EVALUATING DETERMINANTS OF PSYCHOPHYSIOLOGICAL STRESS IN COLLEGIATE STUDENT-ATHLETES

by

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ABSTRACT

Collegiate student-athletes are a unique group of individuals who experience a vast array of cognitive and physiological stressors. In addition to the typical stressors of an average college student, such as homesickness, finances, academics, and social relationships, student-athletes must also cope with lack of free time, pressure to perform, relationships with coaches and teammates, and physiological stress due to training and competing. Student-athletes with unmanaged chronic stress are more likely to experience a plethora of negative health outcomes, effecting performance in the classroom, on the field, and in life. Currently, survey instruments exist to predict cognitive and physiological sources of stress in isolation, but no existing instrument integrates both cognitive and physiological stressors into a single measure of chronic stress. The current cross-sectional study compared magnitude and sources of stress, psychological and physiological, experienced by Montana State University student-athletes (n=30) and their non-athlete counterparts (n=22). In addition, associations between chronic stress (as indicated by hair cortisol concentration, or HCC) and subjective measures of psychological stress, physiological stress and sleep quality were assessed in a subgroup of participants (n=12 student-athletes; n=9 non-athletes). Student-athletes had significantly greater average weekly training load than the non-athlete students ($P < 0.001$), but all other indicators of psychological stress and sleep quality were not significantly different between the two groups. Of those participants who provided a hair sample, the student-athletes had greater average HCC ($P = 0.027$). Although no associations were observed between HCC and measures of psychophysiological stress or sleep quality, a significant correlation was observed between HCC and body fat percentage ($r = -0.59$, $P < 0.045$). Additional research is necessary to elucidate the role of body composition, as well as other factors, on chronic stress development in college student-athletes.

CHAPTER ONE

INTRODUCTION

An Introduction to the Problem

When the human body experiences a cognitive or physiological stressor, the hypothalamus-pituitary-adrenocortical (HPA) axis releases the hormone cortisol into the blood. As a marker of HPA axis activation, acute exposure to cortisol initiates a host of positive physiological effects intended to help the body respond to the stressor, including increased focus and attention, increased glucose availability, and maintenance of electrolyte balance. Chronic exposure to cortisol, however, has been associated with an increased risk for depression, substance abuse, eating disorders, sleep disorders, metabolic syndrome, obesity, Type II diabetes, myocardial infarction, as well as increased rates and severity of sickness and injury (Pereg et al. 2011; Stalder et al. 2013; Stalder et al. 2012a). Thus, those more likely to experience unmanaged chronic stress, whether cognitive or physiological in origin, are also more likely to experience long term negative health outcomes.

College students may be especially susceptible to the influence of chronic stress because of the relatively unique combination of cognitive stressors (financial, social, academic, developmental) and limited stress management skills (Cohen et al. 1983; Mahmoud et al. 2012; Loughran and Etzel 2008; Benton et al. 2003; Pinkerton et al. 1989). In fact, numerous studies have revealed high prevalence of chronic stress and some of its repercussions in this population (ACHA 2012; Mahmoud et al. 2012).

College student-athletes, however, face the additional cognitive and physiological stressors associated with their athletic participation (i.e., training, competing, coaching staff interactions) (Gerber et al. 2013; Silva 1990; Simon and Docherty 2013; Skoluda et al. 2012; Selby et al. 1990). Unlike their non-athlete peers, college student-athletes must also be able to handle the demands of exhaustive training programs, the need and desire to physically perform well and improve over time, competitiveness amongst teammates, extensive travel for competition, as well as the inevitable pressures associated with winning, losing, and getting sick or injured. The use of maladaptive coping strategies and underutilization of counseling resources, accompanied by the sheer number of potential stressors, place collegiate student-athletes at particular risk for chronic stress (Etzel 2009; Yusko et al. 2008). Clearly, the management of chronic stress is a key factor in the eventual success of collegiate student-athletes attempting to be students, athletes, as well as happy and healthy young adults.

In order to monitor chronic stress development among collegiate student-athletes, proper measurement of chronic stress is essential. Traditional biomarkers of stress (e.g., saliva, serum, and urinary cortisol) are only effective for monitoring the *acute response* to a stressor. Long-term exposure to a stressor, or a variety of stressors, are best measured from scalp hair samples which accumulate cortisol regardless of the cause of stress. Like core samples of ice from the Antarctic, scalp hair stores cortisol in direct proportion to HPA axis activation, with the most recent cortisol secretions being represented in hair closest to the scalp (Groeneveld et al. 2013; Kirschbaum et al. 2009; Stalder et al. 2012b; Thomson et al. 2010). At an average growth rate of 1 cm per month, the measurement of

cortisol from hair samples is considered a criterion technique for documenting the body's response to chronic stress (Wennig 2000). Collecting hair samples, however, is neither practical nor inexpensive for monitoring chronic stress within a large group of people. Alternatively, research-validated surveys have traditionally been used to assess perceptions of cognitive stress. The Undergraduate Stress Questionnaire (USQ), for example, is described as a "life events checklist" for both major and minor stressful events that are specific to undergraduate college students (Crandall et al. 1992). The Perceived Stress Scale (PSS), often cited as the most widely used survey for measuring nonspecific perceived stress in adults, was designed to measure the degree to which a person assesses situations as stressful (Cohen et al. 1983). Both the USQ and the PSS can be evaluated with cumulative scores for stress, as well as specific domains made up from specific clusters of questions. For a more general assessment of life satisfaction, the Satisfaction with Life Scale (SLS) has been validated for use in adults as an indicator for a person's sense of well-being (Diener et al. 1985). Recently, Lu et al. developed and validated the College Student-Athlete Life Stress Scale (CSALSS), a 24-item instrument designed to quantify potential stressors uniquely encountered by collegiate student-athletes (Lu et al. 2012). However, the specificity of the CSALS to collegiate student-athletes makes it unsuitable for use by non-athlete students in the current study. It is likely, however, that a combination of survey's used simultaneously (e.g., USQ, PSS, SLS), or specific domains within these surveys, may help to predict non-overlapping domains of chronic stress development in collegiate student-athletes and non-athlete students in the current study.

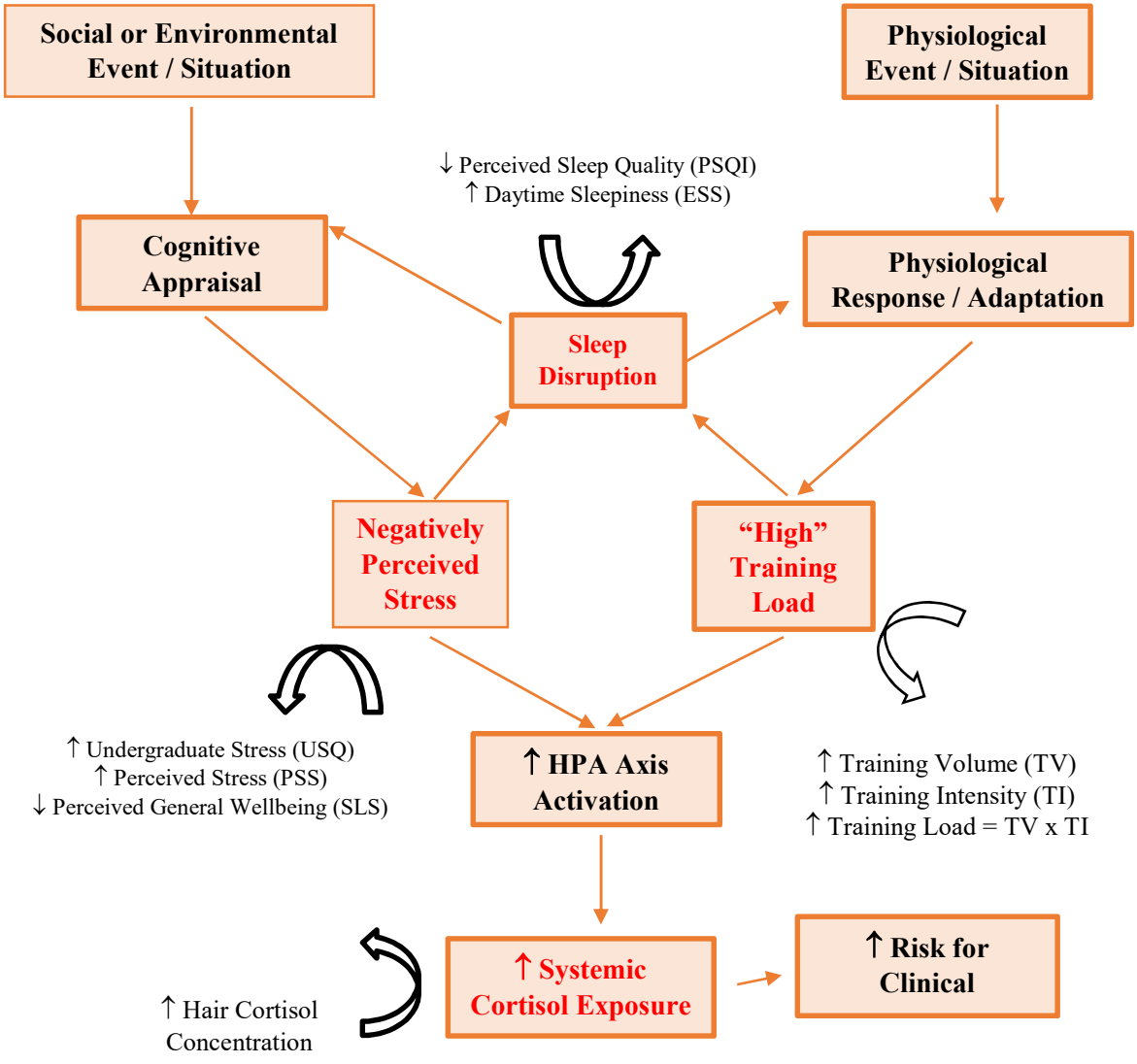
Recently, nighttime sleep quality has been more widely accepted as a moderator of chronic stress development, as well as a contributor to a host of clinical disorders and disease conditions, in both adults and children (Groeneveld et al. 2013; Nielsen et al. 2010; Van Reeth 2000; Veldhorst et al. 2014). Research has demonstrated that college students have particularly poor sleep habits (Lund et al. 2010; Lee et al. 2013). In fact, one study revealed that over half of college students are classified as poor sleepers according to the Pittsburgh Sleep Quality Inventory (Lund et al. 2010). Therefore, poor sleep quality is yet another factor that makes college students, including student-athletes, especially susceptible to development of chronic stress. Similar to the argument for monitoring chronic stress by collecting hair samples, direct monitoring and evaluation of nighttime sleep quality (e.g., polysomnography, wrist-worn activity monitors) is not practical for large groups of people. Alternatively, surveys can be used to indirectly assess sleep quality by monitoring one's perceptions of nighttime sleep quality with the Pittsburgh Sleep Quality Index (PSQI), or self-reported indicators of daytime sleepiness with the Epworth Sleepiness Scale (ESS) (Buysse et al. 1989; Johns 1991). Used for a recent pilot study in our lab, the summative index for each of these surveys correlated significantly with the CSALSS score in collegiate cross country skiers (Heil et al. 2015).

Finally, a dose-response relationship has been reported between hair cortisol concentrations and the volume of physical training within both elite endurance athletes and recreationally active college students (Gerber et al. 2013; Skoluda et al. 2012). Thus, physiological stress due to training is a key component of chronic stress development. The high physical demands of practices and competitions may put collegiate student-

athletes at elevated risk for chronic stress development when compared with their non-athlete counterparts.

In summary, both excessive physical training and cognitive stress are related to elevated hair cortisol. Further, both physical training and cognitive stress are related to decreased sleep quality. Thus, by monitoring both the potential sources of stress (i.e., cognitive and physiological), a key moderator of these stressors (i.e., sleep quality), as well as the outcome for chronic exposure to these stressors (i.e., cortisol accumulation in the hair), it should be possible to cross-sectionally predict the development of chronic stress in collegiate student-athletes and non-athlete students as a combined function of psychophysiological sources of stress. Figure 1 summarizes the proposed relationships between the key factors determining psychophysiological stress (cognitive and physical stress, and sleep disruption) and chronic cortisol exposure.

Figure 1. Proposed model for the influence of both cognitive and physiological sources of stress on perceived stress and training load, respectively, and the subsequent influence on HPA axis activation and the release of cortisol into the systemic system. Also shown is how both perceived stress and training load are also shown to independently contribute to a disruption of sleep. Also shown are the measures proposed for quantifying each factor of interest to the current study. *NOTE: Abbreviations in the figure are the same as those used and defined in the proposal.*



Survey instruments currently exist for measuring either cognitive or physiological sources of stress, but no single instrument has integrated the cognitive and physiological

assessments into a single measure of chronic stress. Given that understanding the integration of these psychophysiological stressors is essential to the management of chronic stress in college students and student-athletes alike, the present study evaluated chronic stress, as determined by cortisol measures in hair samples, and cognitive and physiological sources of stress using a battery of existing surveys, in a cohort of Montana State University (MSU) Division I students-athletes, as well as a reference group of non-athlete MSU students. The student-athlete group was composed of males and females from the alpine and Nordic skiing, volleyball, and track and field teams. Athletes participating in both power- and endurance-based sports were represented due to the inherent differences in physiological stressors (e.g., emphasis on different energy systems).

Purpose

The primary purpose of this study was to compare the source and amount of psychophysiological stress in collegiate student-athletes and non-athlete students to evaluate the assertion that collegiate student-athletes tend to experience greater and/or unique sources of unmanaged chronic stress. The secondary purpose of this study was to determine associations between chronic stress and various cognitive and physiological stressors in the combined sample of collegiate student-athletes and non-athlete students.

Hypotheses

First Research Hypothesis

It was hypothesized that average USQ, ESS, PSQI, and PSS scores, average weekly training load (TL), and hair cortisol concentration (HCC) would be greater (i.e., higher perceived stress, poorer nighttime sleep quality, more daytime sleepiness) within the student-athletes (A) than the non-athlete students (NA). Similarly, it is also hypothesized that average SLS scores would be lower in the student-athletes (A) (i.e., lower life satisfaction) than the non-athlete students (NA). The null hypothesis (H_0) stated that there would be no observed differences in average USQ, ESS, SLS, PSQI, and PSS scores, training load, and hair cortisol concentration between the student-athlete and non-athlete student groups. The alternative hypothesis (H_A) stated that average USQ, ESS, PSQI and PSS scores, total training load, and hair cortisol concentration would be greater and average SLS scores would be lower in student-athletes than non-athlete students.

$$H_0: \mu_A\,(\text{USQ, ESS, SLS, PSQI, PSS, TL, HCC}) = \mu_{NA}\,(\text{USQ, ESS, SLS, PSQI, PSS, TL, HCC})$$

$$H_{A1}: \mu_A\,(\text{USQ, ESS, PSQI, PSS, TL, HCC}) > \mu_{NA}\,(\text{USQ, ESS, PSQI, PSS, TL, HCC})$$

$$H_{A2}: \mu_A\,(\text{SLS}) < \mu_{NA}\,(\text{SLS})$$

where μ_A and μ_{NA} represent the population means for the student-athletes and non-athlete students, respectively.

Second Research Hypothesis

It was hypothesized that HCC would be positively correlated with USQ, ESS, PSQI, PSS, and TL and negatively correlated with SLS. The null hypothesis stated that HCC would be unrelated to USQ, ESS, SLS, PSQI, PSS, SLS, and TL, while the alternative hypothesis stated that HCC would be positively correlated with USQ, ESS, PSQI, PSS, and TL and negatively correlated with SLS.

$$H_0: \rho_{12} = 0; H_A: \rho_1 > 0; H_A: \rho_2 < 0$$

where ρ is the population correlation coefficient; ρ_1 is the population correlation of HCC with USQ, ESS, PSQI, PSS, and TL; ρ_2 is the population correlation of HCC with SLS.

