Perceptions of and Objective Measures of Gendered Stress in Construction

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Abstract

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Background: Women are an underrepresented group in the construction trades; as such, they experience high levels of gendered stressors such as sexual harassment and gender discrimination. While studies have characterized stress outcomes subjectively among this population, objective indicators and relevant coping mechanisms have yet to be evaluated.

Objectives: The primary aim of this research is to explore psychosocial exposures among men and women, and to evaluate whether biomarkers of stress are elevated in a) women, b) those with high perceived-stress, and c) those with specific work and non-work stressors. Furthermore, positive and negative coping mechanisms used to handle workplace stress were evaluated to determine how they may affect the relationship between exposure to gendered stressors and measured stress outcomes.

Methods: Twenty-two women, 17 men, and 1 individual who identified as non-binary from 3 construction trades in the Seattle area participated in this cross-sectional study. Each participant completed a questionnaire and provided a blood sample. The questionnaire data provided information about work-related psychosocial exposures, individual coping mechanisms, and subjective perceived stress scores. Serum from the blood samples were analyzed for the following chronic stress biomarkers: C-Reactive Protein (CRP), Epstein Barr Virus (EBV), Interleukin-6 (IL-6), and Dehydroepiandrosterone Sulfate (DHEAs).

Results: Perceived stress scores were significantly higher among women (6.05 ± 3.12) compared to their male counterparts (3.53 ± 2.85), and women also had significantly lower levels of log transformed

DHEAs measures, which is the expected chronic stress response (0.07 ug/mL ± 0.22 and 0.24 ug/mL± 0.15, respectively). However, this measure is also lower among women in general and older individuals, so results must be interpreted cautiously. Women also experienced greater proportions of work-related stressors, and three of these stressors (gender discrimination, sexual harassment, and heightened vigilance) were significantly associated with higher perceived stress scores among all participants after controlling for age and gender. Greater heightened vigilance was associated with higher changes of the inflammatory biomarker CRP (063%, CI: -0.8%, $1.7x10^{2}$%) among all participants after controlling for age and gender. Finally, women exercised significantly more than men, and this work-related stress coping mechanism was significantly associated with decreases in CRP and IL-6 measures (50%, CI: -67%, -29% and 30%, CI: -45%, -10% respectively).

Conclusions: These exploratory analyses demonstrated significant differences in the experience of psychosocial stressors and perceived stress between men and women in the pipe, sheet metal, and carpentry trades. Use of "heightened vigilance" as one of these stressors in the context of gender discrimination rather than racial discrimination is novel, and it is the first study to assess stress biomarkers among women in this industry. This study also lends insight into ways in which these women cope with work-related stress at an individual level; however, identifying organizational and industry changes necessary to prevent gender-specific, work-related psychosocial stressors is important for improving health and overcoming barriers to women's full participation in the construction industry.

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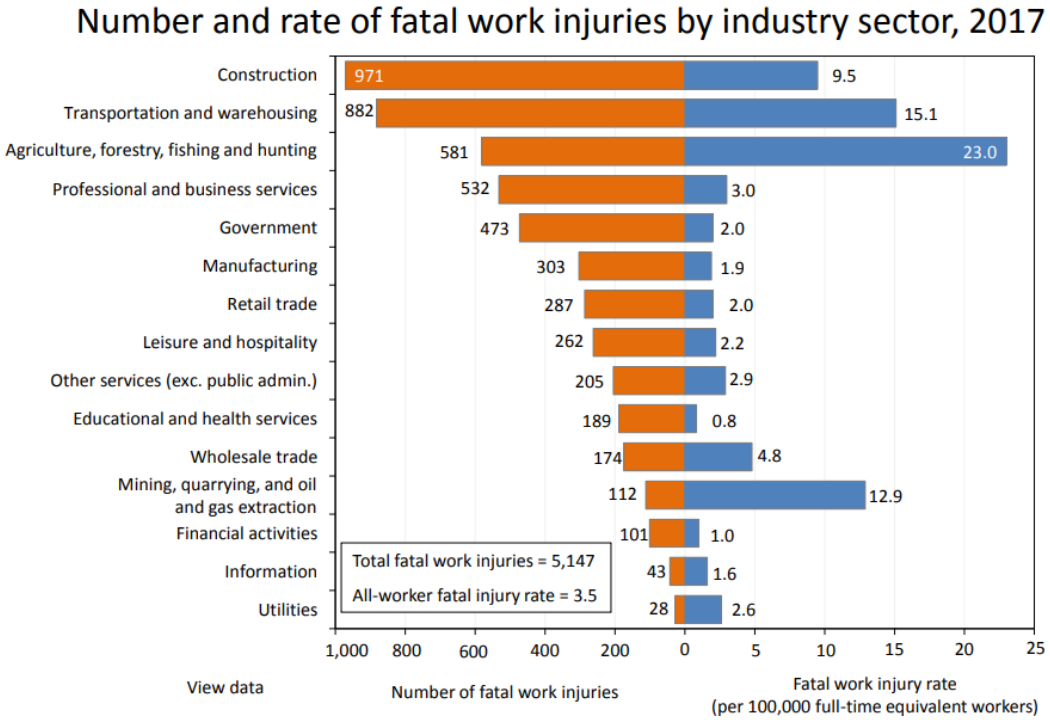
BACKGROUND

Hazards in the Construction Industry

Construction work is very hazardous in the United States. According to the Bureau of Labor Statistics (BLS), 971 employees in construction experienced fatal occupational injuries in 2017 (Figure 1); this count of fatalities is the highest among all listed occupations, and this industry sector has one of the top five fatal work injury rates (BLS, 2017a). The industry as a whole can be broken down into three subsectors, and these consist of: 1) the construction of buildings; 2) heavy and civil engineering construction; and 3) specialty trade contractors. Of these construction industry subgroups, the greatest proportion of the 971 fatal work injuries occurred among construction trades workers (BLS, 2017a; BLS, 2019). Trades workers are contractors who specialize in performing a specific component of work that is involved in both building and nonbuilding projects; their work can include activities such as painting, electrical work, carpentry, plumbing, heating, air-conditioning, roofing, and sheet-metal (OSHA, n.d.a). These activities can take place on site and in their own shops (BLS, 2019).

Figure 1. The number of fatalities and rate of fatal work industry by industry sector for 2017, Bureau of Labor Statistics



Source: B.L.S, Bureau of Labor Statistics. (2017) Census of Fatal Occupational Injury Charts. Retrieved from https://www.bls.gov/iif/oshwc/cfoi/cfch0016.pdf

The construction industry also poses a high risk for injury and illness among the workforce, which is reflected by the 194,300 nonfatal occupational injuries and 38,000 illnesses reported nationwide in 2017 (BLS, 2018a). The overall injury rate is 3.1 injuries per 100 construction workers as a whole, and injury rates differ for each of the trades in the industry (BLS, 2017). The injury rate among all specialty trade contractors in 2017 was 3.3 injuries per

100 workers, and the injury rates among specific trades included in this study, carpentry and sheet metal, were 2.3 and 4.8 injuries per 100 workers, respectively (BLS, 2018b). Pipe fitting is the third trade included in this study, and their injury rate ranged from 3.1 – 5.4 injuries per 100 workers due to being included as part of multiple North American Industry Classification System categories under the BLS (BLS, 2018b).

