yielded more significant findings, they would not necessarily have had a larger effect size. Finally, in order to understand potential nuances in the social threat → sleep problems → cardiovascular risk, I conducted a good number of statistical tests with individual indicators. Such a high number of statistical tests could result in chance findings; therefore results from our models with individual indicators should not be over-interpreted.

Nevertheless, the study design offers many strengths. First, to my knowledge this is the first mediational test of social threat-sleep problems-cardiovascular risk associations during

adolescence. Second, the sample used is a community sample. Participants were not recruited for their presentations of social threat, sleep problems, or cardiovascular risk. Thus, compared to studies that use clinical samples, the current study allows us to understand these associations in a community sample. Third, the current study is longitudinal, with two time points. This allows us to draw preliminary conclusions about overall directions of effect that cannot be drawn from cross-sectional studies. Lastly, several indicators of each variable were assessed. Unlike previous studies that rely on only one dimension of social threat, sleep problems, or cardiovascular risk, the current study represents a more comprehensive analysis of the associations among these three variables.

Future Directions

The current study provided novel insight regarding the associations among social threat, sleep problems, and cardiovascular risk in adolescence, and pointed to several directions for future research. First, more time points should be used to better assess the longitudinal nature of the associations. By measuring sleep problems during the first time point, a baseline level of this factor could be assessed. Additionally, measuring sleep and cardiovascular risk at different time points would be beneficial, as the current study measured them both at age 16, thus limiting inferences of direction of effects. Next, a more comprehensive test of mediation via structural equation modeling (SEM) is recommended for future work. Through the use of SEM, researchers would be better able to model the potential mediating role of sleep. Also, without the need for listwise deletion, SEM and full maximum likelihood models would allow for a more complete use of the available data. Lastly, future research should strive to create interventions aimed at decreasing social threat during adolescence. The creation of these interventions can aid in the reduction of sleep and cardiovascular issues during this important developmental period.

In addition, the implementation of such interventions would further illuminate whether the reduction of social threat and sleep problems would indeed result in a reduction of cardiovascular risk.

Conclusion

The current study found evidence of associations among social threat, sleep problems, and cardiovascular risk. Adolescence is a time of heightened social risk; therefore, it is important to examine the possible consequences of such risk, including sleep problems and increased cardiovascular risk at a later point in time. This study provides a basis for future research aimed at understanding the complex psychological and physiological processes that influence the emergence of cardiovascular risk in adolescence.

Table 1. Means and standard deviations of continuous study variables. N and % for categorical study variables

	Overall		Male		Female		Sex Diff. Test
	N = 152		N = 64		N = 88		
	Continuous Variables						
	Mean	SD	Mean	SD	Mean	SD	p
Cardiovascular Risk							
BMI	24.15	5.60	23.89	5.64	24.33	5.61	n.s.
SBP	113.06	9.69	114.52	8.46	111.98	10.43	n.s.
Social Threat							
Loneliness	29.55	9.56	29.78	8.21	29.37	10.49	n.s.
Relational Victimization	9.19	5.11	8.08	3.58	10.01	5.87	*
Physical Victimization	4.75	2.31	5.14	2.36	4.47	2.25	†
Sleep							
Sleep Duration	7.80	1.61	7.98	1.56	7.68	1.64	n.s.
Sleep Disturbance	4.54	3.88	3.57	3.17	5.23	4.19	**
	Categorical Variables						
	N	%	N	%	N	%	
Cardiovascular Risk							
Overweight/Obese	50	32.9	22	34.4	28	31.8	n.s.
Pre-/Hypertensive	28	21.7	13	23.6	15	20.3	n.s.

Social Threat

Bullied at School	22	14.8	7	11.3	15	17.2	n.s.
Electronically Bullied	15	10.1	5	8.1	10	11.5	n.s.