Assumptions

It was assumed that participants' scalp hair growth rate is approximately one centimeter per month (Wennig 2000). In addition, it was assumed that participants accurately logged every exercise bout in their training log and assigned a reasonable session rating of perceived exertion (sRPE).

Limitations

1. The cross-sectional design of the present study did not allow for observation of changes in chronic stress and its determinants throughout the year.
2. The use of athletes from select sports from a single university limited the generalizability of the study results.

3. The use of a subjective measure (sRPE) to characterize training intensity, as opposed to an objective measure (such as personally calibrated measures of heart rate), may have led to systematic overestimation in some individuals and systematic underestimation in others.

Delimitations

This study was delimited to individuals who:

1. Are enrolled full-time at Montana State University in the 2016 spring semester.
2. Have scalp hair ≥ 1 cm in length at the time of enrollment into the study.
3. Have not treated (e.g., dyed, permed, chemically straightened) their hair within the last month at the time of enrollment into the study.

The student-athlete group was delimited to individuals who:

1. Were members of the track and field, volleyball, or alpine and Nordic skiing teams.

Definitions

Collegiate student-athlete: a college or university student currently participating in competitive athletics sponsored by the institution, excluding intramural and club sports (Etzel et al. 2006).

Cortisol: glucocorticoid hormone released from the adrenal cortex in response to HPA axis activation; common biomarker of the stress response

Hair cortisol concentration (HCC): concentration of cortisol found in a sample of hair; biomarker of chronic stress.

Hypothalamic-pituitary-adrenocortical (HPA) axis: a neuroendocrine pathway triggered in response to a stressor (cognitive or physiological in nature), resulting in the release of cortisol from the adrenal cortex.

Non-athlete Student: a college or university student not currently participating in institutionally sponsored athletes, not including intramural and club sports.

Physiological stress: HPA axis activation and subsequent cortisol production due to physical training.

Psychological stress: HPA axis activation and subsequent cortisol production due to negative cognitive appraisal of an event or circumstance.

Session rating of perceived exertion (sRPE): the average RPE (1-10; Borg 1987) for a given training session.

Training volume: time spent in training sessions over an interval of time.

Operational Definitions

Weekly training load (WTL) will be calculated by summing the products of sRPE and duration (min) for each exercise bout recorded in the training log.

Average weekly training load (TL) was calculated by averaging the weekly training loads for all four weeks.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction to Stress

"Stress" is a familiar term, yet difficult to describe. In the words of Hans Selye, an endocrinologist who dedicated most of his life to the study of stress, "Everybody knows what stress is and nobody knows what stress is" (Selye 1973; Holsboer and Ising 2010). Although the term first referred to physical strain placed on an object in the field of engineering, it has since been applied to a universal phenomenon observed in humans (Holsboer and Ising 2010). In engineering, stress occurs when there is threat to the structural integrity of an object. Similarly, in humans, stress occurs when there is a threat, real or perceived, to the homeostatic integrity of the organism (Chrousos 2009). These "threats," or stressors, can be either cognitive (i.e., one's perception of an event or circumstance) or physiological (i.e., disruption in homeostasis due to physical exercise) in nature (Chrousos 2009; Holsboer and Ising 2010). Exposure to stressors leads to a host of physiological responses, initiated by the hypothalamic-pituitary-adrenocortical (HPA) axis, intended to help the body respond to the threat and restore and/or maintain homeostasis. Thus, stress is a positive response intended to assist and protect the human body. However, when the HPA axis is frequently activated under chronic exposure to cognitive and/or physiological stressors, the same responses intended to help the body begin to have detrimental effects. Individuals who experience chronic stress are at increased risk of developing numerous psychological and physiological disorders.

Clearly, the well-being of individuals in high-stress circumstances hinges on chronic stress management.

Stress in College Students

During the stage of emerging adulthood (18-24 years of age), individuals are in the process of developing skills required for independence and self-sufficiency, forming and maintaining relationships, consolidating their identity, and establishing values (Mahmoud et al. 2012; Pinkerton et al. 1989). Managing these new challenges can lead to stress and anxiety in this population. In addition to these developmental tasks, college students must also navigate issues regarding new social demands, academic rigor, homesickness, finances, and career indecision (Mahmoud et al. 2012; Loughran and Etzel 2008; Benton et al. 2003; Pinkerton et al. 1989). The overwhelming demands placed upon college students results in unusually high levels of stress in this group of young adults.

Numerous studies have highlighted both the prevalence and severity of stress in college students. The American College Health Association (ACHA 2012) collected data regarding the health, safety, and demographics of university students attending the University of Southern California using the National College Health Assessment questionnaire. Of the 663 undergraduate respondents, 55.5% of students reported experiencing “more than average” or “tremendous” stress over the past 12 months. Further, 35.8% of respondents claimed that stress impacted their academic performance

over that same interval. Stress is not only a pervasive issue affecting over half of university students, but it has a detrimental effect on the wellbeing of the individual.

Other studies utilizing different survey measures have reported varying frequencies of stress. In one such study, Mahmoud et al. (2012) administered the Depression Anxiety Stress Scale-21 (DASS-21) to 508 full-time undergraduate students. The DASS-21 is a self-report survey instrument measuring depression, anxiety, and stress. According to their results, 24% of the sample was found to have abnormally high levels of stress according to the DASS-21 (defined as a score > 14 out of 28 on the 7-item stress subscale). Although this is only half the prevalence reported in the ACHA study, it is far from negligible. Further, stress was negatively correlated with life satisfaction ($r = -0.39$; $p < 0.0001$), reinforcing the claim that stress is not only a ubiquitous issue, but also a serious one. Regardless of the survey instrument or sample, unmanageable stress seems to be a predominant issue among undergraduate college students.

The frequency of stress-inducing issues experienced by college students has only grown in recent decades. In 2003, Benton and colleagues compared the prevalence of issues observed among university counseling center patients in 1988-1992 and 1996-2001 using the Case Descriptor List (CDL), a 30-item questionnaire completed by the clinician at the close of a case. They reported that over the previous 13 years, the frequency of less severe issues (e.g., developmental issues, situational emotional concerns, and academic troubles) has remained relatively constant; however, the prevalence of more severe issues (e.g., relationship and family issues, personality disorders, sexual assault, and physical

problems) have approximately doubled. According to this study, the problem of stress-inducing issues facing this population is not subsiding.

According to Lazarus and Folkman (1984), stress is a negative feeling that occurs when one feels unable to cope with the demands placed on them by their environment. Thus, the stress response is mediated by an individual's ability to cope. College students' underdeveloped coping skills adds yet another layer to their susceptibility to the negative consequences of stress. In the aforementioned study by Mahmoud and colleagues (2012), the research team also collected information regarding coping habits (both adaptive and maladaptive) of undergraduate students using the Brief COPE Inventory (BCI). As defined in this survey instrument, *adaptive coping* includes acceptance, planning, and positive reframing, while *maladaptive coping* includes denial, self-blaming, and substance use. They found that students who utilized maladaptive coping strategies were more likely to be classified as depressed or anxious. Additionally, a significant positive correlation was found between maladaptive coping and stress ($r = 0.63$; $p < 0.0001$). With the combination of high (and ever increasing) exposure to stressful situations and lack of adaptive coping skills, it is no surprise that college students are susceptible to stress and its negative implications for physical and mental health.

Stress in Collegiate Student-Athletes

As previously addressed, the demands of young adulthood and college life lead to high levels of stress in undergraduate students. Collegiate student-athletes must learn to navigate all the stressors of a typical college student, as well as the added complexity and

stress due to athletic participation (Selby et al. 1990; Watt and Moore 2001; Howard-Hamilton and Sina 2001; Humphrey et al. 2000; Etzel et al 2006). Balancing the identities of student and athlete is an overwhelming endeavor that makes collegiate student-athletes even more prone to stress and its negative impacts.

Literature over the past three decades has enumerated many unique sources of stress in the collegiate student-athlete population. Selby, Weinstein, and Bird (1990) collected information from 267 college student-athletes from a variety of athletic teams at a Division 1 private university regarding general health, alcohol and drug use, weight and body image, stress factors, and health resource knowledge and use. The study identified ten stress factors for college student-athletes. Topping the list were injury and academics, followed by sport time demands, coach expectations, sport competition, general health, social life, athletic scholarship, weight, and eating behaviors. The list of specific stressors mentioned in the literature goes on: play time, poor athletic performance, loss of "star status" from high school, pressure to represent a university, travel schedules, inflexible and demanding daily schedules, and physically demanding training, to name a few (Etzel et al. 2006; Pinkerton et al. 1989; Selby et al. 1990; Watt and Moore 2001; Jordan and Denson 1990; Wilson and Pritchard 2005). Examining the sheer number of stressors a collegiate student-athlete is likely to experience eliminates any doubt that this population is at risk and in need of attention.

Any of the previously mentioned stressors can be categorized into at least one of the following domains: personal, athletic, and academic. In a chapter of *New Directions for Student Services* entitled "How College Affects Student Athletes," Howard-Hamilton

and Sina (2001) emphasize the importance of maintaining balance among these three domains. A disruption in this precarious balance can lead to a multitude of deleterious outcomes for the student-athlete. For example, a lack of attention to academics may lead to athletic ineligibility and delayed graduation, yet too much focus on academics may cause a student-athlete to forfeit their social life, resulting in personal dissatisfaction. Another common penalty of imbalance among these three domains occurs when a student-athlete places too much emphasis on their sport; not only do academics and personal life suffer, the student-athlete is likely to let their self-worth be determined by athletic performance. Preserving this delicate balance is a stressful endeavor with which student-athletes must continually cope.

As with the typical college student, a collegiate student-athlete's stress response is moderated by their ability to cope with, or manage, a stressor. The presence of maladaptive coping strategies, such as alcohol consumption, among student-athletes may contribute to negative, unmanaged stress. A study by Yusko et al. (2008) comparing the risk factors and motives for alcohol use between student-athletes and non-athlete students revealed that although student-athletes were less likely than non-athlete students to report drinking as a coping method, there was a greater association between coping motivations and negative drinking consequences in this group. Additionally, a positive correlation was observed between stress and negative drinking consequences among collegiate student-athletes ($r = 0.20$; $p < 0.01$). Thus, alcohol use is one method of maladaptive coping that may exacerbate rather than ameliorate chronic stress development in collegiate student-athletes.

Another adaptive coping strategy that may moderate the stress response is seeking the help of a counselor or psychologist. Not only are student-athletes often unable to manage stress on their own, but they are also less likely to utilize counseling resources (Watson 2006; Etzel 2009). In his book *Counseling and Psychological Services for College Student-Athletes*, Etzel (2009) enumerates a variety of unique barriers that often prevent collegiate student-athletes from getting the help they may need. First, student-athletes are frequently well-known faces around campus, and they may not want to be seen in a counseling office waiting room. Secondly, the rigid schedule and numerous time constraints of student-athletes may prevent them from seeing a counselor or committing to regular sessions. Finally, many athletes are likely to see seeking help as a sign of weakness or think that they should be capable of working through issues on their own. Although one study has suggested the majority of student-athletes would be willing to seek help from a coach, they would likely benefit from an external professional (Selby et al. 1990). Due to the prevalence of maladaptive coping strategies and unwillingness to seek psychological help, it is likely that the stress experienced by collegiate student-athletes will go unmanaged.

Unmanaged stress in collegiate student-athletes may have a multitude of negative physical and psychological outcomes. Etzel and colleagues (2006) mentioned a variety of such outcomes commonly observed by psychologists working with college student-athletes, including loss of passion, feeling exhausted, loss of sleep, frequent illness, poor eating, increased alcohol consumption, feelings of isolation, relationship problems, and

overtraining symptoms. When student-athletes are chronically stressed, their mental and physical health suffer.

The negative impacts of the stressful student-athlete lifestyle may not end at graduation. Recent research suggests that collegiate student-athletes may be sacrificing their physical and psychological health decades later. Simon and Docherty (2013) compared the health-related quality of life of former Division 1 athletes and non-athlete controls between 40 and 65 years of age. The Patient-Reported Outcomes Measurement Information System (PROMIS), including scales for sleep, anxiety, depression, fatigue, pain interference, physical function, and satisfaction with participation in social roles, was used to assess health-related quality of life. The results of this study suggest that former collegiate student-athletes have less physical function and increased rates of depression, fatigue, sleep disturbance, and pain interference than the recreationally active control group. Simon and Docherty (2013) conclude that athletic participation in college years has high physical, psychological, and social costs for years to come, if stress is not managed properly. Clearly, management of stress in collegiate student-athletes is critical not only for a successful athletic and academic experience, but also for successful development into happy and healthy adults.

The Hypothalamic-Pituitary-Adrenocortical Axis and Cortisol

Chronic exposure to psychosocial stressors has been linked to an increase risk for a variety of negative health outcomes, including depression, cardiovascular disease, autoimmune disease, infection, and more. The oft-proposed physiological mechanism for

this phenomenon is dysfunction of the hypothalamic-pituitary-adrenocortical (HPA) axis (Karlén et al. 2011; McEwen and Lasley 2003; Miller et al. 2007; Chrousos 2009). When an individual is exposed to a stressor, either physical or cognitive in nature, the body initiates a physiological response to prepare to react to the perceived threat and maintain homeostasis (Holsboer and Isling 2010; McEwen and Lasley 2003). The stress response begins with the activation of the HPA axis by stimulating the release of corticotrophin-releasing hormone (CRH) from the hypothalamus. Small, specialized blood vessels transport CRH to the pituitary gland, where it stimulates production and secretion of adrenocorticotropic hormone (ACTH). Subsequently, ACTH travels through the blood to the adrenal glands, resulting in the release of glucocorticoid hormones, including cortisol, into the bloodstream (Holsboer and Ising 2010; Gow et al. 2010).

In the short-term, cortisol has a variety of effects that help the body respond and adapt to a stressor. Some of these acute functions include increasing glucose availability, maintaining electrolyte balance, increasing focus and attention, and decreasing immune activity (Holsboer and Ising 2010; Chrousos 2009). In addition, cortisol replenishes energy sources including fat and glycogen, assuming that more energy was spent responding to the stressor (McEwen and Lasley 2003). Under normal circumstances, cortisol assists the body in responding to the stressor and returns to baseline levels with the help of its negative feedback system. An increase in serum cortisol downregulates HPA axis activity in the hypothalamus and pituitary gland (Gow et al. 2010; Holsboer and Ising 2010). However, when an individual is under chronic stress, the system

becomes overwhelmed, leading to HPA axis dysregulation and hypercortisolism (McEwen and Lasley 2003; Miller et al. 2007; Chrousos 2009).

The numerous effects of cortisol are beneficial in the short-term, but they become detrimental under prolonged exposure. For example, decreasing immune function allows the body to prioritize more immediate concerns when responding to an acute stressor, but over time this leads to increased susceptibility to infection. Further, increases in hunger and energy storage in the short-term assist the body in recovery, but if this process continues, it becomes a fast track to obesity (McEwen and Lasley 2003). These are just two of the many negative outcomes associated with hypercortisolism.

Biomarkers of Chronic Stress

Dysfunction of the HPA axis is frequently blamed for the increased disease risk associated with chronic stress. Thus, measurement of the end-product of the HPA axis, cortisol, is of clinical interest when assessing chronic stress and disease risk. Traditionally, cortisol has been measured in saliva, blood, and urine; however, use of the aforementioned media poses a problem when attempting to asses *chronic* hypercortisolism. In a healthy individual, cortisol is released in pulses throughout the day, dictated by circadian rhythms, acute stress, food consumption, and exercise (Holsboer and Ising 2010; Stalder and Kirschbaum 2012). Cortisol levels are naturally higher in the morning to help the body cope with the stress of waking up and continue to fluctuate throughout the day (McEwen and Lasley 2003). Acutely high levels of cortisol, therefore, are not necessarily indicative of chronic stress or hypercortisolism. Saliva and

blood cortisol concentrations represent a single point in time and urine samples represent an average over only a few hours, but neither is able to detect chronically elevated cortisol in a single sample.