Four of the traditionally known hazards that result in fatalities and injuries in this industry and contribute to its hazardous nature are: falls, being struck by an object, being caught in or between objects, and electrocution (OSHA, n.d.b). However, due to the wide variety of operations that construction work involves, "…almost every occupational affliction has been recorded among construction workers," (Snashall, 2005).

While prevention of these hazards is extremely important due to their frequency of occurrence and potentially fatal endpoints, this workforce also faces prevalent psychosocial stressors such as poor work life balance and high job strain that negatively affect mental and physical health. Although few studies in the United States have assessed job stressors associated with construction work (Dembe et al. 2005; Alterman et al., 2013; Curtis et al., 2018), their results reflect stressors that have been identified in studies from other developed countries. In the 1990's, construction work was identified as the third most stressful job behind police work and mining in a comparative study of industries in England (Statt, 1994), and a more recent survey conducted among construction workers in the United Kingdom indicated that work-related stress in construction has become worse over time (Campbell, 2006). Common stressors contributing to these stress levels include: lack of feedback, poor communication, inadequate staffing, too much work, long work hours, ambitious deadlines, work pressure, and conflicting demands (Campbell, 2006; Sunindijo et al., 2017).

This study focuses on chronic, ongoing experiences of work-related stressors as opposed to episodic, or acute, stressor experiences among construction workers; however, both exposure scenarios have been associated with adverse mental and physical health outcomes such as hypertension and depression within and outside of this workforce (Peter et al., 1997; Hammen et al., 2009). Stressors such as lack of social support at work resulted in burnout and health complaints among male construction workers (Jansen et al., 2001). Greater levels of musculoskeletal disorders, injuries, and near misses were also related to stressors such as high job demands, low job control, poor job training, in this workforce (Goldenhar et al., 2003; Sobeih et al., 2006).

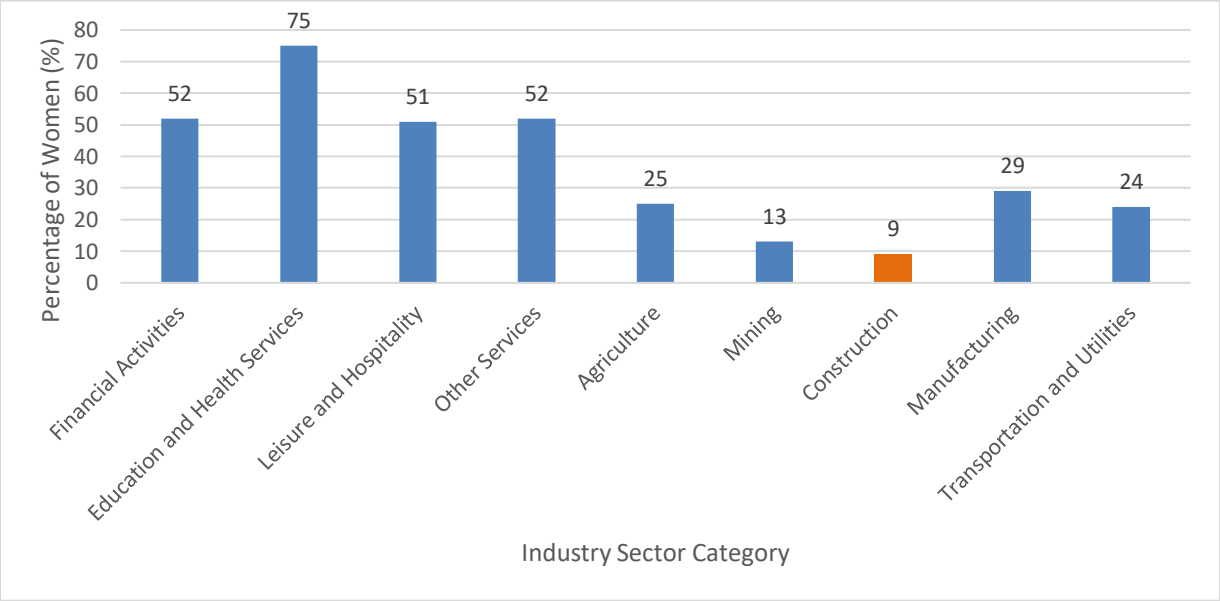
Another concerning outcome associated with experiencing work-related stressors is elevated perceived stress levels observed among multiple professions, including construction (Gershon et al., 2009; Curtis et al., 2018; Bowen et al., 2014). Higher measures of depression, anxiety, job burnout, fatigue, and injury have been associated with elevated perceived stress among students and professionals in the medical field and in athletic training (DeFreese et al.,

2016; Lebares et al., 2018; Kizhakkeveettil et al., 2017; Racic et al., 2017). On a more broad scale, research suggests that chronic stress can contribute to issues with drug addiction (Cleck et al., 2008), has been associated with worse memory impairments when experienced during older age (Sonia et al., 2009), and is a risk factor that contributes to the development of cardiovascular disease (Bairey et al., 2002).

Women in Construction

Although these psychosocial stressors are common among all trades workers, there are some that are more prevalent among underrepresented and vulnerable groups within the trades. Women in particular are one of these underrepresented groups; 9% of all workers in the construction industry are women, and only 3.4% of construction trades workers in the United States are women.[6] According to the BLS, the construction industry as a whole has the lowest proportion of women of any industry sector (See Figure 2) (BLS, 2017b). The U.S. Department of Labor classifies construction as a non-traditional occupation for women because the proportion of women in its workforce is less than 25% (U.S. DOL, n.d.).

Figure 2. Percentage of women by industry sector



Data retrieved from the B.L.S, Bureau of Labor Statistics. (2017b). Women in the labor force: a databook. Retrieved from https://www.bls.gov/opub/reports/womens-databook/2017/home.htm

A career in the construction industry offers many positive benefits for women. Women have reported high job satisfaction and autonomy performing this type of work (Moir et al., 2011). Furthermore, the industry's ability to offer a livable wage should aid in recruiting more women to address the current shortage and demand for skilled trade workers in the United States (Gross et al., 2018).

Unfortunately, many barriers to entry and retention exist for women pursuing a career in the trades. Studies have exposed underlying sexism faced by women working non-traditional jobs that contributes to these barriers. Those who are able to succeed in the industry face additional hurdles. Women are deemed less likeable and more hostile than men when successful in a male-dominated field, and a woman's violation of societal gender stereotypes contributes to these negative reactions (Heilman et al., 2004; Heilman et al., 2007). Research by Heilman et al. elaborates on this point by suggesting that, "…these women's perceived violation of feminine 'shoulds,' not their taking on of masculine 'should nots,' underlies and fuels the penalties these women incur from their success," (2007, pg. 91). Furthermore, women who ascribe to the masculine attributes associated with male dominated work face greater risk of harassment (Leskinen et al., 2015).