Sleep

Poor Sleep Quality	22	14.8	6	9.4	16	18.2	n.s.
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Cumulative Risk Variables

	N	%	N	%	N	%
<i>Cumulative Social Threat</i>						
0	65	43.6	25	39.7	40	46.5
1	37	24.8	20	31.8	17	19.8
2	23	15.4	9	14.3	14	16.3
3+	24	16.1	9	14.3	15	17.4
<i>Cumulative Sleep Problems</i>						
0	63	43.2	30	49.2	33	38.8
1	51	34.9	23	37.7	28	32.9
2	23	15.8	7	11.5	16	18.8
3	9	6.2	1	1.6	8	9.4

[†]p < .10 *p < .05 **p < .01 ***p < .001

Table 2. Pearson Correlations Among Continuous Variables

	Loneliness	Relational Victimization	Physical Victimization	<i>Cumulative Sleep Problems</i>	Sleep Duration	Sleep Disturbance Sum	BMI	Blood Pressure
<i>Cumulative Social Threat</i>	.59***	.66***	.62***	.16 [†]	-.02	.18*	.10	.15 [†]
Loneliness		.28***	.24**	.21*	-.05	.17*	.08	.16 [†]
Relational Victimization			.47***	.12	.10	.27**	.06	.08
Physical Victimization				-.07	.16 [†]	.02	.02	-.04
<i>Cumulative Sleep Problems</i>					-.59***	.65***	.22**	.11
Sleep Duration						-.20*	-.06	-.07
Sleep Disturbance Sum							.14 [†]	.03
BMI								.44***

[†]p < .10 *p < .05 **p < .01 ***p < .001

Table 3. Summary of Standardized (β) and Unstandardized (B) Regression Coefficients for Regression Models Predicting the Continuous BMI and Systolic Blood Pressure Variables

BMI Outcome Variable				Blood Pressure Outcome Variable		
	B	SE (B)	β	B	SE (B)	β
<i>Covariates</i>¹						
Sex	.05	.06	.06	-2.61	1.79	-.13
Race	.25***	.07	.29***	1.75	2.04	.08
SES	<-.001	.003	-.004	-.09	.09	-.10
Bivariate Models – Adjusted for Sex, Race, and SES						
<i>Cumulative Social Threat</i>	.03	.03	.11	1.30 [†]	.71	.16 [†]
Loneliness	.002	.003	.06	.17 [†]	.09	.16 [†]
Relational Victimization	.01	.01	.07	.25	.18	.13
Physical Victimization	.01	.01	.07	-.23	.38	-.06
Bullied at School	.10	.09	.09	1.44	2.49	.05
Electronically Bullied	-.17	.10	-.13	1.21	2.78	.04
<i>Cumulative Sleep Problems</i>	.08*	.04	.18*	1.28	.96	.12
Sleep Duration	-.01	.02	-.06	-.47	.59	-.07
Sleep Disturbance	.01	.01	.14	.21	.24	.09
Multivariate Models						
<i>Social Threat</i>	n/a	n/a	n/a	n/a	n/a	n/a
Loneliness	.001	.004	.02	.21*	.11	.21*
Relational Victimization	.001	.01	.01	.14	.23	.08
Physical Victimization	.01	.02	.04	-.41	.45	-.10
Bullied at School	.15	.10	.13	-1.90	2.87	-.07
Electronically Bullied	-.27*	.12	-.21*	-.38	3.11	-.01
<i>Sleep Problems</i>	n/a	n/a	n/a	n/a	n/a	n/a
Sleep Duration	-.03	.02	-.10	-.57	.60	-.09

Sleep Disturbance	.02 [†]	.01	.15 [†]	.09	.25	.04
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[†]p < .10 *p<.05 **p<.01 ***p<.001

¹Sex (0=male, 1=female), Race (0=White, 1=non-White)

Table 4. Odds Ratios for Social Threat and Sleep Problems Predicting Categorical CVR Outcomes

	Overweight/Obesity	95% Confidence Interval	Pre-/ Hypertension	95% Confidence Interval
<i>Covariates</i>				
Sex	.997	.48, 2.07	.84	.34, 2.06
Race	2.96**	1.34, 6.54	1.69	.64, 4.46
SES	.99	.95, 1.02	.99	.95, 1.03
Unadjusted Odds Ratios				
<i>Cumulative Social Threat</i>	1.00	.75, 1.34	1.40*	1.01, 1.95
Loneliness	1.03	.97, 1.04	1.02	.98, 1.07
Relational Victimization	.997	.93, 1.07	1.06	.98, 1.14
Physical Victimization	1.03	.89, 1.19	.89	.73, 1.10
Bullied at School	.84	.33, 2.15	.97	.29, 3.20
Electronically Bullied	3.51	.76, 16.18	.45	.14, 1.47
<i>Cumulative Sleep Problems</i>	1.46 [†]	.99, 2.14	1.23	.78, 1.94
Sleep Duration	.94	.76, 1.17	.89	.66, 1.19
Sleep Disturbance	1.05	.96, 1.15	1.07	.95, 1.19
Odds Ratios Adjusted for Sex, Race, and SES				
<i>Cumulative Social Threat</i>	1.01	.75, 1.38	1.47*	1.03, 2.10
Loneliness	1.00	.96, 1.04	1.02	.97, 1.07
Relational Victimization	1.01	.94, 1.09	1.08 [†]	.99, 1.18
Physical Victimization	1.05	.89, 1.23	.88	.70, 1.11
Bullied at School	.84	.31, 2.27	.88	.26, 3.01
Electronically Bullied	3.86 [†]	.80, 18.66	.42	.12, 1.42
<i>Cumulative Sleep Problems</i>	1.48 [†]	.97, 2.25	1.29	.78, 2.11