In order to use acute measures of cortisol to investigate chronic stress and HPA axis dysregulation, multiple samples per day must be taken over multiple days. Studies utilizing this rigorous protocol must face issues of practicality and subject adherence (Stalder and Kirschbaum 2012). However, in recent years a new technique has emerged resolving many of the shortcomings of blood, saliva, and urine cortisol measures. Measuring the concentration of cortisol stored in hair provides a cumulative, retrospective snapshot of cortisol levels over a prolonged period of time.

The use of hair cortisol concentration (HCC) as a biomarker of chronic stress has many potential benefits. Unlike acute measures, HCC is reflective of a larger time interval, retrospective in nature, non-invasive, not influenced by acute circumstances, easy to store, and reduces the issue of non-adherence (Stalder and Kirschbaum 2012). Further, assuming a growth rate of 1 $cm \cdot month^{-1}$, HCC of a particular segment of hair can be associated with a specific period of time (Wennig 2000).

In the last decade, a number of studies have aimed to validate HCC as a biomarker of chronic stress in both animals and humans. Davenport and colleagues (2006) compared HCC in Rhesus monkeys with salivary cortisol. Salivary cortisol, assessed using the mean of 8 samples obtained over a two-week period, positively correlated with HCC of a segment of hair regrown over a 14-wk period ($r = 0.80$, $p < 0.001$). In subsequent years, additional studies have validated HCC to fecal and salivary

cortisol measures in domestic dogs and cats (Accorsi et al. 2008; Bennet and Hayssen 2010). The findings of these studies affirm the notion that cortisol is stored in hair in direct proportion to endogenous cortisol secretion.

In contrast, direct validation studies in humans have been slightly less decisive. In one of the first studies assessing the use of HCC in humans, Sauve et al. (2006) compared serum, saliva, and urine cortisol measures with HCC from a 2-cm segment. A significant, but weak correlation with HCC was only observed in the 24-h urinary cortisol ($r = 0.33$; $p < 0.05$). This finding is not surprising, because both serum and saliva cortisol levels were assessed using a single morning sample. Morning cortisol is typically higher than the rest of the day, and therefore not reflective of average cortisol secretion (McEwen and Lasley 2003). Additionally, the hair sample analyzed was not corresponding to the time period assessed by the acute measures. The methodology of this study was not well-suited for validation of HCC.

Other studies have suggested that HCC is a valid measure for assessing long-term, cumulative cortisol concentration in humans (Xie et al. 2012; van Holland et al. 2012: D'Anna-Hernandez et al. 2011). Perhaps one of the most convincing studies, performed by D'Anna-Hernandez and colleagues (2011), involved a sample of 21 pregnant females. During each trimester of the pregnancy, as well as three months postpartum, diurnal salivary cortisol profiles and HCC were measured. Diurnal salivary cortisol profiles, involving multiple saliva samples taken throughout the day to capture natural variations, were collected over a three-day sampling period either once (1st trimester and postpartum) or twice (2nd and 3rd trimesters) throughout each of the four time periods.

Hair was shaved and regrown to accurately represent the time interval of interest and account for variations in hair growth rate. Significant correlations were observed between HCC and mean salivary cortisol in the 2nd and 3rd trimesters (r = 0.43 and 0.57, respectively; p <0.05), while the same correlation during the 1st trimester and postpartum failed to reach statistical significance. The lack of statistical significance can be explained in part by the absence of a second 3-d salivary cortisol sampling period. Despite some inconsistencies in existing literature, protocols correlating salivary, serum, or urine cortisol measured repeatedly over multiple days with HCC measures associated with a corresponding time interval suggest that HCC is a valid measure of cumulative cortisol.

In addition to direct validation studies, a number of studies have indirectly assessed the validity of HCC by comparing a population known to have elevated cortisol levels with a healthy control group (Thomson et al. 2010; Manenschijn et al. 2011; Kirschbaum et al. 2009; Stalder et al. 2010). One such study examined a group of individuals with Cushing's syndrome, a clinical condition characterized by chronically high serum cortisol levels (Thomson et al. 2010). Assuming that serum levels of cortisol directly correlate with HCC, individuals with Cushing's syndrome should have significantly greater HCC than healthy individuals. This assumption was confirmed by the findings of the study; a significant difference (p < 0.001) was found in HCC between the group with Cushing's syndrome (n = 6) and the healthy control group (n = 32). Additionally, HCC levels decreased in Cushing's syndrome patients following treatment. The results of this study indirectly validate HCC as a method for assessing patterns of HPA activity over prolonged periods of time. Studies utilizing other conditions, including

pregnancy, alcoholism, and Addison's disease, as natural models of cortisol change over time have yielded results similar to Thomson et al. (2010), further validating the use of HCC to reflect long-term physiological changes in endogenous cortisol production (Manenschijn et al. 2011; Kirschbaum et al. 2009; Stalder et al. 2010).

Reliability of HCC has also been demonstrated in the literature. Two studies reported by Stalder et al. (2012) analyzed either two hair samples one year apart or three hair samples at two-month intervals. Both studies showed strong intraindividual reliability, with correlation coefficients ranging from 0.68 to 0.79. These results demonstrate stronger association than previously reported for acute cortisol measures. Consequently, despite the relative novelty of this technique, the majority of existing literature shows promising results for the use of HCC as a valid and reliable tool for investigating chronic stress in a variety of populations.

Chronic Stress and Disease Risk

Hypercortisolism is a pattern of abnormal HPA activity commonly caused by chronic stress and characterized by an increase in average serum cortisol levels. More specifically, hypercortisolism involves lower than normal cortisol production in the morning and greater than normal cortisol production throughout the rest of the day, creating a high, flat cortisol profile (McEwen and Lasley 2003; Miller et al. 2007). Cortisol is a pleiotropic hormone affecting approximately 20% of all expressed human genes and all major homeostatic systems. Consequently, it is not surprising that a dysfunction in cortisol regulation can cause widespread damage and increase the

likelihood of developing behavioral, endocrine, metabolic, cardiovascular, autoimmune, and allergic disorders (Chrousos 2009). A number of recent research studies have linked both chronic stress and hypercortisolism to a variety of chronic diseases, as well as increased rates of injury and illness (Chrousos 2009; Stalder et al. 2013; Veldhorst et al. 2014; Williams 1996; Dettenborn et al. 2012; Pereg et al. 2011).

Research involving clinical depression has yielded convincing evidence associating both chronic life stress and hypercortisolism with development and recurrence of the psychological disorders. In a review of the literature surrounding stress and depression, Hammen (2005) found that depressive episodes are most frequently preceded by stressful life events. Although life events can be characterized as acute stressors, chronic life stress was found to be even more predictive of depressive episodes (Hammen 2005; McGonagle and Kessler 1990). Further, Hammen (2005) suggested that prolonged exposure to "adverse conditions," including marital discontent, medical disability, and poverty, increase risk for developing depression. Dysregulation of the HPA axis was the proposed mechanism for the link between chronic life stress and depression.

Research involving measurement of cortisol confirms the supposition of Hammen (2005), stating that HPA dysregulation may be responsible for the increased risk of clinical depression in chronically stressed individuals. Dettenborn and colleagues (2012) compared HCC in a group of depressed patients (n = 23) and healthy controls (n = 64). Results from this study found that depressed patients had 50% higher HCC in the proximal 3 cm of hair than the healthy control group. Thus, chronic stress was predictive

of depression, with HPA axis dysregulation and hypercortisolism as the likely mechanism.

Chronic stress is also a well-established predictor of both acute cardiac events and cardiovascular disease progression. Studies suggest that chronic workplace stress can increase the risk of a cardiac event anywhere from 2- to 6-fold (Brotman et al. 2007). The relationship between cardiovascular disease progression and chronic stress in the workplace is well-documented, and individuals in jobs with high demand, but low control and/or reward seem to be at highest risk (Rozanski et al. 1999). These findings have been corroborated by numerous recent studies correlating HCC with indicators of cardiovascular disease. A particularly interesting study by Pereg and colleagues (2011) analyzed HCC in a 3-cm segment of hair in a group of patients admitted to the hospital with acute myocardial infarction (AMI) and a control group with a similar cardiovascular risk profile. Although the groups had no significant differences in cholesterol, type 2 diabetes, hypertension, dyslipidemia, smoking status, or family history, AMI patients had significantly greater HCC (295.3 vs. 224.9 ng/g, $p = 0.006$). Additionally, they found that HCC was the strongest predictor of AMI. These findings and the current body of literature investigating the relationship between stress and cardiovascular disease suggest that chronic stress is a risk factor for acute and chronic cardiovascular conditions.

Equally supported in literature is the association between chronic stress and obesity (Manenschijn et al. 2011; Stalder et al. 2013; Veldhorst et al. 2014). As mentioned in a previous section, cortisol stimulates abdominal fat storage; therefore, it is likely that prolonged exposure to elevated cortisol increases an individual's risk for

becoming overweight or obese (McEwen and Lasley 2003). A few studies have found positive correlations between measures of abdominal obesity, including waist-hip ratio and waist circumference, and HCC (Manenschijn et al. 2011; Stalder et al. 2013; Veldhorst et al. 2014). Veldhorst et al. (2014) compared HCC in obese children and a healthy age- and sex-matched control group. The obese children were considered early in the disease progression and had few additional weight-related pathologies. The results indicated that the obese group had significantly greater HCC values, suggesting that elevated cortisol levels are associated with the onset of obesity, not simply a consequence of its associated pathologies.

In addition to influencing the prevalence and progression of chronic disease, chronic stress is also related to frequency of acute illness. Cohen et al. (1998) investigated the influence of different types of stressors on susceptibility to the common cold. The research team inoculated participants with the common cold virus and found that presence of acute stressors (< 1 month exposure) had no effect on whether they developed the illness; on the other hand, participants who reported a chronic stressor (> 1 month) were more likely to develop a cold following exposure to the virus. The immunosuppressant effect of cortisol is likely to blame for the increased risk of illness associated with chronic stress (Chrousos 2009).

Physiological Stress

Perceived cognitive stress is one mechanism of HPA axis activation, but it is not the only factor. Physical stress contributes to HPA axis activation independently of

psychological stress. It is well established that HPA axis activity and serum cortisol levels increase in response to an acute bout of exercise, a response mediated by both intensity and duration (Galbo 1981; Davies and Few 1973). More recently, researchers have begun to study the relationship between chronic physical stress, measured both objectively and subjectively, and HCC.

Amateur endurance athletes who subject themselves to repeated physical stress in the form of training and competition was the population of interest in a study performed by Skoluda and colleagues (2012). When compared to an age- and BMI-matched control group, endurance athletes had 46 % greater HCC (p <0.001). Additionally, a dose-response relationship was observed between self-reported training volume and HCC (r = 0.32, p < 0.001), suggesting that a competitive athlete, devoting copious amount of time to training and competition, will have chronically higher levels of cortisol than an individual who does not regularly participate in endurance athletics. To build on these findings, a different research team utilized accelerometers to monitor physical activity objectively over a 7-day collection period in a group of university students (Gerber et al. 2013). They found that while a positive correlation existed between vigorous physical activity (> 6 METs) and HCC, no relationship was found between moderate physical activity (3-6 METS) and HCC. Together, the findings of Skoluda et al. (2012) and Gerber et al. (2013) indicate that individuals who exercise regularly for prolonged periods of time and/or at high intensities will tend to have chronically elevated cortisol levels. Clearly, physical stress as a contributor to long-term HPA axis activity and dysregulation cannot be ignored.

Sleep as a Moderator of Chronic Stress

Responding to stress is only one of the functions of the HPA axis. In addition to this *adaptive* function, the HPA axis also plays a *predictive* role, preparing the body to respond to predictable stressors such as waking up in the morning. This aspect of the HPA axis is modulated by circadian rhythms and plays a major role in sleep/wake transitions (Van Reeth et al. 2000). Thus, HPA axis activity and sleep are closely related; disturbances in sleep can negatively affect HPA axis function, and HPA axis dysfunction can negatively affect sleep quality.

Studies examining the effects of sleep disturbance reveal that subsequent HPA axis recovery must occur. In a study performed in young adult males involving various methods of sleep disturbance showed changes in cortisol release throughout the following day (Leproult et al. 1997). While evening cortisol levels are typically low, high evening cortisol levels were observed the day following sleep disruption. This observation likely reflects a temporary impairment in the regulatory function of the HPA axis at the hypothalamus (Van Reeth et al. 2000). Impairment in HPA axis regulation following sleep disruption may have a subsequent effect on the ability of the HPA axis to respond to and recover from additional exogenous stressors. Therefore, sleep loss may exacerbate the effects of preexisting stressors and accelerate the progression of stress-related disease (Van Reeth et al. 2000). In fact, poor sleep quality has been linked to clinical disorders and disease in both adults and children (Nielsen et al. 2010; Groeneveld et al. 2013; Van Reeth et al. 2000). Clearly, sleep quality is a key moderator of chronic stress development and stress-related disease progression.

A number of studies have characterized the sleep habits of college students and the relationship between sleep quality and psychological and physical health. Lund et al. (2010) used survey measures including the Pittsburgh Sleep Quality Inventory (PSQI) and the Epworth Sleepiness Scale (ESS) to investigate sleep quality in a group of 1127 college students. They found that over 60% of students were classified as poor sleepers by the PSQI. Further, those classified as poor-quality sleepers were significantly more likely to experience both physical and psychological health problems. Interestingly, tension and stress accounted for 24% of the observed variance in sleep quality. Similarly, Lee et al. (2013) utilized the PSQI and ESS, among other measures, to characterize sleep patterns in a group of female college students. Their findings suggest that an average of 6 h of sleep per weeknight, moderate fatigue, and high stress are typical among college females. High stress, assessed using the Perceived Stress Scale (PSS), was associated with sleep disturbance, decreased nighttime sleep, increased fatigue, and increased depressive symptoms. Those students classified as good sleepers by the PSQI reported experiencing less daytime sleepiness and fewer psychological and physical symptoms. The findings of both studies suggest a moderating effect of sleep; better sleep quality was associated with fewer stress-related symptoms. They also reveal that poor sleep habits is yet another factor that makes college students particularly susceptible to chronic stress and its numerous negative health outcomes.

Given the role of sleep in either curtailing or exacerbating the effects of chronic stress exposure, measurement of sleep quality is crucial in assessing contributors to chronic stress development, particularly among college students. The gold standard for

sleep quality measurement is polysomnography, but this method is expensive, difficult to transport, and impractical in many research applications (Lastella et al. 2015). Recently, wrist-worn activity monitors have been validated as a more practical alternative (Weiss et al. 2010); however, direct monitoring of nighttime sleep quality is not practical for large groups of people. Survey instruments, such as the PSQI and ESS, allow researchers to indirectly, quickly, and effectively assess average sleep quality over an extended interval in large groups.

The PSQI is a valid and reliable survey instrument yielding a simple global score for sleep quality (Buysee et al. 1988). The instrument is composed of questions relating to seven clinical constructs of sleep quality: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of sleep medications, and daytime dysfunction. In addition to a single global score, the PSQI can also be used to determine scores for each of the individual sleep constructs. On the global scale, a larger score indicates poorer sleep quality, and on a scale of 0-21, a score greater than 5 indicates a "poor sleeper." In a study performed to assess the validity of the PSQI, the survey instrument was able to effectively distinguish sleep-disordered patients from healthy controls (Buysse et al. 1989). Further, test-retest reliability assessment revealed a strong correlation between PSQI scores obtained on separate occasions in a group of 91 adults ($r = 0.85$, $p < 0.001$). Thus, the PSQI is a valid and reliable alternative to direct assessment of sleep quality.