These negative perceptions of women in non-traditional jobs create gendered physical and psychosocial stressors faced by women in these work environments. The New York Committee for Occupational Safety and Health (NYCOSH, 2014) identified two major categories of stressors that act as barriers for women entering or staying in the trades, the first of which is workplace culture. NYCOSH's assessment of adverse components of workplace culture was based on interviews and focus groups conducted through the Chicago Women in Trades (CWIT) and the National Institute for Occupational Safety and Health (NIOSH) in 1996. The results indicated that hostile workplaces, sexual harassment, isolation, and job insecurity were the most prevalent negative components of workplace culture that made it hard for women to enter or stay in the workforce. One quote from a former welder who contributed to the CWIT study, illustrates the severe level of hostility that some of these tradeswomen faced: "I applied for an apprenticeship with the ironworkers. The men who were applying formed groups and sent someone from each group to talk to me. They threatened me. They said, 'You may get this job because of the government, but you won't leave it alive. We'll be on a site with you some day, and we'll take care of that,'" (OSHA, 1999).

The second major category of barriers is safety concerns for tradeswomen on worksites. The specific safety concerns addressed were: 1) ergonomic issues associated with lifting techniques and tools being tailored to men's bodies; 2) an increased risk of injury due to ill-fitting personal protective equipment not designed for women and often not available; 3) reproductive hazards for women who are pregnant associated with strenuous activity and extended periods of standing; and 4) a lack of access to adequate sanitary facilities, which can result in illnesses such as heat stress or kidney stones if they avoid drinking water or using the restroom (NYCOSH, 2014, p. 3).

Many studies explore the association between these hazards and adverse health outcomes among both women in trades and women working other non-traditional jobs. Data from three General Social Surveys, an instrument used to collect and evaluate data regarding societal attitudes and beliefs among the general population (GSS, 2016) showed that women's perceptions of workplace gender discrimination and sexual harassment were associated with

poor mental health and physical health (Harnois et al., 2018). These associations were not observed among men. Another hazard that is differentially prevalent in the workplace between men and women is violence against women; Cruz Rios et al. analyzed data from 2013 reports in the Census of Fatal Occupational Injuries (CFOI) database, and concluded that women were murdered twice as often as men in the workplace (2017). The latest CFOI data from 2017 reveals that 22% of fatal injury events for women in the workplace was attributable to homicides compared to 8% for men (BLS, 2017c).

These mental and physical health outcomes as well as the higher rate of fatalities among working women as a whole are concerning, and studies specific to the construction workforce have demonstrated similar adverse outcomes. Women in a recent study of welders and electricians reported higher levels of hazards such as harassment and bullying on the job than their male counterparts, and these were associated with higher levels of anxiety and depression (Cherry et al., 2018). Older research demonstrated positive associations between both overcompensation, which is the need to constantly prove oneself on the job, and job uncertainty with insomnia among the female construction workers who participated (Goldenhar et al., 1998). Also, harassment and discrimination were associated with increased nausea and headaches among this population (Goldenhar et al.,1998).

An additional study that adds to this body of literature was conducted by researchers at the University of Washington. The university collaborated with Washington Women in Trades, a nonprofit organization, and with the Washington State Labor Education and Research Center to conduct the "Safety and Health Empowerment for Women in Trades" (SHEWT) study. They aimed to develop a better understanding of hazards women face in the trades, using focus groups and surveys of psychosocial stressors faced by all construction workers in addition to gender specific stressors, both work and non-work. The main work-related stressor assessed was job strain, which is quantified by capturing the demands of one's work relative to the control one has over their job (Hicken et al. 2014). Discrimination, harassment, tokenism, poor work/life balance, isolation, and physical overcompensation were identified to be common gender-specific psychosocial stressors faced by tradeswomen (Curtis et al., 2018).

The study found that these psychosocial hazards were associated with both adverse physical and mental health outcomes among tradeswomen. Women reported greater levels of high perceived stress than men (Curtis et al., 2018, pg.12), and both bad work/life balance and age discrimination were associated with higher perceived stress scale scores among women. High social support was associated with lower levels of perceived stress among women. High physical overcompensation and gender discrimination were associated with higher numbers of injury among women (Curtis et al., 2018, pg. 16-17).

This study also made an important distinction between another subgroup within the trades that may be differentially affected by stress: career levels consisting of either being an apprentice or a journey-level worker (Curtis et al., 2018, page 13). According to the Washington

Department of Labor and Industries (WA L&I), "Apprenticeship is a combination of on-the-job training (OJT) and related classroom instruction under the supervision of a journey-level craft person or trade professional in which workers learn the practical and theoretical aspects of a highly skilled occupation," (n.d.). Journey-level workers are those who have completed their apprenticeship and are qualified to perform the trade work that they trained for without being under supervision (State of California, 2014). Apprentices reported that their work was high stress, meaning that they had high demands and low control over their work, compared to journey-level workers (Curtis et al., 2018, page 14). Women in this study were predominantly journey-level workers, which would suggest that stress associated with being an apprentice would discontinue; yet, focus group data suggests that women still continue to be treated like an apprentice well into their role as a journeywoman (Curtis et al., 2018, page 13). Therefore, they continue to experience stressors associated with being a woman and also those unique to starting in an apprenticeship.

All of these studies have relied on self-report and subjective measures of stress to evaluate the effects of experiencing psychosocial stressors and having high levels of perceived stress among tradeswomen. However, there is a gap in the literature concerning how objective measures of stress, which may manifest as a result of psychological stress, may play a role in understanding some of the mechanisms connecting stressors and high levels of perceived stress with adverse health outcomes, in addition to how they contribute independently to other adverse effects.

Subjective and Objective measures of stress

Experiencing psychosocial stressors can result in both perceived stress and physiologic stress responses that are activated by the brain. Upon processing a stressor, the brain activates two systems: the autonomic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis (Tsigos et al., 2016; Rotenberg et al., 2016). The autonomic nervous system can be further broken down into the sympathetic (SNS) and parasympathetic nervous systems (PSNS). The SNS is often referred to the body's "fight or flight" response to a stressful situation; quick physiological changes are meant to help someone escape an acutely dangerous situation (Porges, 2007; Gilbey et al., 1993). The HPA axis is a hormone response system that secretes glucocorticoids from the adrenal cortex, which helps to bring the body back to homeostasis after a stress response (Stephens et al., 2012). Additionally, the cardiovascular, metabolic, and immune systems work to protect the body during stressful experiences (Flier et al., 1998).