Sleep Duration	.96	.76, 1.22	.88	.64, 1.20
Sleep Disturbance	1.07	.97, 1.18	1.09	.96, 1.23

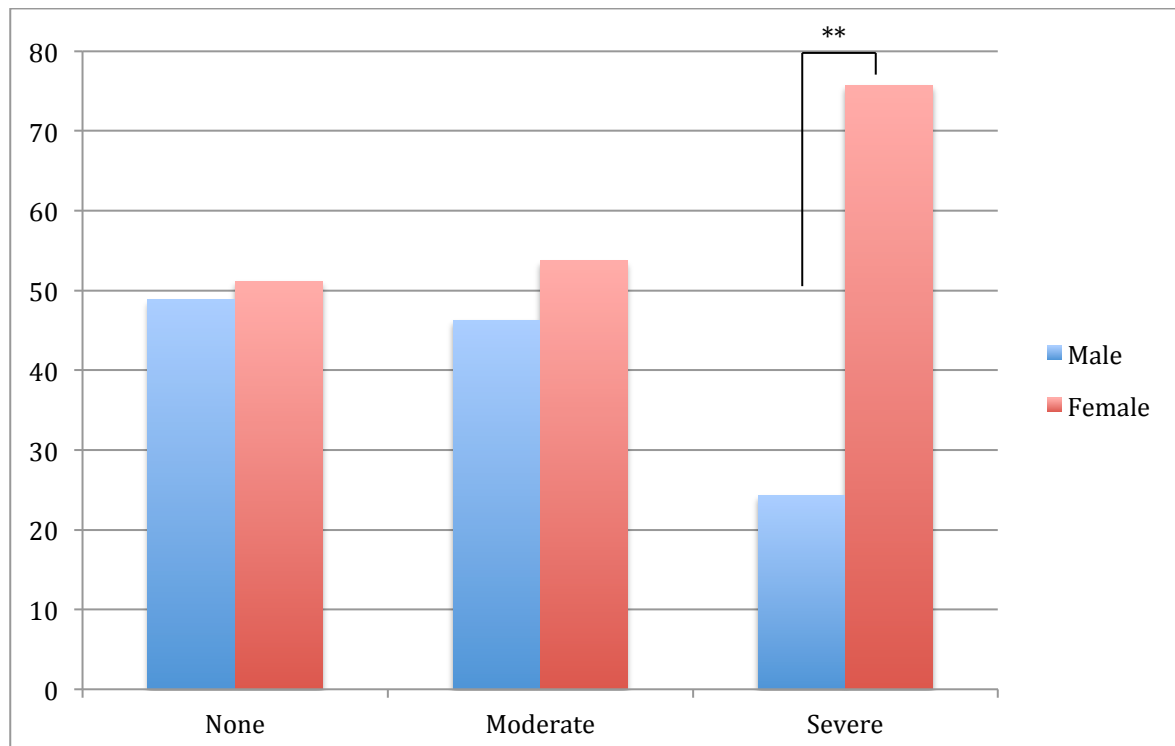
[†]p < .10 *p < .05 **p < .01 ***p < .001

Table 5. Summary of Standardized (β) and Unstandardized (B) Regression Coefficients for Continuous Measures of Sleep Problems