The PSQI is intended to assess sleep quality over a one-month interval and is not susceptible to nightly variations in sleep quality, making it ideal for use in studies relating

general sleep quality to other variables of interest (Buysse et al. 1988). The ability of the PSQI to distinguish good and poor sleepers without the influence of nightly fluctuation is beneficial in studying the impact of sleep on chronic stress. Although a single night of bad sleep will likely not have a long-term impact on stress-related outcomes, prolonged sleep disturbance may impact chronic stress development. Numerous studies, including some mentioned earlier in this review, use the PSQI to relate sleep quality to measures of chronic stress and negative stress-related outcomes (Lund et al. 2010; Lee et al. 2013). The PSQI is a commonly used survey instrument in research applications requiring an easy-to-administer measure of average sleep quality.

The ESS is a commonly used supplement to the PSQI, expanding on the sleep construct of daytime dysfunction. Daytime sleepiness is an indicator of the degree to which nighttime sleep quality affects one's ability to perform daily activities. Similar to the PSQI, ESS scores were able to distinguish sleep-disordered patients from a group of healthy controls (Johns 1991). Additionally, ESS significantly correlated with measures of sleep quality obtained using polysomnography, considered the gold standard of sleep quality assessment. The ESS and the PSQI are frequently used in conjunction to assess sleep quality in a variety of populations (Lund et al. 2010; Lee et al. 2013).

Survey Measures of Chronic Stress

Although hair cortisol concentration is currently considered the criterion measure for assessing chronic stress, collecting and analyzing hair samples is expensive and impractical for monitoring chronic stress in most applications (Foster et al. 1996).

Alternatively, research-validated survey measures have traditionally been used to assess perceptions of cognitive stress. For example, the Perceived Stress Scale (PSS) is designed to measure the degree to which a person perceives various situations as stressful (Cohen et al. 1983). The questionnaire contains 14 items, where an individual is asked how often they feel a certain way regarding general stressors (i.e., "How often have you been upset because of something that happened unexpectedly?"). Scores on the PSS correlated with various negative stress-related outcomes, including use of the university health center and physical and depressive symptomology, in two groups of college students (Cohen et al. 1983). One benefit of the PSS is its generalizability; it is appropriate for use in any population and therefore can be used in comparison among groups. Conversely, its generalizability is also one of its drawbacks. Because different populations experience unique stressors, a general measure of perceived stress may limit understanding of stress within a specific population (Crandall et al. 1992).

Crandall et al. (1992) sought to remediate the issue of generality and create a survey instrument to assess chronic stress in college students specifically. The result was the Undergraduate Stress Questionnaire (USQ), a modified "life events checklist" containing 83 events, both major and minor, that college student may experience. The USQ differs from a traditional life events checklist, which asks individuals to indicate which events from a list they have recently experienced, in that it takes into account the perceptions of the individual. The questionnaire asks students to rate how stressful each event would be if it had happened to them. Because cognitive appraisal of an event is an important factor in chronic stress development, this strengthens the USQ as a predictor of

chronic stress. Events listed on the questionnaire range in severity and include topics such as family and relationship issues, daily hassles, academic stressors, and health problems. Studies validating the USQ, reported by Crandall et al. (1992), demonstrate that scores are positively correlated with physical symptoms. The USQ provides a valid, reliable method of measuring perceived stress in college undergraduate students.

Similar to the USQ, Lu et al. (2012) developed a survey instrument intended to assess chronic stress in collegiate student-athletes, the College Student-Athletes' Life Stress Scale (CSALSS). The CSALSS is a valid and reliable 24-item questionnaire with content pertaining to eight discrete factors. As discussed at length in a previous section of this review, collegiate student-athletes are exposed to a variety of unique stressors beyond those of the typical college student. Thus, use of a more general scale, such as the USQ, may underestimate total stress in this population. The CSALSS expands on the topics covered in the USQ to include those related to sports injury, performance demands, and coach relationships and more accurately describe chronic stress in collegiate student-athletes.

In addition to survey measures of perceived chronic stress, measures of one's sense of wellbeing can provide information regarding the degree to which an individual's stress is influencing their life satisfaction. The Satisfaction with Life Scale (SLS) is a questionnaire in which individuals indicate the degree to which they agree with each of five statements regarding general life satisfaction (Diener et al. 1985). This short survey indicator of general wellbeing has been negatively correlated to perceived stress (Weinstein et al. 2009). Thus, the SLS provides a measure that is independent from, yet

related to, chronic stress. When used in combination, the SLS and survey measures of perceived stress may help to predict non-overlapping domains of chronic stress development.

Summary

In addition to the developmental challenges of young adulthood, college students are exposed to an overwhelming variety of stressors regarding academics, relationships, choosing a career path and more (Mahmoud et al. 2012; Loughran and Etzel 2008; Benton et al. 2003; Pinkerton et al. 1989). Collegiate student-athletes must simultaneously manage all the stressors of a typical college student as well as those unique to athletic participation, including travel schedules, lack of free time, coach and player interactions, pressures to perform, and injury (Selby et al. 1990; Watt and Moore 2001; Howard-Hamilton and Sina 2001; Humphrey et al. 2000; Etzel et al 2006). On top of these numerous cognitive stressors, student-athletes must undergo rigorous training and competitions adding a large amount of physical stress. Both cognitive and physical stress activate the HPA axis and cause release of cortisol into the bloodstream (Gow et al. 2010). Chronically elevated cortisol levels have been shown to contribute to development of numerous physical and psychological disorders and diseases (Chrousos 2009). To avoid the negative consequences of chronic stress and promote wellbeing, monitoring and management of stress are particularly critical among collegiate student-athletes.

Measuring cortisol concentration in hair is considered the criterion technique for measuring chronic stress; however, this approach is expensive and impractical for

monitoring chronic stress in most applications, where time and resources are limited. In place of this method, survey instruments, such as the PSS and USQ, are easy-to-administer measures of perceived chronic stress (Cohen et al. 1983; Crandall et al. 1992). However, perceived stress is only one contributor to chronic stress development. Although survey instruments currently exist for measuring either cognitive or physiological sources of stress, no single instrument has integrated both cognitive and physical sources of stress into a single global measure of chronic stress. Understanding the complex relationship between cognitive and physical stress, sleep quality, and hair cortisol concentrations is the first step in developing a comprehensive, easily administered instrument for assessing chronic stress in collegiate student-athletes.

CHAPTER THREE

EVALUATING DETERMINANTS OF PSYCHOPHYSIOLOGICAL STRESS ON COLLEGIATE STUDENT-ATHLETES

Contribution of Authors and Co-Authors

Manuscript in Chapter 3

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Contributions: Assisted in study design, executed subject recruitment and data collection, processed and analyzed data, and wrote manuscript.

Co-Author: Daniel P. Heil

Contributions: Formulated study design, assisted with subject recruitment, and edited the manuscript at all stages.

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ABSTRACT

Collegiate student-athletes are a unique group of individuals who experience a vast array of cognitive and physiological stressors. In addition to the typical stressors of an average college student, such as homesickness, finances, academics, and social relationships, student-athletes must also cope with lack of free time, pressure to perform, relationships with coaches and teammates, and physiological stress due to training and competing. Student-athletes with unmanaged chronic stress are more likely to experience a plethora of negative health outcomes, effecting performance in the classroom, on the field, and in life. Currently, survey instruments exist to predict cognitive and physiological sources of stress in isolation, but no existing instrument integrates both cognitive and physiological stressors into a single measure of chronic stress. The current cross-sectional study compared magnitude and sources of stress, psychological and physiological, experienced by Montana State University student-athletes (n=30) and their non-athlete counterparts (n=22). In addition, associations between chronic stress (as indicated by hair cortisol concentration, or HCC) and subjective measures of psychological stress, physiological stress and sleep quality were assessed in a subgroup of participants (n=12 student-athletes; n=9 non-athletes). Student-athletes had significantly greater average weekly training load than the non-athlete students ($P < 0.001$), but all other indicators of psychological stress and sleep quality were not significantly different between the two groups. Of those participants who provided a hair sample, the student-athletes had greater average HCC ($P = 0.027$). Although no associations were observed between HCC and measures of psychophysiological stress or sleep quality, a significant correlation was observed between HCC and body fat percentage ($r = -0.59$, $P < 0.045$). Additional research is necessary to elucidate the role of body composition, as well as other factors, on chronic stress development in college student-athletes.

Introduction

When the human body experiences a cognitive or physiological stressor, the hypothalamus-pituitary-adrenocortical (HPA) axis releases the hormone cortisol into the blood. Acute exposure to cortisol initiates a host of positive physiological effects intended to assist the body in responding to the stressor. In contrast, chronic exposure to cortisol leads to dysregulation of the HPA axis and increased disease risk. In fact, chronically high cortisol production has been associated with an increased risk for depression, substance abuse, eating disorders, sleep disorders, metabolic syndrome, obesity, Type II diabetes, myocardial infarction, as well as increased rates and severity of sickness and injury (Pereg et al. 2011; Stalder et al. 2013; Stalder et al. 2012a). Thus, those more likely to experience unmanaged chronic stress, whether cognitive or physiological in origin, are also more likely to experience long term negative health outcomes due to HPA axis dysregulation and hypercortisolemia.

College students may be especially susceptible to the influence of chronic stress because of the relatively unique combination of cognitive, or psychological, stressors (financial, social, academic, developmental) and limited stress management skills (Cohen et al. 1983; Mahmoud et al. 2012; Loughran and Etzel 2008; Benton et al. 2003; Pinkerton et al. 1989). In fact, numerous studies have documented a high prevalence of chronic stress and some of its repercussions in this population (ACHA 2012; Mahmoud et al. 2012). College student-athletes, however, face the additional psychological and physiological stressors associated with their athletic participation (i.e., training, competing, coaching staff interactions) (Gerber et al. 2013; Silva 1990; Simon and

Docherty 2013; Skoluda et al. 2012; Selby et al. 1990). Unlike their non-athlete peers, college student-athletes must be able to handle the demands of exhaustive training programs, the need and desire to physically perform well and improve over time, competitiveness amongst teammates, extensive travel for competition, as well as the inevitable pressures associated with winning, losing, and getting sick or injured. The use of maladaptive coping strategies and underutilization of counseling resources, accompanied by the sheer number of potential stressors, place collegiate student-athletes at particular risk for chronic stress (Etzel 2009; Yusko et al. 2008). Clearly, the management of chronic stress is a key factor in the eventual success of collegiate student-athletes attempting to be students, athletes, as well as happy and healthy young adults.

In order to monitor chronic stress development among collegiate student-athletes, proper measurement of chronic stress is essential. Traditional biomarkers of stress (e.g., saliva, serum, and urinary cortisol) are only effective for monitoring the acute response to a stressor. Long-term exposure to a stressor, or a variety of stressors, are best measured from scalp hair samples which accumulate cortisol regardless of the cause of stress. Thus, the concentration of cortisol in hair provides a retrospective, cumulative indicator of HPA axis activation, with most recent cortisol secretions being represented in hair closest to the scalp (Groeneveld et al. 2013; Kirschbaum et al. 2009; Stalder et al. 2012b; Thomson et al. 2010). At an average growth rate of 1 cm per month, the measurement of cortisol from hair samples is considered a criterion technique for documenting the body's response to chronic stress (Wennig 2000). Collecting hair samples, however, is neither practical nor inexpensive for monitoring chronic stress within a large group of people.

Alternatively, research-validated surveys have traditionally been used to assess perceptions of cognitive stress. The Undergraduate Stress Questionnaire (USQ), for example, is described as a "life events checklist" for both major and minor stressful events that are specific to undergraduate college students (Crandall et al. 1992). The Perceived Stress Scale (PSS), often cited as the most widely used survey for measuring nonspecific perceived stress in adults, was designed to measure the degree to which a person assesses situations as stressful (Cohen et al. 1983). For a more general assessment of life satisfaction, the Satisfaction with Life Scale (SLS) has be validated for use in adults as an indicator for a person's sense of well-being (Diener et al. 1985). Recently, Lu et al. (2012) developed and validated the College Student-Athlete Life Stress Scale (CSALSS), a 24-item instrument designed to quantify potential stressors uniquely encountered by collegiate student-athletes. However, the specificity of the CSALSS to collegiate student-athletes makes it unsuitable for use by non-athlete students in the current study. It is likely, however, that a combination of surveys used simultaneously (e.g. USQ, PSS, and SLS) may help to predict non-overlapping domains of chronic stress development in collegiate student-athletes and non-athlete students in the current study.

Recently, night time sleep quality has been more widely accepted as a moderator of chronic stress development, as well as a contributor to a host of clinical disorders and disease conditions, in both adults and children (Groeneveld et al. 2013; Nielsen et al. 2010; Van Reeth 2000; Veldhorst 2014). Research has demonstrated that college students have particularly poor sleep habits (Lund et al. 2010; Lee et al. 2013). In fact, one study revealed that over half of college students are classified as poor sleepers according to the

Pittsburgh Sleep Quality Inventory (Lund et al. 2010). Therefore, poor sleep quality is yet another factor that makes college students, including student-athletes, especially susceptible to development of chronic stress. Additionally, previous research has demonstrated that poor sleep quality leads to acute disruptions in HPA axis activity (Leproult et al. 1993; Van Reeth et al. 2000). Similar to the argument for monitoring chronic stress by collecting hair samples, direct monitoring and evaluation of night time sleep quality (e.g., polysomnography, wrist-worn activity monitors) is not practical for large groups of people. Alternatively, surveys can be used to indirectly assess sleep quality by monitoring one's perceptions of night time sleep quality with the Pittsburgh Sleep Quality Index (PSQI), or self-reported indicators of daytime sleepiness with the Epworth Sleepiness Scale (ESS) (Buysse et al. 1989; Johns 1991). Used for a recent pilot study in our lab, the summative index for each of these surveys correlated significantly with the CSALS score in collegiate cross country skiers (Heil et al. 2015).

Finally, a dose-response relationship has been reported between hair cortisol concentrations and the volume of physical training within both elite endurance athletes and recreationally active college students (Gerber et al. 2013; Skoluda et al. 2012). The high physical demands of practices and competitions may put collegiate student-athletes at elevated risk for chronic stress development when compared with their non-athlete counterparts.

In summary, both excessive physical training and cognitive stress are related to elevated hair cortisol. Further, both physical training and cognitive stress are related to decreased sleep quality. Thus, by monitoring both the potential sources of stress (i.e.,

cognitive and physiological), a key moderator of these stressors (i.e., sleep quality), as well as the outcome for chronic exposure to these stressors (i.e., cortisol accumulation in the hair), it should be possible to cross-sectionally predict chronic stress exposure in collegiate student-athletes and non-athlete students as a combined function of psychophysiological sources of stress.

Although survey instruments currently exist for measuring either cognitive or physiological sources of stress, no single instrument has integrated the cognitive and physiological assessments into a single measure of chronic stress. Given that understanding the integration of these psychophysiological stressors is essential to the management of chronic stress in college students and student-athletes alike, the present study evaluated chronic stress, as determined by cortisol measures in hair samples, as well as psychological and physiological sources of stress using a battery of existing surveys, in a cohort of Montana State University (MSU) Division I student-athletes, as well as a reference group of non-athlete MSU students. This an important first step toward developing a comprehensive instrument for assessing chronic stress in collegiate student-athletes. In doing so, the first goal of this study was to compare the psychophysiological stress and sources of stress in the athlete and non-athlete student groups to evaluate the assertion that collegiate student-athletes tend to experience greater and/or unique sources of unmanaged chronic stress. A second goal of the current study was to determine the relationship between chronic stress and various cognitive and physiological stressors and demographic variables in the combined sample of collegiate student-athletes and non-athlete students.