Temporary physiological responses to stressors and stress, known as allostasis, can be beneficial for handling a stressful situation as it allows an individual to better respond to the environment in the event of a stressor (Flier et al., 1998). However, when these responses are experienced chronically, the constant challenge to adapt causes wear and tear on the body, which is referred to as allostatic load (Sterling et al., 1988). Allostatic load is often caused in one of the following kinds of situations: 1) frequent stress; 2) lacking the ability to adapt to a frequent

stressor; 3) inability of stress response to discontinue when the stressor is gone; and 4) other physiological system triggers to compensate for inadequate allostatic response (Flier et al., 1998).

Researchers have used a variety of stress biomarkers and other anthropometric factors to quantify a value for allostatic load, and as standalone measures of response to stressors and perceived stress (Duong et al., 2017; Juster et al., 2010). For example, C-Reactive protein (CRP) and Interleukin-6 (IL-6) are markers of inflammation that are often used in population-based studies of stress (Van Dyke et al., 2017; Fuller-Rowell et al., 2015; Dowd et al., 2006). IL-6 concentrations have been found to increase in response to chronic stress (Kiecolt-Glaster et al., 2003) and in stressful situations such as caring for relatives with Alzheimer's disease (Von Kanel, 2006). Elevated IL-6 concentrations have also been associated with low socioeconomic status (SES) (Gimeno et al., 2007; Koster et al., 2006). Higher levels indicate greater inflammatory activity in the body (Rohleder et al., 2012).

While IL-6 is a cytokine that stimulates CRP response, research has demonstrated that CRP levels are higher among individuals experiencing greater amounts of perceived stress (Gurung et al., 2018; Gouin et al., 2012). Elevated levels of CRP have been associated with job burnout among women and people with low SES (Gurung et al., 2018; Toker et al., 2005; Van Dyke et al., 2017). Higher levels of inflammation have been associated with adverse effects for cardiovascular health (Hanson et al., 2019; Pahwa et al., 2018). While these inflammatory biomarkers can increase in response to stress, they also increase naturally with aging (Hänsel, 2010), are correlated with a higher body mass index (BMI) (Khaodhiar et al., 2004), and can be elevated if there are sites of inflammation or infection in the body (Sproston, 2004, Haran et al., 2012). Higher measures of IL-6 have also been associated with disordered sleep (Rohleder et al., 2012). Conversely, use of medications such as NSAIDs are associated with lower levels of CRP and IL-6 (Yan et al., 2018).

Biomarkers from the immune system are also often used to measure stress. Epstein-Barr virus (EBV) is a herpesvirus that remains dormant in the body subsequent to contracting the virus, and it can reactivate in response to psychological stress (Glaser et al., 1991). EBV infects at least 95% of the population, and infection typically occurs during infancy or childhood (Cohen, 2009). Individuals with high EBV antibody levels are considered to have poorer immune function (Dowd et al., 2011), and higher EBV measures have been associated with psychosocial stress (Borders et al., 2010). EBV has also been shown to reactivate as an individual's immune system ages (Stowe et al., 2007).

Finally, DHEAs is a sex hormone that is produced as part of a protective and regenerative role in HPA axis stress response (Nguyen et al., 2008). While many studies postulate that DHEAs levels are lower among individuals with greater psychological stress (Lennartsson et al., 2013; Walker et al., 2017), conflicting research indicates that these measures may increase with greater psychological stress (Lac et al., 2012; Maninger et al., 2010). However, these increases

may be associated with acute stress while lower levels are associated with chronic stress responses (Lennartsson, A.K., 2013). While research has established that DHEAs levels are known to decrease in the event of acute psychosocial stress (Lennartsson et al., 2012; Izawa et al., 2008), according to Lennartsson et al., less is known about the true response and mechanism associated with DHEAs levels decrease during chronic, long-term stress (2013). Lennartsson et al. postulates that levels may decrease during chronic stress as part of one's "fight or flight" response; the body may not prioritize production of this hormone in favor of preparing to contend with a stressor (2013). Furthermore, DHEAs is naturally lower among women than men and lower among older individuals (Lennartsson et al., 2015). Low levels influence the immune and inflammatory systems, and they have been associated with aging, heart disease, and other inflammatory conditions (Lennartson et al., 2013; Stárka et al., 2015).

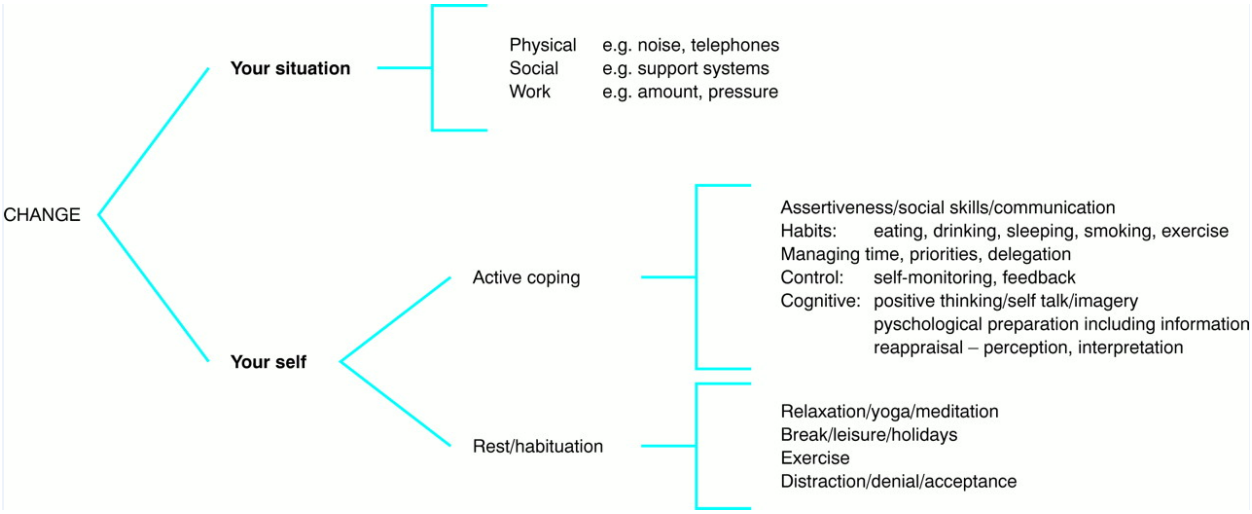
To date, no studies have included female construction workers in the evaluation of objective measures of stress biomarkers. In one study, male construction workers exhibited higher salivary cortisol excretion as compared to white collar workers (Hansen et al., 2006) In other occupational settings, both qualitative data and biomarker data have been associated with stressors between women and men (Krajnak, 2014; Siegrist et al., 2017). However, the contributions of gender and specific psychosocial stressors in construction on objective measures of stress have not been examined.

Coping Mechanisms and Individual Factors

When evaluating subjective and objective measures of stress, it is important to understand factors that reduce these endpoints given their association with adverse health outcomes. Stress management is particularly important to understand among women in construction given their low level of retention after entering the trades. Moreover, if a woman decides to remain in the trades despite facing overall and gender specific psychosocial stressors posed by this work environment, understanding the different coping mechanisms that are implemented may inform mediators or confounders in the relationship between stressors, perceived stress, and biomarkers of stress.