	Sleep Duration			Sleep Disturbance			Cumulative Sleep Problems		
	B	SE (B)	β	B	SE (B)	β	B	SE (B)	β
<i>Covariates</i>									
Sex	-.25	.27	-.08	1.52*	.65	.20*	.33*	.15	.18*
Race	-.27	.30	-.08	-.16	.74	-.02	.19	.18	.09
SES	.01	.01	.09	-.05	.03	-.14	-.01	.01	-.09
Bivariate Models, Adjusted for Sex, Race, and SES									
<i>Cumulative Social Threat</i>	-.02	.11	-.01	.50 [†]	.26	.16 [†]	.11 [†]	.06	.15 [†]
Loneliness	-.004	.01	-.02	.06 [†]	.03	.15 [†]	.02*	.01	.19*
Relational Victimization	.04	.03	.13	.18**	.07	.23**	.02	.02	.10
Physical Victimization	.10 [†]	.06	.15 [†]	.09	.14	.05	-.01	.03	-.04
Bullied at School	-.15	.37	-.03	-.18	.90	-.02	.11	.21	.05
Electronically Bullied	-.46	.43	-.09	2.03*	1.02	.16*	.35	.24	.12
Multivariate Models									
Loneliness	-.01	.02	-.05	.04	.04	.10	.02 [†]	.01	.18 [†]
Relational Victimization	.04	.03	.14	.17*	.08	.22*	.02	.02	.09
Physical Victimization	.10	.07	.14	-.11	.17	-.07	-.05	.04	-.14
Bullied at School	-.32	.41	-.07	-1.18	.98	-.11	-.01	.23	-.01
Electronically Bullied	-.65	.47	-.13	1.31	1.13	.11	.18	.27	.06

[†]p < .10 *p<.05 **p<.01 ***p<.001

Figure 2. Distribution of Sleep Disturbance Tertiles by Sex



APPENDIX

Victimization Measure

Directions: Please read each statement and indicate how true each is for you, **now and during the last year**. Circle a number from 1 (“Not at All True”) to 7 (“Very True”) to answer each question.

Relational Victimization

Physical Victimization

	Not at All True			Sometimes True			Very True
1. I try to get my way by physically intimidating others.	1	2	3	4	5	6	7
2. I have a friend who ignores me or gives me the “cold shoulder” when they are angry with me.	1	2	3	4	5	6	7
3. My friends know that I will think less of them if they do not do what I want them to do.	1	2	3	4	5	6	7
4. When I am not invited to do something with a group of people, I will exclude those people from future activities.	1	2	3	4	5	6	7
5. I have been pushed or shoved by people when they are mad at me.	1	2	3	4	5	6	7
6. When I want something from a friend of mine, I act “cold” or indifferent towards them until I get what I want.	1	2	3	4	5	6	7
7. A friend of mine has gone “behind my back” and shared private information about me with other people.	1	2	3	4	5	6	7
8. When someone makes me really angry, I push or shove that person.	1	2	3	4	5	6	7
9. When I have been angry at, or jealous of someone, I have tried to damage that person’s reputation by gossiping about them or by passing on negative information about them.	1	2	3	4	5	6	7
10. When someone does something that makes me angry, I try to embarrass that person or make them look stupid in front of their friends.	1	2	3	4	5	6	7
11. When I have been mad at a	1	2	3	4	5	6	7

friend, I have flirted with their boyfriend or girlfriend.							
12. When I am mad at a person, I try to make sure they are excluded from group activities (e.g. going to the movies).	1	2	3	4	5	6	7
13. I have a friend who tries to get their way through physical intimidation.	1	2	3	4	5	6	7
14. When I have been provoked by something a person has said or done, I have retaliated by threatening to physically harm that person.	1	2	3	4	5	6	7
15. I have threatened to share private information about my friends with other people in order to get them to do what I want.	1	2	3	4	5	6	7
16. When someone has angered or provoked me in some way, I have reacted by hitting that person.	1	2	3	4	5	6	7
17. I have a friend who excludes me from doing things when they are mad at me.	1	2	3	4	5	6	7
18. I have threatened to physically harm other people in order to control them.	1	2	3	4	5	6	7
19. I have spread rumors about a person just to be mean.	1	2	3	4	5	6	7
20. When a friend of mine has been mad at me, other people have "taken sides" with that friend and been mad at me too.	1	2	3	4	5	6	7
21. I have a friend who has threatened to physically harm me in order to get their way.	1	2	3	4	5	6	7
22. When someone hurts my feelings, I intentionally ignore that person.	1	2	3	4	5	6	7
23. I have intentionally ignored a person until they gave me what I wanted.	1	2	3	4	5	6	7
24. I have pushed and shoved others around in order to get things that I want.	1	2	3	4	5	6	7

YRBS Bullying Measure

The next 2 questions ask about bullying. Bullying is when 1 or more students tease, threaten, spread rumors about, hit, shove, or hurt another student over and over again. It is not bullying when 2 students of about the same strength or power argue or fight or tease each other in a friendly way.