Methodology

Subject Recruitment

Division I student-athletes and non-athlete students (hereafter referred to as non-athletes) enrolled full-time at MSU-Bozeman for the spring semester of 2016 were recruited to participate in the study. The student-athlete group consisted of track and field, alpine skiing, Nordic skiing, and volleyball athletes. The non-athlete student group was comprised of MSU students who were not a member of an NCAA athletic team.

To recruit student-athletes, researchers first contacted team coaches to request permission to speak with their athletes. Once coach consent was received, researchers contacted student-athletes via email and/or in-person to outline the requirements of participation in the study. To recruit non-athletes, an informational recruitment email was sent to all undergraduate students in the department of Health and Human Development. Additionally, researchers visited classrooms to explain the study and ask for volunteers. Students who volunteer to participate took part in a single four-week data collection period.

Study Design

This cross-sectional study design took place over a four-week data collection period. All volunteers completed a survey battery at the beginning and end of the four-week period. At the conclusion of the fourth week, all participants who were willing provided a hair sample. The hair sample analysis reported hair cortisol concentration as

an average over the previous month. In addition, all participants submitted Excel-based training logs electronically at the conclusion of each of the four weeks.

Data Collection Procedures

To collect these measures, participants visited the MSU Movement Science Teaching Lab (MSTL) at the commencement of the four-week data collection period to complete an MSU IRB-approved consent form (Appendix A), measure demographics (i.e., body height and mass, fat percentage, age, ethnicity), as well as receive instructions for accurately completing the Excel-based weekly training log and survey battery on SurveyMonkey®. Completing the survey battery at this time served to familiarize volunteers with the surveys and on-line process. Each week thereafter, participants completed and submitted a 7-day training log of their exercise bouts using an Excel spreadsheet template. At the conclusion of the four-week collection period, participants returned to the MSTL to complete the entire survey battery again. At this time, a hair sample was provided by willing individuals.

Measurement of Hair Cortisol

Hair samples were collected by one member of the research team using standardized sampling and storage techniques. Each hair sample was obtained from the nape of the neck, minimally 1 cm long and 1 cm wide (when the hairs are laid flat side-by-side). Excess hair length (greater than 4 cm) was removed from the distal end, and the proximal sample was stored immediately within a labeled plastic pouch. Participants with hair that had been treated (i.e., dyed or permed) or contained heavy hair products (e.g., hair spray, gel, oil, etc.) were not eligible to provide a hair sample, as these processes

interfere with the analysis. Of course, volunteers who are unable (e.g., extensive hair treatments, shaved head) or unwilling to provide a sufficient hair sample for cortisol measurement were excluded from this portion of the study.

All collected hair samples were analyzed by a third-party laboratory (Rocky Mountain Analytical, Calgary, AB, Canada). Unwashed hair samples were cut down to 1 cm, weighed, and incubated overnight in methanol. The samples were then centrifuged, and a portion of the supernatant was drawn off and dried under a stream of warm nitrogen. The resultant was resuspended in phosphate-buffered saline. Hair cortisol concentration was determined via duplicate aliquots using an IBL International Cortisol Saliva Luminescence Immunoassay (Tecan Trading AG, Switzerland). The protocol for quantifying hair cortisol concentration issued by the kit manufacturer was utilized. The limit of quantification for the assay is 1.5 pg/mg with an average coefficient of variance of 10%.

Measurement of Perceived Stress and Sleep Quality

Cognitive perceptions of stress, quality of life and well-being, as well as indicators of sleep quality were assessed using a collection of validated surveys from the research literature. The surveys included in the survey battery were the USQ (Crandall et al. 1992), PSS (Cohen et al. 1983), SLS (Diener et al. 1985), PSQI (Buysse et al. 1989), and ESS (Johns 1991). Additionally, the CSALSS was included for the collegiate student-athletes only.

In the current study, the USQ, PSS, SLS, and CSALSS were all used to indicate cognitive perceptions of stress. The USQ is described as a “life events checklist” for both

major and minor stressful events that are specific to undergraduate college students. The USQ was found to be valid and reliable, and scores correlated positively with negative health outcomes and negatively with mood (Crandall et al. 1992). The PSS (Cohen et al. 1983), often cited as the most widely used survey for measuring nonspecific perceived stress in adults, was designed to measure the degree to which a person assesses situations as stressful. Cohen and colleagues (1983) found the PSS to be valid, reliable, and predictive of clinical outcomes in two samples of college students. Both the USQ and the PSS can be evaluated with cumulative scores for stress, as well as specific domains made up from specific clusters of questions. For a more general assessment of life satisfaction, the SLS has been validated for use in adults as an indicator for a person's sense of well-being (Diener et al. 1985). Thus, the USQ, PSS, and SLS were used to measure overlapping, but not identical constructs related to cognitive perceptions of stress.

Sleep quality, a potential moderator of chronic stress development, was quantified using the PSQI and the ESS. The PSQI, developed by Buysse and colleagues (1989), validly and reliably assesses seven clinical constructs of sleep quality based on an individual's perceptions. Much like the USQ and PSS, the PSQI can be evaluated with a cumulative score for sleep quality, as well as construct-specific scores. The ESS has been validated as a self-report measure of one's daytime sleepiness. Together, the PSQI and ESS served as indirect assessments of the participants' sleep quality.

Measurement of Physiological Stress

The stress from physical training was easily tracked by all participants using a simplified weekly training log from prior studies in our lab (Heil et al. 2015; Whiton et

al. 2015). For each bout of training and competition during the four-week collection period, all participants recorded both the duration (Time, in minutes) and an assessment of average intensity, where average intensity is rated according to a Session Rating of Perceived Exertion (sRPE), where RPE is the 0-10 scale rating originally described by Borg et al. (1987). Weekly Training Load (WTL) for each bout of training or competition was then computed as: TL = Time x sRPE (Foster et al. 1996). Average weekly training load (TL), calculated by averaging WTL for all four weeks, was then used for the analyses. Additionally, average weekly training volume (TV) was calculated as the average number of hours of activity recorded per week for each individual. Reported activities that were not associated with intentional physical activity were not included in the training volume and training load calculations (e.g., walking between class, working, housework).

Body Fat Testing

Body fat percentage was measured once during the initial visit to the MSTL using the Seca Medical Body Composition Analyzer (mBCA) 514. Participants were asked to step onto the platform of the body fat analyzer and grab hold of two electrodes on a hand rail. Participants remained in this position for approximately 20 seconds while the body fat analyzer ran a low frequency current through the body. Results were made available to the participants at the conclusion of the study.

Statistical Analyses

Following standard data screening procedures, data from the various surveys were categorically summarized (Mean±SD, Range) by group (student-athlete or non-athlete

student) and sex. Demographic data (age, body height and mass, body mass index, and BF) were compared between student-athletes and non-athletes for males and females separately using two-tailed two-sample *t*-tests. Only survey measures from the conclusion of the fourth week of data collection were used for analyses. Next, 2-factor ANOVA (Group x Sex) were performed to identify differences in survey outcomes between the groups (alpha = 0.05), which satisfied the first goal of the study. Finally, to achieve the second goal, Pearson correlations with a Holm-Bonferroni correction were used to assess associations between hair cortisol concentrations and PSS, USQ, SLS, PSQI, ESS, and TL scores for the entire sample. The goal of these analyses was to determine which variables were associated with chronic stress, as indicated by hair cortisol measures, in undergraduate students. All statistical analyses were evaluated at the 0.05 alpha-level using the software Statistix (Version 10; Analytical Software, Tallahassee FL USA).

Results

Subjects

Fifty-six participants were recruited during January 2016 to participate in the study: 32 student-athletes and 24 non-athletes. Four of the 56 participants failed to attend the second laboratory session, and were removed from the study (two student-athletes and two non-athletes). The remaining 30 student-athletes (8 males and 22 females) and 22 non-athletes (9 males and 13 females) were included in the analyses. The demographic information for these participants is provided in Table 3.1. No significant differences were observed in age, body height, body mass, body mass index (BMI), or BF between

male student-athletes and non-athletes. The female student-athletes had significantly greater body mass than the non-athlete females (P = 0.002), but no significant differences were observed in age, body height, BMI, or BF between groups. The student-athlete group consisted of seven freshmen (23.3%), nine sophomores (30%), seven juniors (23.3%), and seven seniors (23.3%), while the non-athlete student group consisted of two freshmen (9.1%), six sophomores (27.3%), six juniors (27.3%), and eight seniors (36.4%). Additionally, the student-athlete group was composed of 23 track and field athletes (76.7%; five throwers, five sprinters, two multi-event athletes, five distance runners, and six jumpers), two volleyball players (6.7%), three Nordic skiers (10.0%), and two alpine skiers (6.7%). Data collection occurred during competition season for track and field athletes and skiers, while volleyball players were out of season.

Table 3.1. Demographic information for all participants by athletic group (collegiate student athletes and non-athlete students) and sex. All values expressed as Mean±SD.

		Age (years)	Height (cm)	Weight (kg)	BMI ($kg \cdot m^2$)	Body Fat (%)
Student-athletes	Males (n=8)	20.5±1.3	184.4±6.3	80.9±10.3	23.8±2.6	12.4±3.8
	Females (n=22)	20.4±1.4	170.5±5.4	65.5±11.2	22.5±2.9	21.1±5.5
Non-athlete students	Males (n=9)	21.3±2.7	179.7±5.9	76.6±7.2	23.8±3.2	13.7±6.9
	Females (n=13)	20.3±1.1	163.8±5.3	61.9±9.1	23±2.5	25.7±8.7

Physiological Stress

Data for physiological stress obtained from the weekly training logs are outlined in Table 3.2. Average weekly TV and TL were both significantly greater in the student-athletes than the non-athlete students (P < 0.001). Additionally, the female athletes had

greater TV and TL than non-athlete females. However, when comparing male student-athletes with non-athlete males, significant differences were observed in TL, but not TV (P = 0.036 and 0.200, respectively).

Table 3.2. Average weekly training volume (TV) and training load (TL) for all participants, by athletic group (collegiate student athletes and non-athlete students) and sex. All values expressed as Mean±SD.

		TV (hrs)	TL (RPE·hrs)
Student-athletes	All Subjects (n=30)	9.5±2.6**	35.0±9.6**
	Males (n=8)	9.9±3.1	37.1±6.5*
	Females (n=22)	9.3±2.4**	34.3±10.5**
Non-athlete students	All Subjects (n=22)	5.7±4.2	19.0±12.7
	Males (n=9)	6.9±5.5	23.2±15.8
	Females (n=13)	4.7±2.8	15.8±9.3

RPE: Rating of Perceived Exertion (Borg 1-10); TL: Calculated as the product of duration (min) and session RPE for each activity, summed for one week, and averaged across four weeks for each participant.
*denotes significantly greater value than non-athlete students within same sex classification (P=0.036)
** (P <0.001)

Psychological Stress

Survey data for psychological stress are reported in Table 3.3. Participants were provided the incorrect responses to the questions for the USQ, which did not allow for scoring of the survey. No significant differences in survey measures of psychological stress (PSS and SLS) were observed between student-athletes and non-athlete students. However, a trend toward significance was identified in SLS score when comparing female student-athletes with their non-athlete counterparts (P = 0.078). Additionally, the mean PSS for all females tended to be greater than the mean PSS for all males (Mean±SD: 24.3±7.1 and 20.4±7.8, respectively), though not significantly (P = 0.08).

Table 3.3. Scores for the Perceived Stress Scale (PSS), Satisfaction with Life Scale (SLS), and the Collegiate Student-Athlete Life Stress Scale (CSALSS; student-athletes only) for all participants, by athletic group (collegiate student athletes and non-athlete students) and sex. All values expressed as Mean±SD.

		PSS	SLS	CSALSS
Student-athletes	All Subjects (n=30)	23.7±7.9	29.2±5.1	53.3±15.9
	Males (n=8)	23.4±7.7	28.0±6.9	47.5±11.2
	Females (n=22)	23.8±8.1	29.7±4.3	55.4±17.0
Non-athlete students	All Subjects (n=22)	22.1±7.0	26.0±6.6	-
	Males (n=9)	17.8±7.3	25.6±6.9	-
	Females (n=13)	23.8±8.1	26.3±6.7	-

Sleep Quality

Survey data for sleep quality and daytime sleepiness are reported in Table 3.4. No significant differences were observed in either PSQI or ESS global scores between student-athletes and non-athletes for both the total sample and within-sex analyses.

Table 3.4. Scores for the Pittsburgh Sleep Quality Inventory (PSQI) and Epworth Sleepiness Scale (ESS) for all participants, by athletic group (collegiate student athletes and non-athlete students) and sex. All values expressed as Mean±SD.

		PSQI	ESS
Student-athletes	All Subject (n=30)	5.1±2.6	8.2±3.9
	Males (n=8)	3.8±1.8	7.5±4.9
	Females (n=22)	5.5±2.7	8.4±3.6
Non-athlete students	All Subjects (n=2)	6.0±2.8	7.8±4.0
	Males (n=9)	5.8±2.7	6.2±3.1
	Females (n=13)	6.2±3.0	8.9±4.3

Hair Cortisol Concentration

The original hair samples did not include enough hair to be analyzed. Hair was recollected from those willing to provide a second sample, and these new samples were adjusted in length assuming a 1 cm/month growth rate. Hair cortisol concentration data for the second samples collected, as well as demographic data for these participants, are reported in Table 3.5. Of the 12 student-athletes who provided a second sample, 11 were

track and field athletes (two distance runners, four throwers, three jumpers, one sprinter, and one multi-event) and one was a Nordic skier. The student-athletes had a significantly greater mean HCC than the non-athlete student group (P = 0.027). Despite the difference between groups in all participants, there was no significant difference between female athletes and non-athletes (P = 0.28), whereas there were too few males (n=3) to analyze separately. Additionally, a larger range in hair cortisol concentration is observed in the student-athletes than the non-athlete students, as depicted in Figure 3.1 (1.0 to 24.3 and 0.9 to 8.0 pg/mg for student-athletes and non-athletes, respectively).

Hair cortisol concentration did not correlate significantly with TV, TL, PSQI, ESS, PSS, SLS, or CSALSS. However, a significant, moderate correlation was observed between body fat percentage (BF) and HCC (r = -0.59, P = 0.045) in the student-athletes, as demonstrated by Figure 3.2. This relationship did not exist in the non-athlete students or the total sample.

Table 3.5. Hair cortisol concentration values for all samples, by athletic group (collegiate student athletes and non-athlete students) and sex. All values expressed as Mean±SD.