Coping strategies can take place at an organizational level and/or individual level, as outlined in Figure 3. Changes can be made at an organizational level to the physical environment, social support network, and aspects of work such as the amount of work or deadlines to mitigate sources of stress, while individual-level stress management involves active coping, rest, and habituation (Michie, 2002). Many studies have demonstrated ameliorating effects of strategies such as self-care promotion, engagement or disengagement strategies, physical activity, and yoga on both perceived stress and biomarkers of stress (MacLaughlin et al, 2011; Wadsworth, 2015; Sladek et al., 2016; Tsatsoulis et al., 2006; Fedewa et al., 2017).

Figure 3. Individual Forms of Stress Management



Source: Michie S, CAUSES AND MANAGEMENT OF STRESS AT WORK, *Occupational and Environmental Medicine* 2002;**59:**67-72.

Although construction workers face high levels of job stress, as previously discussed, coping mechanisms for stress have been rarely studied among construction workers in developed countries. Coping mechanisms seem to be studied more commonly among medical personnel or police officers (O'Dowd et al., 2018; Lark et al., 2018). Furthermore, the limited research involving this industry suggests that maladaptive coping mechanisms are implemented among this workforce. A study conducted by Langdon et al. discovered through survey data that construction workers in Australia who implemented coping mechanisms such as acceptance, blame, and disengagement had higher levels of psychological distress (2018). Negative coping mechanisms that do not directly deal with the problem can exacerbate it, which is demonstrated in situations faced by the general public and in work-related scenarios (Suzuki et al., 2019; Li et al., 2017).

Despite the limited research evaluating stress coping mechanisms among construction workers specifically, a study evaluating a sample of the U.S. population suggests that there are gender differences in the implementation of these coping mechanisms. According to the American Psychological Association's "Stress in America" survey, women in the United States report higher levels of stress and manage stress differently compared to men (APA, 2011, pg. 21). Women placed greater emphasis on the importance of stress management; 68% of women believed that managing stress is very or extremely important as compared to 52% of men (APA, 2011, pg. 22). Furthermore, greater proportions of women reported that stress was impactful on physical and mental health than their male counterparts, and 70% of women reported trying to reduce their stress in the past five years, compared to just half of men (APA, 2011, pg. 23).

Resilience is another factor that may contribute to inter-individual differences in stress outcomes. Higher resilience, which can be characterized by traits such as hardiness, can attenuate

the effects of stressors on perceived stress and other mental health outcomes (Reknes et al., 2018). Qualities associated with hardiness that contribute to these effects are having a strong commitment to self, putting energy and strength toward factors in their environment, having a sense of meaningfulness, and feeling like they have control within themselves (Kobassa, 1979). When evaluating stress biomarkers, resilience has been defined as how quickly one's physiological systems return to baseline after experiencing a stressor (Bairey et al., 2002). Resilience in this capacity can be measured through assessing changes from baseline of acute stress biomarkers after a specific amount of time following a stressor and can differ between people (Bairey et al., 2002).

Further evaluation of the coping mechanisms being implemented among this population is important for understanding how they may affect the objective stress measures. Effective coping mechanisms at the organizational level and individual level can also inform improvements within the industry to offer resources for stress management.

SPECIFIC AIMS

Based on the knowledge that: 1) women in the trades have been shown to experience high levels of psychosocial hazards, 2) experience of these kinds of stressors have resulted in objective measures of stress in general and working populations, and 3) these stress measures have been associated with adverse health outcomes, evaluating stressors and their association with objective stress measures among tradeswomen is important for improving their health and safety at work. Moreover, the number of inter-individual differences that affect stress outcomes make the combined assessment of subjective and objective measures of stress important for understanding the potential for health risks associated with these outcomes, particularly in an environment with many stressors.

In this study we aim to do the following:

Aim 1: Evaluate differences in stress between men and women using subjective and objective indicators of stress.

1A. Compare perceived stress and biomarkers of stress by gender.

1B. Examine the association between perceived stress measures and stress biomarker measures across the full sample.

Aim 2: Explore workers' sources of stress in relation to stress as measured by perceived stress and biomarkers.

2A. Compare differences in work and non-work related stressors by gender.

2B. Explore the association of work-related stressors and non-work related stressors with perceived stress.

2C. Assess psychosocial stressors that are significantly associated with perceived stress for their association with each of the stress biomarkers.

Aim 3: Determine differences in stress coping mechanisms between men and women.

3A. Evaluate self-reported coping mechanisms used to deal with work-related stress to determine those that are significantly different between gender groups.

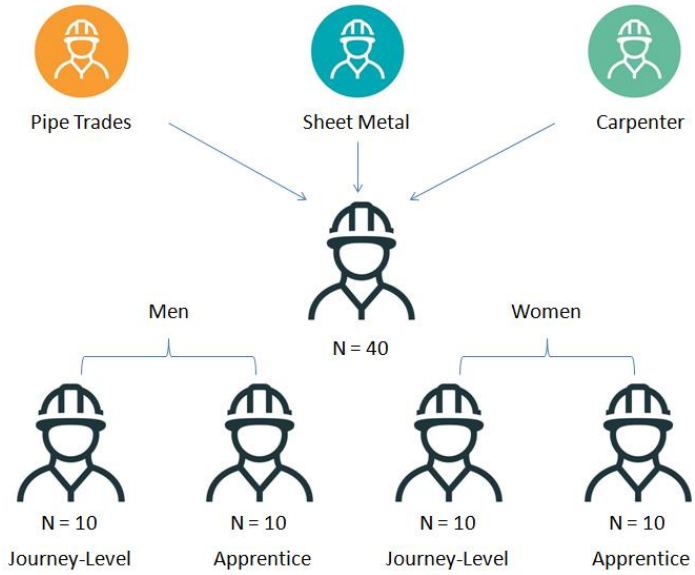
3B. Investigate associations between significantly different coping mechanisms and biomarkers of stress across the full sample.

METHODS

Participant Recruitment

Recruitment efforts were undertaken by the advisory committee for this project, which consisted of five constituents from the University of Washington and one representative from each of the carpentry, pipe, and sheet metal trades. Study information was included on materials that were disseminated among apprentices and journey-level workers during union meetings and apprenticeship events. The study aimed to recruit 20 men and 20 women from the Puget Sound region of Washington to participate, with half of each gender group comprising of apprentices and the other half journey-level workers (Figure 3). In light of being a pilot study, sample size was determined largely based on cost and accounting for enough participants to feasibly conduct exploratory analyses given our exposures and outcomes of interest.

Figure 3. Illustration of recruitment goals



Design and Protocol

Participants consented to being part of this cross-sectional study prior to completing data collection that was approved by the University of Washington's Institutional Review Board (IRB). After obtaining informed consent, participants completed the following data collection procedures during one of four sample collection days: 1) questionnaires administered in the form of in-person interviews 2) provided a blood sample that was collected by a certified phlebotomist; and 3) anthropometric measures, height and weight. Participants each received a $50 gift card for their participation.