1. During the past 12 months, have you ever been bullied **on school property**?
A. Yes
B. No

2. During the past 12 months, have you ever been **electronically** bullied? (Include being bullied through e-mail, chat rooms, instant messaging, Web sites, or texting.)
A. Yes
B. No

Loneliness Scale: Activities and Feelings (Adolescent)

Please read each item and indicate your answer by circling the number under the most accurate description of your feelings.

	Not at all true	Hardly ever true	Sometim es true	Most of the time true	Alwa ys true
1. It's easy for me to make new friends at school.	1	2	3	4	5
2. I like to read.	1	2	3	4	5
3. I have nobody to talk to.	1	2	3	4	5
4. I'm good at working with other teens.	1	2	3	4	5
5. I watch TV a lot.	1	2	3	4	5
6. It's hard for me to make friends.	1	2	3	4	5
7. I like school.	1	2	3	4	5
8. I have lots of friends.	1	2	3	4	5
9. I feel alone.	1	2	3	4	5
10. I can find a friend when I need one.	1	2	3	4	5
11. I play sports a lot.	1	2	3	4	5
12. It's hard to get other teens to like me.	1	2	3	4	5
13. I like science.	1	2	3	4	5
14. I don't have anyone to play with.	1	2	3	4	5
15. I like music.	1	2	3	4	5
16. I get along with other teens.	1	2	3	4	5
17. I feel left out of things.	1	2	3	4	5
18. There's nobody I can go to when I need help.	1	2	3	4	5
19. I like to paint and draw.	1	2	3	4	5
20. I don't get along with other teens.	1	2	3	4	5
21. I'm lonely.	1	2	3	4	5
22. I am well-liked by the students in my class.	1	2	3	4	5
23. I like playing board-games a lot.	1	2	3	4	5
24. I don't have any friends.	1	2	3	4	5

PITTSBURGH SLEEP QUALITY INDEX

INSTRUCTIONS:

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, what time have you usually gone to bed at night?

BED TIME _____

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

NUMBER OF MINUTES _____

3. During the past month, what time have you usually gotten up in the morning?

GETTING UP TIME _____

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

HOURS OF SLEEP PER NIGHT _____

For each of the following questions, check the one best response. Please answer all questions.

5. During the past month, how often have you had trouble sleeping because you . . .	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
a) Cannot get to sleep within 30 minutes				
b) Wake up in the middle of the night or early morning				
c) Have to get up to use the bathroom				
d) Cannot breathe comfortably				
e) Cough or snore loudly				
f) Feel too cold				
g) Feel too hot				
h) Had bad dreams				

i) Have pain				
j) Other reason(s), please describe_____				

For each of the remaining questions, circle the one best response. Please answer all questions.

6. During the past month, how would you rate your sleep quality overall?

- | | | | |
|-----------|-------------|------------|----------|
| 1 | 2 | 3 | 4 |
| Very good | Fairly Good | Fairly bad | Very bad |

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

- | | | | |
|---------------------------|-----------------------|----------------------|----------------------------|
| 1 | 2 | 3 | 4 |
| Not during the past month | Less than once a week | Once or twice a week | Three or more times a week |

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

- | | | | |
|---------------------------|-----------------------|----------------------|----------------------------|
| 1 | 2 | 3 | 4 |
| Not during the past month | Less than once a week | Once or twice a week | Three or more times a week |

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

- | | | | |
|-------------------|----------------------------|-----------------------|--------------------|
| 1 | 2 | 3 | 4 |
| No problem at all | Only a very slight problem | Somewhat of a problem | A very big problem |

Supplementary Table S1. Standardized (β) and Unstandardized (B) Regression Coefficients for Regression Models Predicting the Continuous BMI and Systolic Blood Pressure Variables, Adjusting for Age 15 BMI and Systolic Blood Pressure