		Age (years)	Body Fat (%)	Hair Cortisol Concentration (pg/mg)
All Subjects	(n=21)	20.7±1.7	21.1±7.4	6.1±6.3
Student-athletes	All Subjects (n=12)	20.6±1.4	21.4±5.7	8.0±7.7*
	Males (n=1)	20.0	9.8	17.9*
	Females (n=11)	20.6±1.4	22.4±4.5	7.1±7.4
Non-athlete students	All Subjects (n=9)	20.8±2.2	20.7±9.6	3.5±2.2
	Males (n=2)	23.0±4.2	17.1±14.0	2.5±0.1
	Females (n=7)	20.0±0.6	21.7±9.2	3.8±2.4

*denotes significantly greater value than non-athlete students within same sex classification (P < 0.05)

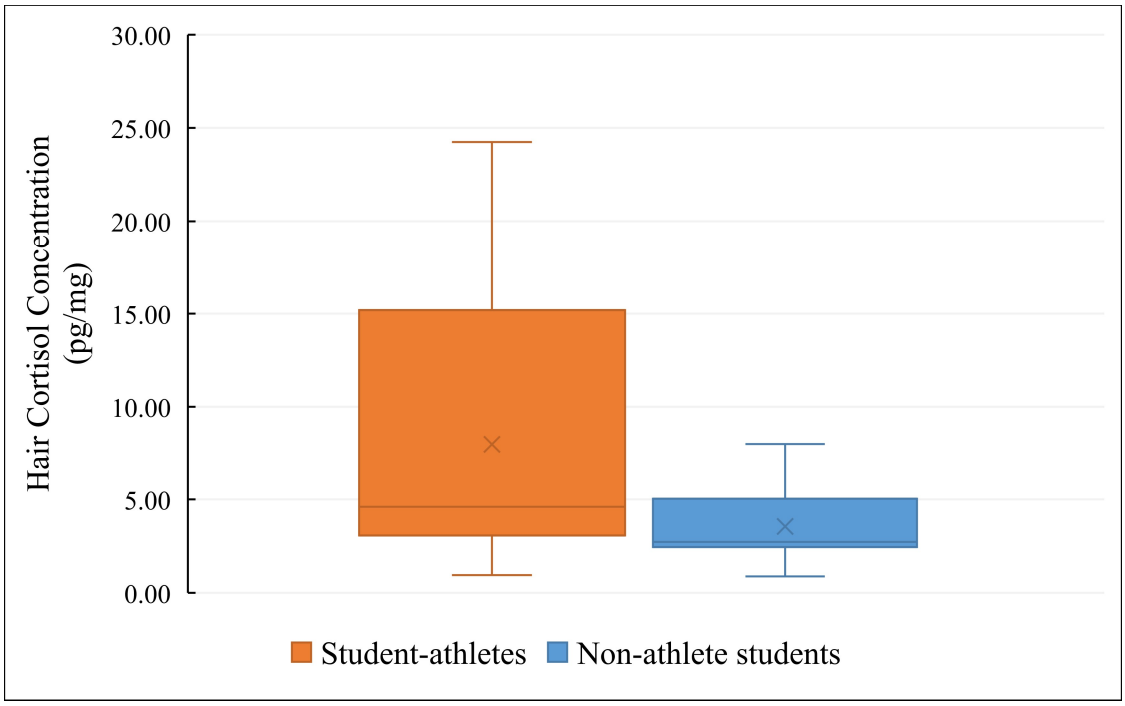


Figure 3.1. Box and Whisker Plot depicting hair cortisol concentrations for student-athletes and non-athlete students.

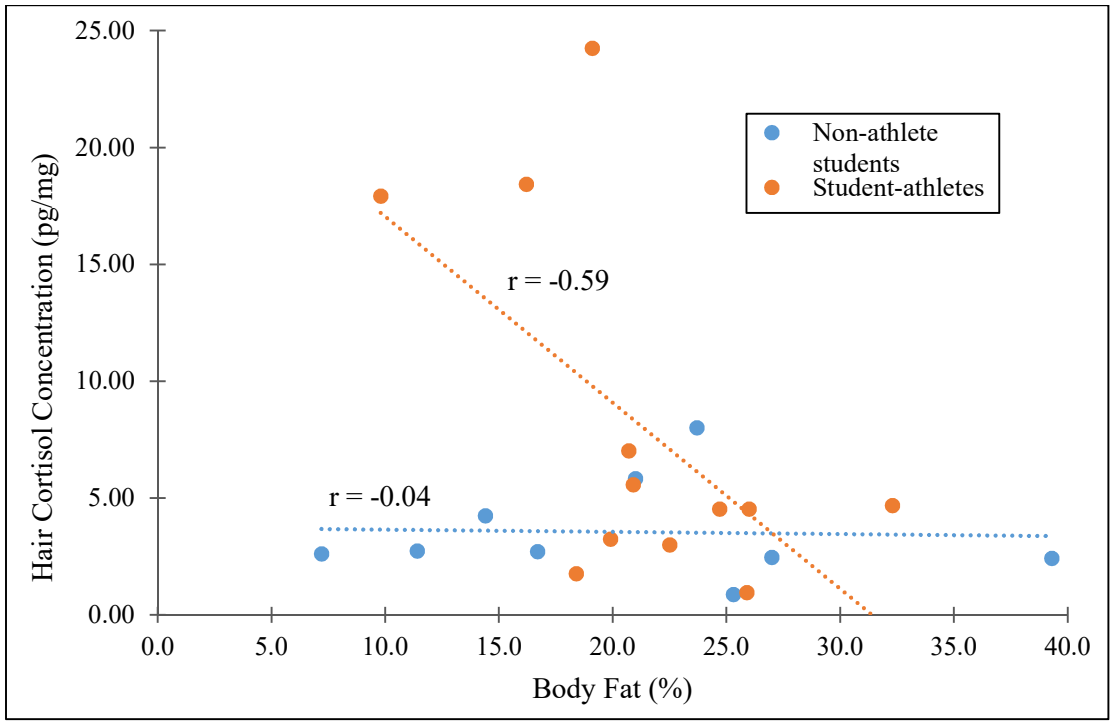


Figure 3.2. Correlation between hair cortisol concentration and body fat percentage for student-athletes and non-athlete students.

Discussion

To our knowledge, no previous research has investigated the relationships between measures of psychological and physiological stress, sleep quality, and hair cortisol concentration in collegiate student-athletes and non-athletes. Therefore, the first goal of the current study was to compare the source and amount of psychophysiological stress in collegiate student-athletes and non-athlete students. The second goal of the study was to determine associations between chronic stress and various cognitive and physiological stressors in the combined sample of collegiate student-athletes and non-athletes. It was hypothesized that average ESS, PSS, and PSQI scores, training load, and hair cortisol concentration would be greater in the student-athletes than the non-athlete students. Similarly, it was hypothesized that average SLS score would be lower in the student-athletes than the non-athletes. Further, it was hypothesized that HCC would be positively correlated with ESS, PSS, and PSQI scores and training load and negatively correlated with SLS score.

Physiological Stress

The average training load values observed in this study are greater than those observed in previous literature. Foster et al. (1996) used the same technique for quantifying training load in a group of competitive athletes, ranging from serious recreational athletes to members of U.S. National and Olympic teams. They observed average weekly training load values of 20.7 RPE·hrs during preseason training and 23.1 RPE·hrs during a period of increased training load. In contrast, average weekly training

load values observed in the current study were 19.0 and 35.0 RPE·hrs in the non-athlete students and student-athletes, respectively. The cause of the difference between the athletes in the study by Foster et al. (1996) and the student-athletes in this study can be attributed to the difference in number of training hours logged. Foster and colleagues observed an average weekly training volume of 5.8 hrs. This value is similar to the average weekly training volume observed in the non-athlete students (5.7 hrs), but notably less than training volumes reported by the student-athletes in the current study (9.5 hrs).

One observation regarding training log entries may help explain the observed differences in training volume and training load between Foster et al. (1996) and the current study. Training time recorded in the logs seemed to reflect time associated with the activity, rather than time spent in physical activity. For example, student-athletes tended to report the length of time spent at practice, rather than the amount of time spent performing the workout. Another activity in which duration was most-likely over-reported is recreational skiing; some participants recorded the amount of time spent at the mountain, rather than time spent engaged in the activity. This tendency to overestimate training time for activities may have contributed to the high average weekly training volume and training load values observed in this study relative to the observations of Foster and colleagues (1996).

Although the observed training load values were dissimilar to previously reported data, the method did reflect differences in training load between the student-athletes and the non-athlete students. The student-athletes reported significantly greater average

weekly training volume and training load values than their non-athlete counterparts ($P < 0.001$), which is consistent with the first hypothesis of the study.

Despite a significant difference between the student-athlete and non-athlete student groups, neither training volume nor training load were significantly correlated to hair cortisol concentrations, which did not support the second hypothesis of the study. These findings are contrary to relationships between physical activity and hair cortisol concentration previously reported in the research literature. Skoluda and colleagues (2012) reported elevated HCC in endurance athletes. Moreover, a relationship between HCC and training volume (kilometers run per week) was observed ($r = 0.32$, $P < 0.001$). Although training volume was calculated using self-report data, the use of distance as a metric is a less subjective indicator of physiological stress than training load calculated using session RPE. In fact, the subjectivity of session RPE could account, in part, for the lack of a significant relationship between HCC and training load in the current study. However, the use of a distance metric of training load, such as $km \cdot wk^{-1}$, is not an appropriate measure in the context of the present study where the primary training modes of the participants were diverse.

Previous literature has also reported a significant relationship between HCC and objectively assessed physical activity (Gerber et al. 2013). Surprisingly, this relationship was only observed for minutes of vigorous physical activity per week ($r = 0.34$, $P < 0.05$). There was no relationship between HCC and minutes of moderate physical activity per week. The finding of Gerber and colleagues (2013) further explain the lack of relationship observed in the present study. The subjective measure of training load

(RPE·hrs) does not indicate the quantity of physical activity that qualified as vigorous. Future studies investigating physiological stress in collegiate student-athletes and non-athlete students should quantify vigorous physical activity specifically, either objectively or subjectively.

Psychological Stress

Survey measures of psychological stress revealed no significant differences between the student-athletes and the non-athlete students, which did not support the first hypothesis of the study. Despite a lack of significance, a couple of observations can be made regarding differences in life satisfaction between student-athletes and non-athlete students. First, the average SLS score was greater in the student-athletes than the non-athlete students (29.2 vs. 26.0, respectively). Although this difference was not statistically significant ($P = 0.10$), the within-sex analysis revealed that this difference approached significance for the females ($P = 0.08$). The greater SLS scores in student-athletes contradicted the hypothesis that life satisfaction scores would be lower in student-athletes due to high perceived stress.

Other studies have similarly reported greater life satisfaction in athletes. Malekian et al. (2014) investigated happiness and life satisfaction in high school student-athletes. Although a different survey instrument was utilized (Oxford Happiness Inventory), this study also reported greater life satisfaction in student-athletes than non-athlete high school students. Kiyani and colleagues (2011) measured happiness and mental health in adult athletes and non-athletes in the work force and found that those individuals who identified as athletes had greater happiness and mental health. These researchers also

identified theories to explain the relationship between athletic participation and life satisfaction. First, the Sonstroem model states that an increase in physical capability leads to greater self-esteem, which in turn produces greater satisfaction with life (Sonstroem 1989). Second, the distraction theory proposes that exercise and sport participation serve as a distraction from negative aspects of life, leading to greater life satisfaction. Finally, the third proposed theory is the biological model. The biological model attributes life satisfaction to the biochemical changes that occur during physical activity. A combination of these three models could explain the greater SLS scores in student-athletes than non-athlete students in the current study.

Perceived Stress Scale scores in this study were similar to values previously reported. Cohen et al. (1983) reported average PSS scores of 21.7±8.4 and 25.7±6.2 in groups of male and female college students, respectively. Similarly, PSS scores observed in this study for the combined sample (student-athletes and non-athlete students) were 20.4±7.8 and 24.3±7.1 for males and females, respectively. Both the current study and Cohen and colleagues reveal a sex difference in PSS scores. Although this difference did not reach statistical significance in either study, the present study reported a near-significant difference ($P = 0.08$) and a previous study has reported a statistically significant sex difference ($P < 0.01$; Hall et al. 2006). These observations demonstrate that females tend to self-report greater levels of perceived stress than males.

Neither PSS nor SLS correlated significantly with HCC, which did not support the second hypothesis of this study. Although it seems logical that perceived stress would relate to HPA axis activation and lead to increased HCC, other studies have also failed to

identify a significant correlation between HCC and perceived stress. Gerber and colleagues (2013) measured perceived stress using PSS and found no correlation with hair cortisol concentration. Additionally, Karlén and colleagues (2011) measured HCC and PSS and found a statistically significant, yet practically meaningless correlation between the two variables (r = -0.016, P = 0.025). Although perceptions of stress play a role in HPA axis activation, PSS is not a primary determinant of chronic stress, as measured by hair cortisol concentration.

Sleep Quality

It was hypothesized that sleep quality would be lower and daytime sleepiness would be greater in student-athletes compared to non-athlete students, however, no significant differences were observed between the two groups in survey measures of sleep quality and daytime sleepiness. Previous research has revealed that athletes experience sleep disruption and poor sleep quality before and during competitions (Lastella et al. 2014; Lastella et al. 2015). Further, Leeder and colleagues (2012) observed traits of poorer sleep quality, objectively assessed using wrist-worn actigraphy, in a group of Olympic athletes compared to a non-athlete control group. In contrast, another body of literature reports beneficial effects of exercise on sleep quality. In a literature review summarizing the influence of exercise on sleep quality, Shapiro (1981) revealed that exercise intensity is positively associated with feelings of tiredness, short wave sleep, and sleep duration and negatively associated with sleep latency. This summary of findings suggests that student-athletes could potentially experience improved sleep quality compared to their non-athlete counterparts.

Previous research investigating the sleep habits of college students reveals that college students typically have relatively poor sleep quality (Lee et al. 2013). In the present study, 52.2% of the non-athlete students were classified as poor sleepers according to the PSQI (score of greater than 5). The student-athlete group consisted of 33.3% poor sleepers. The prevalence of poor sleep quality in the student-athlete group was notable, but not as large as the prevalence observed in the non-athlete student group. Therefore, although collegiate student-athletes may potentially have poorer sleep quality than a typical adult, college students in general do not demonstrate sleep characteristics consistent with a healthy adult population.

Neither sleep quality nor daytime sleepiness correlated significantly with HCC, which did not support the second hypothesis of the study. Although there is convincing evidence that sleep quality impairs HPA axis function acutely, no study has investigated the relationship between sleep quality and chronic stress development (Leproult et al. 1997; Van Reeth et al. 2000). The current study does not support the assertion that perceived sleep quality is an important determinant of total chronic stress.

Hair Cortisol Concentration

In the subsample of participants who provided a hair sample, the student-athletes had significantly greater hair cortisol concentration than the non-athlete students (8.0±7.7 compared to 3.5±2.2 pg/mg, $P = 0.03$). Upon further observation, this significant difference was primarily established by three student-athletes with exceptionally high HCC values (17.9, 18.4, and 24.3 pg/mg). These values are all more than double the next highest value (8.0 pg/mg). Although no generalizations can be made about causes of high

HCC based on these three participants, observing a few characteristics of these individuals may provide clues for future research. First, two of the three individuals were distance runners. In fact, they were the only two endurance athletes who provided hair samples. Because it has been previously reported that endurance athletes had greater HCC than a control group, further investigation is necessary to better understand the effect of this type of training on HCC in collegiate endurance athletes. Additionally, all three individuals with high HCC were classified as good sleepers by the PSQI; thus, poor sleep quality was not likely a contributor to chronic stress development in these athletes.

Another interesting observation can be made by examining the relationship between HCC and BF. A significant correlation was found between BF and HCC in the student-athlete group only, indicating that student-athletes with a lower body fat percentage tended to have greater HCC (r = -0.59, P = 0.045; see Figure 3.2). The negative relationship between BF and HCC was primarily established by the three student-athletes with exceptionally high HCC values. All three of these individuals had a below-average body fat percentage when compared with other student-athletes of their sex. The two female student-athletes had 19.1 and 16.2% body fat compared to an average body fat of 21.1% observed among female student-athletes in this study. The male student-athlete had 9.8% body fat compared to the average body fat of 12.4% observed in all male athletes in this study.

The negative relationship between BF and HCC is not surprising when previous literature is examined. Schorr and colleagues (2015) investigated the relationship between body mass index (BMI) and HPA axis activation, assessed using repeated

salivary cortisol measures as a biomarker. They observed a U-shaped relationship between cortisol and BMI, meaning that hypercortisolemia was present in both underweight and severely overweight individuals. The increases in cortisol observed in underweight individuals is potentially responsible for the relationship between low body fat and increased risk of bone fracture, menstrual dysfunction, and low bone mineral density observed in athletes (Yard and Comstock 2011; Thralls et al. 2016). Our findings, in the context of previous literature, indicate that low body fat may be an important predictor of chronic stress. However, further research involving a larger sample size is necessary to confirm the negative correlation between BF and HCC in collegiate student-athletes.