Questionnaire Data

Questionnaire data was collected through in-person interviews led by trained researchers who recorded each participant's answers through an online survey platform called RedCap. The questionnaire data provided information regarding perceived stress, work stressors, non-work stressors, demographic information, and other health outcomes of interest. All survey items were presented in English and the questions were based on previously-validated scales that were pilot tested with a subset of representative workers.

Demographic Information

Participant sociodemographic characteristics such as gender identity, age, race, ethnicity, education level, marital status, household annual income, smoking status, and alcohol use were ascertained using validated questions derived from the Behavioral Risk Factor Surveillance System Survey (BRFSS, 2014).

Job Information

Participants reported their trade (carpenter, pipe trades, or sheet metal), the number of years they have been part of their specified trade, and their career level (journey-level or in their apprenticeship).

Work-Related Stressors

All questionnaire scales that incorporated scoring metrics such as a Likert Scale were scored such that higher values indicate unhealthy exposures. These scores were then dichotomized at the 75th percentile. Other scales that incorporated binary "Yes/No" responses remained as such, so all stress exposure information is presented and analyzed as categorical data.

These work-related psychosocial stressors were selected based on those identified and evaluated in the SHEWT study, along with an additional variable "heightened vigilance"; this variable was identified through further review of focus group quotes and further elaborated upon below.

Job Content Questionnaire - A shortened, 8-item version of the Job Content Questionnaire (JCQ) was used to assess decision latitude, physical demands, and workplace social support from supervisors and coworkers among participants. (Kristensen, 1995)

Bullying At Work Scale – A one question scale used to identify being bullied, threatened, or generally harassed over the last 6 months. (Einarsen et al., 1996).

Discrimination – A four question scale has asked about discrimination due to age, race or ethnic origin, gender and sexual orientation or gender identity at any point during their most recent job (NIOSH, 2010).

Sexual Experiences – A nine question shortened version of the Sexual Experiences Questionnaire form W (SEQ-W) was used to assess exposure to high or low levels of sexual harassment over the past month at work. (Fitzgerald et al., 1995).

Isolation – Two items from the 16 item Loneliness at Work scale were used to assess emotional dependence and social companionship at work, ultimately indicating whether or not a participant felt isolated. (Wright et al., 2006).

Work/Life Balance – Three questions taken from the NIOSH Quality of Work Life Scale to assess poor or good work/life balance (NIOSH, 2010).

Physical Overcompensation – This question was created by the University of Washington's research team associated with the SHEWT study using feedback garnered from the focus groups. Answers to this question aimed to assess how often participants pushed themselves past their comfort level to get the job done (Curtis et al., 2018).

Heightened Vigilance Scale – This 4 item scale asks questions to address how someone prepares to face adversity at work. While typically used for evaluating relationships between racial discrimination and stress response (Himmelstein et al., 2014), we adopted this scale to ask generally about vigilance with differences in gender response being our primary interest (Hicken et al. 2014). Answers pertained to how often an individual prepared for possible insults, needed to care about their appearance, carefully watch what they do or say, and avoid certain situations and places.

Non-Work Stressors

Non-work stressors were also considered in this assessment because they may also contribute in part to an individual's total perception of stress and measured biomarkers of stress. Identifying and controlling for these sources of stress in regression models can help to determine stress associated with work-related stressors. However, characterizing sources of stress is a total worker health issue; perceived stress is not only relegated to workplace exposures. Furthermore, since perceived stress overall has been associated with outcomes such as increased risk of injury on the job, even if perceived stress is not associated with work related tasks, this perception of stress due to non-work stressors may still contribute to a greater risk of injury on the job (Kirschenbaum et al., 2000).

Financial distress – Financial distress comprised of three separate questions, and the question "What do you feel is the level of your financial stress today?" was used as the primary variable for analysis to determine above or below average levels of financial stress. **(**Prawitz et al. 2006). This variable is important in the construction industry; although wages are high, timelines are unpredictable and workers experience frequent lags between jobs (Curtis et al. 2018).

Life events inventory – Participants were asked to answer in a Yes/No fashion to experiencing each of the seven life events listed within the past year, including (Kendler et al., 1997):

1. Death of a spouse or immediate family member
2. Jail sentence
3. Immediate family member attempting suicide
4. Getting into debt beyond means of repayment or a period of homelessness
5. Immediate family member seriously ill
6. Unemployment for an extended period of time
7. Divorce, marital separation, or marriage

Personal Social Support – 6 of the 7 questions from the Enriched Social Support Instrument, or the ESSI, were used to assess good or poor personal social support among participants. Positively framed questions were reverse scored compared to the negatively framed question, and all scores were summed to create a final value for social support. (Vagalio et al., 2004)

Outcome Assessment

Perceived Stress – The four item perceived stress scale assessed participants' perception of stress during the last month; two positively framed questions were reverse scored from the two negatively framed questions, (Cohen et al.) Items were summed to produce a variable between x and y where higher values indicated worse perceived stress.

Blood Sample Data

The specific biomarkers included in this study are markers of (1) the immune system, Epstein-Barr virus (EBV), (2) the inflammatory system, interleukin-6 (IL-6) and C-Reactive Protein (CRP), and (3) the hypothalamic-pituitary-adrenal (HPA) axis, dehydroepiandrosterone-sulfate (DHEA-S). These key stress response systems have been used frequently in past research (Hansel et al., 2010; Gallo et al., 2014). Thirty nine participants (17 men and 22 women) provided a blood sample for analysis of the these stress biomarkers, but one woman was pregnant so only thirty eight measures were used in statistical analyses. Five ml of blood were drawn by a trained phlebotomist and collected in sample tubes containing silica clot activator, which promoted faster coagulation, from each participant using venipuncture with single use butterfly needles.

A polymer gel layer in the tube helped to separate blood components prior to the tubes being spun on a portable centrifuge on site. Following use of the centrifuge and determining that the serum was adequately separated, our Research Coordinator removed the serum using pipettes and stored in cryovials. These cryovials were placed on ice, and after data collection was finished, the cooler containing these serum samples were transported to the Center for Studies in Demography and Ecology (CSDE) lab and placed in a -70C freezer until assayed.

The CSDE stored the serum samples for 5 months in a -80C freezer prior to running separate assays for CRP, IL-6, DHEAs, and anti-EBV antibody. CRP was measured using an in-house ELISA (Brindle et al 2010). Commercial ELISA kits were used to measure IL-6 (R&D Systems cat# HS600C), DHEAs (DRG cat# EIA1562), and anti-EBV antibody (IBL International cat# RE57351). Bio-Rad LiquiChek quality control samples were run on every plate, which included an immunology control for CRP, IL-6, and anti-EBV antibody, while an Immunoassay Plus control was used for DHEAs. Calibrators, quality control samples, and serum samples were run in duplicate wells. All study samples were initially assayed in a single batch for each ELISA. Assays were repeated for samples with a coefficient of variation of 15% or greater between duplicate wells, and any samples with results outside the calibration range

were retested at an appropriately adjusted dilution. Following these routine quality control repeat tests, the resulting data came from a single assay batch for DHEAs and CRP, and from two assay batches for IL-6 and anti-EBV antibody.