BMI Outcome Variable				Blood Pressure Outcome Variable		
	B	SE (B)	β	B	SE (B)	β
<i>Covariates</i>¹						
Sex	-.003	.03	-.004	.05	1.77	.003
Race	.09*	.04	.11*	.69	1.93	.03
SES	.002	.002	.05	-.11	.08	-.13
Age 15 BMI	.07***	.004	.84***	-	-	-
Age 15 BP	-	-	-	.37***	.07	.48***
Bivariate Models – Adjusted for Sex, Race, SES, and Age 15 BMI or BP						
<i>Cumulative Social Threat</i>	.01	.01	.03	1.10	.67	.14
Loneliness	<-.001	.002	-.004	.15 [†]	.09	.15 [†]
Relational Victimization	<-.001	.003	-.004	.24	.17	.12
Physical Victimization	-.001	.007	-.005	-.11	.39	-.02
Bullied at School	.10*	.05	.09*	1.18	2.33	.04
Electronically Bullied	-.03	.05	-.03	.28	2.54	.01
<i>Cumulative Sleep Problems</i>	.01	.02	.03	.79	.94	.08
Sleep Duration	-.01	.01	-.02	-.05	.56	-.01
Sleep Disturbance	-.001	.005	-.01	.02	.23	.01
Multivariate Models						
<i>Social Threat</i>	n/a	n/a	n/a	n/a	n/a	n/a
Loneliness	<-.001	.002	-.01	.21*	.10	.21*
Relational Victimization	-.002	.005	-.03	.20	.23	.10
Physical Victimization	-.002	.01	-.01	-.42	.47	-.10
Bullied at School	.12*	.05	.11*	-1.86	2.73	-.07
Electronically Bullied	-.05	.06	-.04	-1.09	2.94	-.04

<i>Sleep Problems</i>	n/a	n/a	n/a	n/a	n/a	n/a
Sleep Duration	-.01	.01	-.02	-.11	.58	-.02
Sleep Disturbance	<-.001	.005	-.004	-.08	.25	-.03

[†]p < .10 *p<.05 **p<.01 ***p<.001

Supplementary Table S2. Odds Ratios and 95% Confidence Intervals for Logistic Regression Analyses Predicting Categorical Age 16 CVR Outcomes with for Social Threat and Sleep Problems, Adjusting for Age 15 BMI and Systolic Blood Pressure

	Overweight/Obesity	95% Confidence Interval	Pre-/ Hypertension	95% Confidence Interval
<i>Covariates</i>				
Sex	.997	.48, 2.07	.84	.34, 2.06
Race	.36*	.16, .78	.59	.22, 1.56
SES	.99	.95, 1.02	.99	.95, 1.03
Age 15 BMI	2.62***	1.78, 3.84	--	--
Age 15 SBP	--	--	1.09***	1.04, 1.14
Unadjusted Odds Ratios				
<i>Cumulative Social Threat</i>	1.00	.75, 1.34	1.40*	1.01, 1.95
Loneliness	1.03	.97, 1.04	1.02	.98, 1.07
Relational Victimization	.997	.93, 1.07	1.06	.98, 1.14
Physical Victimization	1.03	.89, 1.19	.89	.73, 1.10
Bullied at School	.84	.33, 2.15	.97	.29, 3.20
Electronically Bullied	3.51	.76, 16.18	.45	.14, 1.47
<i>Cumulative Sleep Problems</i>	1.46 [†]	.99, 2.14	1.23	.78, 1.94
Sleep Duration	.94	.76, 1.17	.89	.66, 1.19
Sleep Disturbance	1.05	.96, 1.15	1.07	.95, 1.19
Sleep Quality	.84	.33, 2.15	1.21	.37, 3.95
Odds Ratios Adjusted for Sex, Race, SES, and Age 15 BMI/SBP				
<i>Cumulative Social Threat</i>	.87	.51, 1.47	1.49*	1.00, 2.23
Loneliness	.96	.89, 1.04	1.02	.97, 1.08
Relational Victimization	.99	.87, 1.12	1.09 [†]	.99, 1.20

Physical Victimization	1.13	.89, 1.43	.89	.68, 1.16
Bullied at School	.76	.15, 3.87	.96	.24, 3.92
Electronically Bullied	1.86	.20, 17.50	.39	.10, 1.48
<i>Cumulative Sleep Problems</i>	1.09	.50, 2.41	1.14	.64, 2.02
Sleep Duration	1.09	.67, 1.77	.96	.69, 1.35
Sleep Disturbance	.98	.83, 1.15	1.04	.91, 1.20

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