Conclusions

The collegiate student-athletes reported a greater average weekly training volume and training load than their non-athlete counterparts, while no significant differences were detected between the two groups in measures of psychological stress or sleep quality. A significant different was observed between student-athletes and non-athlete students in chronic stress, as indicated by HCC. However, this difference was the result of three student-athletes with exceptionally high HCC. All three of these student-athletes had low BF when compared to other student-athletes of their sex, resulting in a statistically significant negative relationship between BF and HCC. Further research with a larger sample size is necessary to elucidate primary causes of high HCC in some student-athletes.

CHAPTER FOUR

CONCLUSIONS

Collegiate student-athletes are a unique group of individuals who experience a vast array of cognitive and physiological stressors. Unmanaged chronic stress increases risk of negative health outcomes, which may diminish athletic, academic, and social performance in this population. A better understanding of the psychophysiological factors that influence chronic stress development in student-athletes is necessary for effective monitoring and prevention of chronic stress. Thus, the purposes of the present study were, first, to assess differences in psychophysiological stressors between student-athletes and non-athlete students, and second, to identify significant correlates of objectively assessed chronic stress in the combined sample of athletes and non-athletes.

The present study revealed that student-athletes had significantly greater physiological stress due to training than non-athlete students. Both training volume and training load, calculated using self-report training log data, were significantly greater among the student-athletes. Survey measures of psychological stress and sleep quality, however, were not significantly different between the two groups, suggesting that student-athletes do not experience significant increases in perceived stress or detriments in sleep quality compared to their non-athlete peers. Despite the lack of differences in perceived stress, student-athletes did have a significantly greater hair cortisol concentration than non-athlete students. The observed difference in mean hair cortisol concentration resulted from three student-athletes with notably higher values. Of these

three athletes, two were distance runners and all three had low body fat compared to other student-athletes of the same sex. Low body fat in these individuals led to a significant negative relationship between body fat and hair cortisol concentration in the student-athlete group.

In order to make generalizations regarding student-athletes and determinants of chronic stress, further research is necessary. First, future studies should involve a larger sample size for hair cortisol concentration analysis to enhance statistical power and generalizability of results. Second, the mechanisms of chronic stress development should be analyzed separately for different types of athletes. Collegiate student-athletes involved in an endurance sports, as well as other sports where low body fat is considered advantageous, may be of particular interest, given the potential relationship between low body fat and high hair cortisol. Lastly, future research should incorporate objective measures of vigorous physical activity to more effectively evaluate the role of physiological stress in chronic stress development in collegiate student-athletes.

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APPENDICES

APPENDIX A

SUBJECT CONSENT FORM

SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH

MONTANA STATE UNIVERSITY – BOZEMAN

Title of Project:	**Evaluating Determinants of Psychophysiological Stress in Collegiate Student-Athletes**
Source of Funding:	Movement Science / Human Performance Lab – MSU, Bozeman
Project Director:	Jennifer Terry, Master's Candidate Department of Health and Human Development Movement Science / Human Performance Laboratory Phone: (503)-415-1814; E-mail: jwheeler312@gmail.com
Lab Director:	Dan Heil, PhD FACSM, Professor – Exercise Physiology Phone: 406-994-6324; E-mail: dheil@montana.edu
Research Assistants:	Cecile Zhu, Lina Hultin, Kim Pribanic HHD Graduate Students in Exercise Physiology

Study Background:

Stress is commonly defined as anything that causes our bodies to prepare for an emergency response, such as getting nervous before taking a test, or getting ready to perform exercise. Short-term exposure to a stressor (i.e., something that causes a stress response by the body) can cause many positive effects that are intended to help the body respond to the stressor. For example, the physical adaptations from planned physical training are good examples of positive responses to a physical stressor (i.e., training). Long-term exposure to stressors, however, has been linked to an increased risk for a variety of poor health conditions such as diabetes and heart attacks, as well as increased rates and severity of sickness and injury. Thus, people who are more likely to experience unmanaged long-term stress are also more likely to experience long-term negative health outcomes.

College students may be especially susceptible to the influence of long-term stress because of the relatively unique combination of mental stressors (financial, social, and academic) and limited stress management skills (e.g., sleep quantity and quality; less developed social network). College student-athletes face the additional mental and physical stressors associated with their athletic participation (i.e., training, competing, coaching staff interactions). The combination of these mental and physical stressors presents unique challenges for the student-athletes, as well as their coaches and school administrators.

Purpose of this Study:
The present study is designed to compare self-report measures of mental and physical stressors between a group of collegiate student-athletes and a group of non-athlete students. In addition, the study will evaluate how mental and physical stressors contribute to overall chronic stress. Your participation in this study does not require you to change anything about your daily activities, your training, or your nighttime sleeping routine. In order to determine your level of chronic stress, a small hair sample will be obtained for laboratory analysis.

General Procedures for Testing:
There is no cost to you (the participant) and participation in this research project is completely voluntary. Study participants are presented with this *Informed Consent Document* to explain the purpose of this testing, as well as the expected risks and benefits associated with participation in this study. At the time of entry into the study, all study participants should be undergraduate students at MSU enrolled in the Spring 2016 semester. The student-athlete group should consist of individuals currently training with the MSU track and field or basketball teams.

If you agree to participate, you will be asked to complete a series of surveys on two separate occasions and give one or two hair samples. Data collection will take place over 4 weeks in the Spring 2016 semester.

Sleep and Stress Monitoring:
To begin your study participation, you will meet with investigators at the MSU Movement Science Teaching Lab (MSTL) in Romney 203. During this initial visit, you will complete the Informed Consent Document and an on-line questionnaire using a Survey Monkey link that you will receive via email. The questionnaire is a collection of standardized surveys from the research literature that will take approximately 15-20 minutes to complete. The surveys include:

Sleep Quality Index – This determines your nighttime sleep quality.

Perceived Stress Scale – This measures the degree to which you assess life events as stressful.
Sleepiness Scale – This measures your general level of daytime sleepiness and/or wakefulness.
Undergraduate Stress Questionnaire – This is a "life events checklist" that measures stress specific to undergraduate students.
Satisfaction with Life Scale – This measures your general sense of well-being.

In addition, you will be asked to keep a **Daily Training Log** using an Excel-based template (which we will provide) that allows you to record the types and amounts of training that you did over a 7-day period. You simply need to fill in the blanks for each workout on each of the 7 days. You will complete a training log during 4 consecutive weeks during the study. Instructions for completing the Daily Training Log will be provided during your first visit to the MSTL. This will be used to determine your *physical stress*.

You will also be asked to fill out the Survey Monkey questionnaire a second time when you return to the MSTL 4 weeks after the initial visit.

Hair Cortisol Testing:
In order to measure chronic stress, you will need to provide a hair sample for analysis. To collect the hair sample, a member of the research team will cut a small sample of hair from the base of your scalp on the back of your head. When hairs from the sample are laid out flat side-by-side, the sample will measure 1 cm x 1 cm (or 3/8 in x 3/8 in). To help make certain that you are comfortable with providing a hair sample, we will show you an example of a hair sample before you provide your own hair sample. Hair samples will be collected for cortisol testing during your second visit to the MSTL. For this reason, in order to participate in the study, your hair must not be dyed, treated (i.e., permed or chemically straightened), or contain hair products (i.e., hair should be rinsed but not washed or treated with any hair products). Additionally, participants with "buzz" cuts or shaved heads will not be able to participate in the study because of not being able to provide an adequate hair sample. Finally, a small number of participants will be randomly selected to provide a second hair sample on this same occasion so that we can assess the consistency of the cortisol measuring process.

Body Fat Testing:
As a way of characterizing the participants in this study, the research team will measure your body fat using bioelectrical impedance during your initial visit to the MSTL. You will be asked to step onto the platform of the body fat analyzer and grab hold of two electrodes on a hand rail. In order to measure your body fat, the analyzer sends a low frequency current through the body. This process takes approximately 20 seconds and does not require the removal of any clothes except for shoes and socks (i.e., bare feet only on the measuring platform).

POTENTIAL RISKS:
The risks associated with the sleep and stress monitoring are relatively minimal and limited to your own comfort level with answering questions about your own sleep quality and sources of daily stress.

PARTICIPANT COMPENSATION:
In exchange for your participation in this study, you will receive a $10 gift card for each hair sample given. Gift cards will be given at the time of the hair cortisol sampling (during the second MSTL visit). In addition, you may request copies of the study findings as they become available in the form of research abstracts submitted to conferences, or published manuscripts.

BENEFITS:
The results of the body fat analysis can be provided to you if you choose. The measures you will receive include body fat, body water, and muscle mass.

CONFIDENTIALITY:
The data and personal information obtained from this project will be regarded as privileged and confidential. Your test results will not be released to anyone else except upon your written request/consent. Your right to privacy will be maintained in any ensuing analysis and/or presentation of the data by using coded identifications of each person's data.

FREEDOM OF CONSENT:
You may withdraw consent for participation in writing, by telephone, in person, or during any test session, without prejudice or loss of benefits (as described above). Participation in this project is completely voluntary.

In the UNLIKELY event that your participation in the project results in physical injury to you, the Project Director will advise and assist you in receiving medical treatment. No compensation is available from Montana State University for injury, accidents, or expenses that may occur as a result of your participation in the project. Additionally, no compensation is available from Montana State University for injury, accidents, or expenses that may occur as a result of traveling to and from you appointments at the Movement Science / Human Performance Laboratory. Further information regarding medical treatment may be obtained by calling the Project Director, Jennifer Terry, at 503-415-1814. You are encouraged to express any questions, doubts, or concerns regarding this project. The Project and Assistant Directors will attempt to answer all questions to the best of their abilities prior to any testing. The Project and Assistant Directors fully intend to conduct the study with your best interest, safety, and comfort in mind. If you have additional questions about the rights of human subjects you can contact the Chair of the Institutional Review Board, Mark Quinn, at 406-994-4707 or mquinn@montana.edu.

SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY- BOZEMAN

STATEMENT OF AUTHORIZATION

I, *the participant*, have read the Informed Consent Document and understand the discomforts, inconvenience, risks, and benefits of this project. I, _____ *(print your name)*, agree to participate in the project described in the preceding pages. I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

Signed:_____ Age _____ Date_____

Signature of Participant

In addition, we would like to take photographs during some testing sessions for use in professional presentations at conferences. Photos will not be taken during all test sessions, or even for all volunteers, but rather a sample of volunteers who provide their consent. Please indicate below whether you give your permission for such photographs during testing.

Please *initial* one of the following:

☐ I give permission for photographs to be taken of me during this project with the understanding that these photographs may be used in professional presentations.

☐ I DO NOT give permission for photographs to be taken of me during this project.

Signed:_____ Date_____

Signature of Investigator

APPENDIX B

WEEKLY TRAINING LOG AND REFERENCE DOCUMENTS

Figure A.1. Sample weekly training log used by all participants.

Participant Name	???	Study ID#	???	Name of Study	Evaluating Determinants of Psychophysiological Stress in Collegiate Student-Athletes

Week #1			2/26/16				
Day of Week	Activity	Type of Training	START Time	STOP Time	Duration (min)	Session RPE (1-10)	Comments about your daily workouts…
Friday							
Saturday							
Sunday							
Monday							
Tuesday							
Wednesday							
Thursday							

Table A.1. Descriptions of all training log components, provided to participants as a reference to assist in completing their weekly training logs

Training Log Component	Description of Training Log Component
Day of Week	Each row corresponds to information for a single workout.
Type of Activity	The type of activity you performed during this workout - e.g., Running, rollerskiing, cycling, hiking, swimming, resistance training, flexibility training, pilates class, yard work etc.
Type of Training	With the cursor in cell, use the pull-down menu to access the following options: Long Distance, Threshold Training, Interval Training, Speed Training, Mixed Endurance, and Resistance Training . If hand-recording, choose one of these types of training and write it in. * **Long Distance** - Typically a lower intensity endurance session that is at least 60 minutes in duration. Zone 1. * **Threshold Training** -Otherwise known as "lactate threshold". A purposeful workout that is comfortably hard for a set duration of time (i.e. 20-50 minutes). Zone 2. * **Interval Training** - A workout that incorporates sets of time intervals at harder work rates. For example, 1 minute hard, 2 minutes easy recovery, for a set number or duration of time. Overall rating for this should be Zone 2 when factoring in the easy recovery bouts. * **Speed Training** - Very short, very hard exercise bouts. Can be incorporated in the middle of a workout, or alone. Hard speed bouts typically last between 30 seconds to 3-5 minutes. Zone 3. * **Mixed Endurance** - Could be a longer workout with some type of harder intensity mixed in, sometimes in an unstructured fashion. Fartleks would be a good example of this. Zone 2. * **Resistance Training** - Weight or strength training. This is always Zone 3. * **Other** - activity of daily life that is higher than resting energy expenditure (i.e. lawn mowing, pilates, yoga, etc.) Specify activity. Zone 1. * **LI Recovery (Low-intensity recovery) - light a** erobic exercise that is designed to act as "active recovery". Zone 1.
START Time	The approximate clock time when you started your workout (e.g., 10:00 AM).
STOP Time	The approximate clock time when your workout ended (e.g., 12:00 PM).
Total Duration	Total time (in minutes) between the START and STOP times (e.g., from 10:00 AM to 12:00 PM gives 2 hrs, or 120 mins).
Session RPE	This is your perception of the average intensity of the entire workout using the 10-point scale in the RPE Chart tab.
Training Zones (0 to 3)	Zone 0 - Easy Zone. Zone 1 - Comfortable to Comfortably-Hard Zone. You are able to talk some. Zone 2 - High Intensity Zone. You are at a race pace zone, going as hard as you can maintain for the intended duration Zone 3 - Very High Intensity Zone. Above race pace at the most maximal effort you can possibly perform.

Table A.2. Rating of Perceived Exertion (RPE) scale provided to participants as a reference for completing the accomanying training log.

RPE Scale	Intensity Description	Detailed Intensity Description/Examples	RPE-ZONE EQUIVALENTS
0	Resting	Sitting or standing quietly at rest; not moving.	RPE 0 represents Zone 0
1	Very Easy	RPE of 0.5 to 2.5 represent light intensity activities (flexibility exercises; pilates or yoga class) and many activities of daily living (walking the dog; mowing the lawn with push mower). These activities often last less than 1 hour.	RPE 1-4 represents **Zone 1**
2	Easy		
3	Moderate	RPE of 3.0 to 4.0 represents most "base training" activities that are performed for 1+ hours as training	
4	Somewhat Hard		
5	Hard	An exercise intensity in which talking becomes difficult, such as during a Race pace for a longer race such as a 32k ski race	RPE 5-6 represents **Zone 2**
6			
7	Very Hard	RPE of 7 to 9 represent interval intensities lasting less than 2-3 minutes each; Very fatiguing.	RPE 7-10 represents **Zone 3**
8	Very, Very Hard		
9	Nearly Maximal		
10	Maximal	Resistance training; Weight training;	

APPENDIX C

SURVEY BATTERY ASSESSING PSYCHOLOGICAL STRESS AND SLEEP QUALITY

2016 MSU Undergraduate Student Stress Study

1. Survey Information

You have volunteered for the research study at MSU titled "*Evaluating Determinants of Psychophysiological Stress in NCAA Collegiate Student-Athletes*".

A part of this study is to answer questions from several standardized surveys about nighttime sleep quality, daytime sleepiness, and sources of daily stress.

These questions should take no more than *15-20 minutes* to complete.