Covariates

Ailments and Medication Use – Questions about use of the following medications within the last 30 days and ailments in the past two weeks were derived from the MESA (Multi-Ethnic Study of Atherosclerosis and Air Pollution) Medical History Questionnaire, and these were important to consider for stress biomarker analyses (MESA, 2001). Standard practice involves adjustment for these variables because they may impact biomarker levels.

Ailments:

- Fever
- Cold, flu, or sore throat
- Urinary infection
- Seasonal allergy
- Bronchitis
- Sinus infection or sinusitis
- Pneumonia
- Gums bleeding while brushing or flossing
- Tooth infection
- Flare-up of gout
- Flare-up of arthritis

Medications:

- Drugs to lower cholesterol
- Oral steroid drugs for allergies, asthma, or an autoimmune disorder
- Cortisone shots
- Immunosuppressive drugs
- Daily use of non-steroidal anti-inflammatory drugs (NSAIDS)

**Reference Appendix B for the specific ailments and medications of concern for each biomarker when assessing associations with exposure to stressors*

Stress-Specific Coping Mechanisms – Participants assessed the frequency in which they participated in one of nine stress coping mechanisms. Each kind of coping mechanism was assessed separately in analyses, and the coping mechanisms include the following positive and maladaptive choices: *positive* - exercise, yoga, meditation, talking to a coworker or friend, being with family, prayer and other spiritual activities; *negative* - distracting oneself, drinking alcohol or using drugs, and trying not to think about work.

Sleep Quality – One question from a set of three sleep quality questions was used during analysis. Participants rated their sleep quality in the past month and were categorized either with having “Poor” or “Good” sleep quality (CPH New).

Statistical Analysis

The statistical software package R was used for data analysis. Demographic characteristics were presented as means and standard deviations, or counts and proportions, and then presented separately by gender group.

Biomarker data was log-transformed to create a normal distribution sufficient for running this type of analysis. T-tests were used to determine whether there was a significant difference in mean values of log-transformed biomarker data and perceived stress scores between gender groups. Fisher's Exact tests were used to determine significant differences in response to dichotomized and binary stressor exposure variables between men and women participants. This analysis was selected to compare the proportion of responses between our gender groups instead of a chi-square analysis because the Fisher's Exact test performs the same kind of analysis as a chi-square but for small sample sizes.

Outliers in the biomarker measures were not removed from the data when conducting data analysis. These measures did not come from participants who took medications or had ailments that would explain the biomarker response; these were the main covariates considered when making this determination.

Linear regression analyses explored associations between the psychosocial stressors of interest and each measured stress outcome (perceived stress scores and four biomarker measures) while controlling for age and gender. Additional linear regression analyses investigated whether an association existed between the subjective and objective stress outcomes: perceived stress scale scores and each of the log-transformed biomarker measures.

RESULTS

Demographics

Twenty-two women, seventeen men, and one participant who identified as non-binary participated in the study (Table 1). Participants' mean age was approximately 34 years (SD = 7.11, Range = 21 - 59), and almost two-thirds reported being White (65%). Just over half (52.5%) of participants have been in the trades for 1-4 years, while 5% have been in the trades for less than one year and 42.5% reported 5 or more years. Most participants were not married (65%), and 77.5% reported their sexual orientation as straight or heterosexual. Approximately 72% of the participants had household incomes equal to or greater than $75,000 annually, and over half of participants were overweight or obese (62.5%).

All participants completed the questionnaire and 38 participants provided blood samples that were used in statistical analyses. The information from the non-binary participant was not included in the analyses that evaluated gender differences in exposures or stress outcomes.Table 1. Sample Demographics

Study Design Variables	**Gender (n=39)**		**Total (n=40)**
	Women	**Men**	**All**
Total Number (%)	22	17	40 (100)
		Age	
Median Age (Years)	36	30	33
Age, Mean (S.D)	35.3 (7.53)	31.6 (6.09)	33.7 (7.11)
Minimum, Maximum Age	21, 59	25, 48	21, 59
		Years in Trade	
<1 year	2 (9)	0 (0)	2 (5)
1 to 4	11 (50)	9 (53)	21 (52.5)
5 to 10	4 (18)	3 (18)	7 (17.5)
11 +	5 (23)	5 (29)	10 (25)
		Annual Household Income	
≥ $75,000	15 (68)	13 (76)	29 (72.5)
≤$75,000	7 (32)	4 (24)	11 (27.5)
		Race/Ethnicity	
White	13 (59)	12 (71)	26 (65)
Other	9 (41)	5 (29)	14 (35)
		BMI	
Normal Weight	9 (41)	5 (29)	15 (37.5)
Overweight/Obese	13 (59)	12 (71)	25 (62.5)
		Sexual Orientation	
Straight or Heterosexual	15 (68)	16 (94)	31 (77.5)
Other	7 (32)	1 (6)	9 (22.5)
		Marital Status	
Married/Long-Term Partner	9 (41)	5 (29)	14 (35)
Not Married	13 (59)	12 (71)	26 (65)

Stress Outcomes

As hypothesized, the subjective stress measure differed significantly between our gender groups (Table 2); women had a significantly higher mean perceived stress scores (6.05 $\pm$ 3.12) than the male participants (3.53 $\pm$ 2.85) (Figure 4).

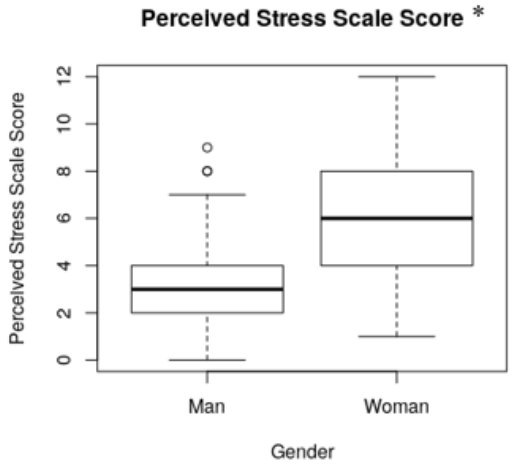
The following stress biomarkers from participant blood serum were analyzed as objective stress measures: DHEA-S, EBV, CRP, and IL-6. Women had significantly lower log-transformed mean measures of the hormone response biomarker DHEA-S (0.07 ug/mL $\pm$ 0.22) than men (0.24 ug/mL $\pm$ 0.15), which is the expected chronic stress response among those individuals with greater perceived stress or those who experience greater psychosocial stressors (Figure 4). Lower levels of DHEAs are also expected to be lower among women and older individuals. Additionally, while not significant, the log-transformed immune response biomarker measure of EBV was higher among women (1.74 U/L $\pm$ 0.0.51) than men (1.39 U/L $\pm$ 0.59). The final biomarkers that were evaluated, CRP and IL-6, were inflammatory biomarkers that did not demonstrate significant mean differences between men and women participants (Table 2).