As with all of the data collected about you for this study, the answers that you provide to these questions are considered privileged and confidential.

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2. **Pittsburgh Sleep Quality Index (PSQI)**

The PSQI by Buysse et al. (1989) is a short set of questions that asks you about things that influence how well you sleep at night.

* 1. What is your study ID number (NOT your MSU student ID)? Your study ID should be 2-3 letters followed by a number from 01 to 50, such as AF44.

If you do not know it, please contact the Project Director (Jenny Terry; jwheeler312@gmail.com) for assistance.

* 2. During the past month, what time have you usually gone to bed?

This is the time that you are in bed, with the lights out, and have the intention of falling asleep. We are looking for the best "average" time, or the most common time, that occurred over the past 2 weeks. For example, if you usually go to be at 10:15 PM, then type "10" for hh, "15" for mm, and then select the "pm" option.

	hh	mm	AM/PM
Time?		:	-

* 3. During the past month, how long (in minutes) does it usually take for you to fall asleep after getting into bed? For example, if it typically takes about 15 minutes to fall asleep, then type the number "15" into the blank.

* 4. During the past month, what is the most typical time that you get out of bed in the morning? Again, provide the best "average" time.

	hh	mm	AM/PM
Time?		:	-

* 5. 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 spend in bed, so please consider your answer carefully. Provide your best guess as an "average" number of hours for the entire period in question AND round your answer to the nearest 15 mins.

For example, if a typical night of sleep is 8 hrs and 15 mins, then type "8.25" as your answer; 8 hrs and 30 mins would be "8.5"; 8 hrs and 45 mins would be "8.75"; 8 hrs exactly would be "8.0".

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3. **Pittsburgh Sleep Quality Index (PSQI) - *continued...***

This is the last set of PSQI questions.

* 6. 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	3 or more times a week
Cannot get to sleep within 30 mins	○	○	○	○
Wake up in the middle of the night or early morning	○	○	○	○
Have to get up to use the bathroom	○	○	○	○
Cannot breathe comfortably	○	○	○	○
Cough or snore loudly	○	○	○	○
Feel too cold	○	○	○	○
Feel too hot	○	○	○	○
Had bad dreams	○	○	○	○
Have pain	○	○	○	○
Other (see below)	○	○	○	○

Other - Use this space to clarify above response

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

- ○ Very Good
- ○ Fairly Good
- ○ Fairly Bad
- ○ Very Bad

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4. **Perceived Stress Scale (PSS)**

The PSS, originally developed by Cohen et al. (1983), was designed to measure the degree to which a person assesses situations as stressful. This is one of the most widely used surveys for measuring nonspecific perceived stress.

* 8. The questions in this survey ask you about your feelings and thoughts during the last 4 weeks. In each case, you are asked t indicate *how often* you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer each question quickly. that is, do not try to count up actual number of times you felt a particular way, but rather indicate the alternative that seems like a reasonable estimate.

	Never	Almost Never	Sometimes	Fairly Often	Very Often
In the last 4 weeks, how often have you been upset because of something that happened unexpectedly?	○	○	○	○	○
In the last 4 weeks, how often have you felt that you were unable to control the important things in your life?	○	○	○	○	○
In the last 4 weeks, how often have you felt nervous and "stressed"?	○	○	○	○	○
In the last 4 weeks, how often have you dealt successfully with irritating life hassles?	○	○	○	○	○
In the last 4 weeks, how often have you felt that you were effectively coping with important changes that were occurring in your life?	○	○	○	○	○
In the last 4 weeks, how often have you felt confident about your ability to handle your personal problems?	○	○	○	○	○

	Never	Almost Never	Sometimes	Fairly Often	Very Often
In the last 4 weeks, how often have you felt that things were going your way?	○	○	○	○	○
In the last 4 weeks, how often have you found that you could not cope with all the things that you had to do?	○	○	○	○	○
In the last 4 weeks, how often have you been able to control irritations in your life?	○	○	○	○	○
In the last 4 weeks, how often have you felt that you were on top of things?	○	○	○	○	○
In the last 4 weeks, how often have you been angered because of things that happened that were outside of your control?	○	○	○	○	○
In the last 4 weeks, how often have you found yourself thinking about things that you have to accomplish?	○	○	○	○	○
In the last 4 weeks, how often have you been able to control the way you spend your time?	○	○	○	○	○
In the last 4 weeks, how often have you felt difficulties were piling up so high that you could not overcome them?	○	○	○	○	○

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5. **Epworth Daytime Sleepiness Scale (ESS)**

The Epworth Sleepiness Scale (ESS), originally published by Johns (1991), is a commonly used survey for evaluating excessive daytime sleepiness. Thus, the following survey will help us determine your general level of daytime sleepiness.

* 9. During the past 4 weeks, how often have you taken medicine (prescribed or "over the counter") to help you sleep?

- ◯ Not during the past 4 weeks
- ◯ Less than once a week
- ◯ Once or twice a week
- ◯ 3 or more time a week

* 10. During the past 4 weeks, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

- ◯ Not during the past 4 weeks
- ◯ Less than once a week
- ◯ Once or twice a week
- ◯ 3 or more time a week

* 11. During the past 4 weeks, how much of a problem has it been for you to keep up enough enthusiasm to get things done during the day?

- ◯ No problem at all
- ◯ Only a very slight problem
- ◯ Somewhat of a problem
- ◯ A very big problem

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6. **Epworth Daytime Sleepiness Scale (ESS) - *continued...***

These questions are a continuation of the ESS survey.

* 12. How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? This refers to your usual way of life during the past 4 weeks. Even if you have not experienced the situations listed recently, use your best judgement (i.e., an educated guess) to evaluate how each situation would have affected you. Check only one option for each situation.

Here is a list of situations...

	I would never doze	I would have a slight chance of dozing	I would have a moderate chance of dozing	I would have a high chance of dozing
1. Sitting and reading.	☐	☐	☐	☐
2. Watching TV.	☐	☐	☐	☐
3. Sitting, inactive in a public place (e.g., a theater, lecture or meeting).	☐	☐	☐	☐
4. As a passenger in a car for an hour without stopping.	☐	☐	☐	☐
5. Lying down to rest in the afternoon when circumstances permit.	☐	☐	☐	☐
6. Sitting and talking to someone during the day.	☐	☐	☐	☐
7. Sitting quietly after a lunch without alcohol.	☐	☐	☐	☐
8. Stopped for several minutes in traffic while driving a car.	☐	☐	☐	☐

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7. **Undergraduate Stress Questionnaire (USQ)**

The USQ by Crandall et al. (1992) is described as a "life events checklist" that is designed to measure stress specific to undergraduate college students. There are a total of 3 pages of questions for the entire USQ survey - Below is Page 1 of 3.

* 13. How stressful would this be if it had happened *to you*?

	Not stressful at all.	A little stressful.	Somewhat stressful.	Very stressful.
Had a lot of tests.	○	○	○	○
Victim of a crime.	○	○	○	○
Found out boy-/girlfriend cheated on you.	○	○	○	○
You have a hard upcoming week.	○	○	○	○
Death of a pet.	○	○	○	○
Had projects, research papers due.	○	○	○	○
Dependent on other people.	○	○	○	○
Got a traffic ticket.	○	○	○	○
Thoughts about the future.	○	○	○	○
Death of a family member or friend.	○	○	○	○
applying to graduate school.	○	○	○	○
Breaking up with boy-/girlfriend.	○	○	○	○
Property stolen.	○	○	○	○
Lost something (especially wallet)	○	○	○	○
Had an interview.	○	○	○	○
Parents getting divorce.	○	○	○	○
Car/bike broke down, flat tire, etc.	○	○	○	○
Coping with addictions.	○	○	○	○

	Not stressful at all.	A little stressful.	Somewhat stressful.	Very stressful.
It's finals week.	◯	◯	◯	◯
Assignments in all classes due the same day.	◯	◯	◯	◯
Lots of deadlines to meet.	◯	◯	◯	◯
Went into a test unprepared.	◯	◯	◯	◯
Did worse than expected on test.	◯	◯	◯	◯
Did badly on a test.	◯	◯	◯	◯
Having roommate conflicts.	◯	◯	◯	◯
Missed your period and waiting.	◯	◯	◯	◯
Had to ask for money.	◯	◯	◯	◯
Cannot understand your professor.	◯	◯	◯	◯
Stayed up late writing a paper.	◯	◯	◯	◯

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8. **Undergraduate Stress Questionnaire (USQ)**

Below is Page 2 of 3 for the USQ.

* 14. How stressful would this be if it had happened *to you*?

	Not stressful at all.	A little stressful.	Somewhat stressful.	Very stressful.
Dealt with incompetence at the Registrar's Office.	○	○	○	○
Sickness or injury.	○	○	○	○
Fought with boy-/girlfriend.	○	○	○	○
Bothered by having no social support of family.	○	○	○	○
Heard bad news.	○	○	○	○
Crammed for a test.	○	○	○	○
Feel isolated.	○	○	○	○
Noise disturbed you while trying to study.	○	○	○	○
Ran out of printing supplies while printing.	○	○	○	○
Trying to get into your major or college.	○	○	○	○
Someone you expected to call did not call.	○	○	○	○
Thought about unfinished work.	○	○	○	○
Had a class presentation.	○	○	○	○
Working while in school.	○	○	○	○
Performed poorly at a task.	○	○	○	○
Had confrontation with an authority figure.	○	○	○	○
Feel unorganized.	○	○	○	○
Parents controlling with money.	○	○	○	○

	Not stressful at all.	A little stressful.	Somewhat stressful.	Very stressful.
Someone borrowed something without permission.	○	○	○	○
Erratic schedule.	○	○	○	○
Registration for classes.	○	○	○	○
Lack of money.	○	○	○	○
No sleep.	○	○	○	○
Applying for a job.	○	○	○	○
Arguments, conflict of value with friends.	○	○	○	○
Cannot finish everything you needed to finish.	○	○	○	○
Maintaining a long-distance boy-/girlfriend.	○	○	○	○
Trying to decided on college major.	○	○	○	○
Could not find a parking place.	○	○	○	○

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9. Copy of page: **Undergraduate Stress Questionnaire (USQ)**

Below is Page 3 of 3 for the USQ.

* 15. How stressful would this be if it had happened *to you*?

	Not stressful at all.	A little stressful.	Somewhat stressful.	Very stressful.
Someone did a "pet peeve" of yours.	○	○	○	○
Bad haircut today.	○	○	○	○
Felt some peer pressure.	○	○	○	○
Problem getting home from bar when drunk.	○	○	○	○
Someone cut ahead of you in line.	○	○	○	○
Decision to have sex on your mind.	○	○	○	○
Exposed to upsetting TV show, book, or movie.	○	○	○	○
Sat through a boring class.	○	○	○	○
Someone broke a promise.	○	○	○	○
Living with boy-/girlfriend.	○	○	○	○
Job requirements changed.	○	○	○	○
You have a hangover.	○	○	○	○
Used a fake ID.	○	○	○	○
Checkbook did not balance.	○	○	○	○
Talked with a professor.	○	○	○	○
Arrived to class late.	○	○	○	○
Favorite sporting team lost.	○	○	○	○
Cannot concentrate.	○	○	○	○
Felt need for transportation.	○	○	○	○

	Not stressful at all.	A little stressful.	Somewhat stressful.	Very stressful.
No time to eat.	◯	◯	◯	◯
Problems with your computer.	◯	◯	◯	◯
No sex in awhile.	◯	◯	◯	◯
Visit from a relative and entertaining them.	◯	◯	◯	◯
You have a new healthcare provider (new doctor, dentist, etc.)	◯	◯	◯	◯
Holiday.	◯	◯	◯	◯

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10. **Satisfaction with Life Scale (i.e., Well-Being) (SLS)**

The questions below make up the Satisfaction with Life Scale (SLS), which is considered to be a valid indicator of a person's general sense of well-being. This survey was originally published by Diener et al (1985).

* 16. Below are 5 statements with which you may agree or disagree. Using the 1-7 scale shown below, indicate your agreement with each item by clicking on the corresponding bubble. Please be open and honest in your responding.

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree or Disagree	Slightly Agree	Agree	Strongly Agree
In most ways my life is close to my ideal.	◯	◯	◯	◯	◯	◯	◯
The conditions of my life are excellent.	◯	◯	◯	◯	◯	◯	◯
I am satisfied with life.	◯	◯	◯	◯	◯	◯	◯
So far, I have gotten the important things I want in life.	◯	◯	◯	◯	◯	◯	◯
If I could live my life over, I would change almost nothing.	◯	◯	◯	◯	◯	◯	◯

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11. Are you a collegiate student-athlete?

17. Are you an NCAA collegiate student-athlete?

- ◯ Yes
- ◯ No

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12. **Collegiate Student-Athlete Life Stress Scale (CSALSS)**

The next two pages lists 24 statements that describe something that may annoy, bother, or make you uncomfortable in your daily life as a college student-athlete. Read each one of the statements carefully and indicate how OFTEN you experience what is described by the statement within the past 4 weeks.

* 18. Below is the first 12 of 24 questions that make up the Student-Athlete Life Stress Scale. Consider each statement as it relates to your life during the past 4 weeks.

	Never, or Not Applicable	Rarely	Sometimes	Quite Often	Very Often	Always
1. I am annoyed by my injury because it has still not yet fully recovered.	○	○	○	○	○	○
2. I worry about my unstable competitive performances.	○	○	○	○	○	○
3. I am annoyed by my disappointing relationship with my coaches.	○	○	○	○	○	○
4. I am annoyed with the current training program.	○	○	○	○	○	○
5. I am bothered by my own poor social skills in handling interpersonal relationships.	○	○	○	○	○	○
6. I am annoyed with not finding time to encounter romantic partners.	○	○	○	○	○	○
7. I am annoyed by my parents' high expectations.	○	○	○	○	○	○
8. I am bothered by a lack of motivation for academic learning.	○	○	○	○	○	○
9. I worry about being frequently injured.	○	○	○	○	○	○
10. I worry about dragging my team down.	○	○	○	○	○	○
11. I am annoyed by my coaches' preference for some teammates.	○	○	○	○	○	○
12. I worry that my training is not beneficial to my performance.	○	○	○	○	○	○

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13. **Collegiate Student-Athlete Life Stress Scale (CSALSS) - *continued...***

This is the second of two pages with statements that describe something that may annoy, bother, or make you uncomfortable in your daily life as a college student-athlete. Read each one of the statements carefully and indicate how OFTEN you experience what is described by the statement within the past 4 weeks.

* 19. Below is the last 12 of 24 questions that make up the Student-Athlete Life Stress Scale. Consider each statement as it relates to your life during the past 4 weeks.

	Never, or Not Applicable	Rarely	Sometimes	Quite Often	Very Often	Always
13. I am annoyed with being friendless.	○	○	○	○	○	○
14. I am annoyed with being too shy to express myself when I encounter someone I love.	○	○	○	○	○	○
15. I am bothered by difficult situations in my family.	○	○	○	○	○	○
16. I am annoyed when preparing for exams.	○	○	○	○	○	○
17. I am bothered by the slow recovery of my current injury.	○	○	○	○	○	○
18. I am afraid of being eliminated from competition because of poor performance.	○	○	○	○	○	○
19. I am annoyed by my coaches' bias against me.	○	○	○	○	○	○
20. I am annoyed by my training load because it is too much for me.	○	○	○	○	○	○
21. I am annoyed by my social skills because it seems like nobody likes me.	○	○	○	○	○	○
22. I am annoyed with not getting along with my romantic partner.	○	○	○	○	○	○
23. I am annoyed with communicating with my family.	○	○	○	○	○	○
24. I worry about my academic skills because I do not know how to learn efficiently.	○	○	○	○	○	○

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14. Survey Completion & Exit

Congratulations, you have completed the survey!

Thank you again!