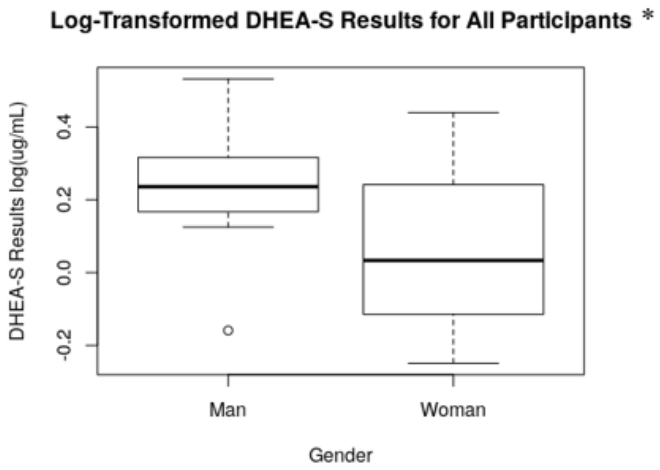
Table 2. Mean (standard deviation) of stress biomarkers by gender

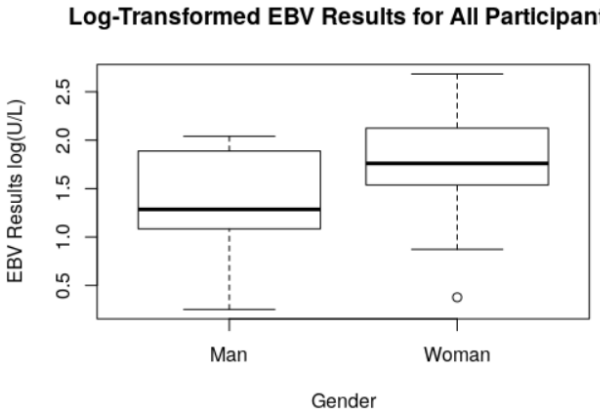
	Gender	
	Women Mean (S.D)	Men Mean (S.D)
Perceived Stress Score		
Score (0 – 12)	6.05 (3.12)*	3.53 (2.85)
Log-Transformed Biomarker Measures		
DHEAs - log(ug/mL)		
	0.07 (0.22)*	0.24 (0.15)
EBV - log(U/L)		
	1.74 (0.51)	1.39 (0.59)
IL-6 - log(pg/mL)		
	0.17 (0.43)	0.24 (0.29)
CRP - log(mg/L)		
	0.26 (0.65)	0.36 (0.56)

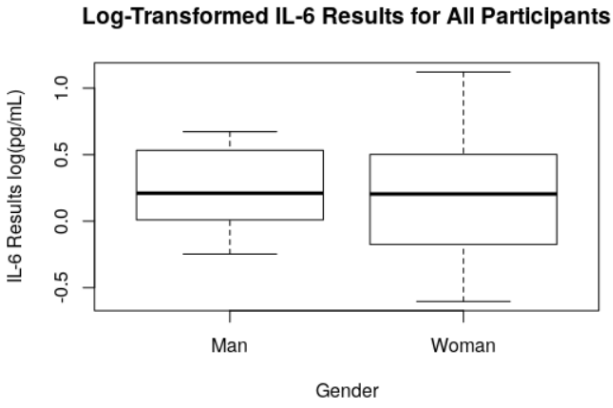
*p<0.05 **p<0.01 ***p<0.001
T-test analysis

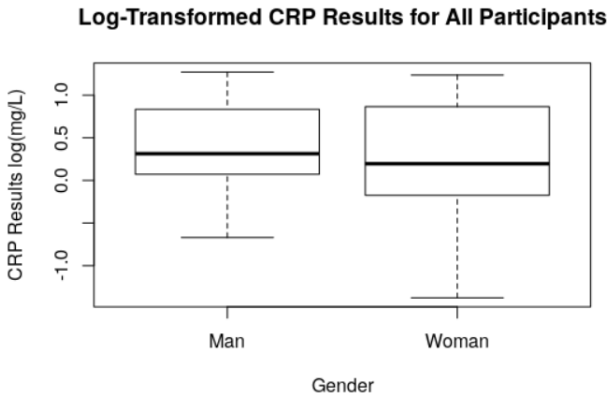
Figure 4. Boxplots depicting objective and subjective stress measures











In addition to assessing the differences in subjective and objective outcome measures between gender groups, the association between these outcome measures among all participants was assessed. Regression analyses did not show any significant associations between an increase in one point of perceived stress score and percent change of any of the log-transformed biomarker measures (Table 3).

Table 3. Percent change and 95% confidence interval of association between log-transformed biomarkers (dependent variable) and perceived stress score (independent variable)

Perceived Stress Score (PSS) Range: 0-12	% Change of Biomarker Measure per PSS Point (CI)		
	All Participants[1]	**Men**	**Women**
DHEA-S (log(ug/mL))			
% Change	0.33 (-1.8, 2.4)	-0.0039 (-3.1, 3.3)	0.49 (-2.5, 3.6)
EBV (log(U/L))			
% Change	1.5 (-4.9, 8.3)	-1.3 (-12, 12)	3.3 (-4.9, 12)
IL-6 (log(pg/mL))			
% Change	2.1 (-2.4, 6.8)	1.9 (-3.2, 7.3)	2.1 (-4.8, 9.4)
CRP (log(mg/L))			
% Change	4.4 (-3.6, 8.2)	2.0 (-8.6, 13.9)	5.7 (-4.7, 17)

*p<0.05 **p<0.01 ***p<0.001 †Overall model p<0.05

[1]Models that include all participants control for gender.

All models control for age.

Linear regression used for analyses.

Work and Non-Work Stressors

Women experienced significantly higher levels of gender discrimination (n=11, 50%) and reported the need for heightened vigilance (n=11, 50%) than men (n=0 and n=1, 6%, respectively) (Table 4). Although not all differences in response were statistically significant, a greater proportion of women reported experiencing many of the additional psychosocial stressors than men (i.e. bullying, overcompensation, sexual harassment).

Table 4. Psychosocial stressors by gender

	Women (n=22) n (%)	Men (n=17) n (%)
Psychosocial Stressors		
Gender Discrimination		
Yes	11 (50)***	0 (0)
Racial Discrimination		
Yes	0 (0)	1 (6)
Age Discrimination		
Yes	4 (18)	1 (6)
Sexual Orientation/Gender Identity Discrimination		
Yes	1 (4.5)	1 (6)
Bullying		
Yes	7 (30)	2 (12)
Overcompensation		
Often	10 (45)	8 (47)
Sexual Harassment		
High	8 (36)	2 (12)
Heightened Vigilance		
High	11 (50)**	1 (6)
Isolation		
High	8 (36)	8 (47)
Supervisor Support		
Poor	7 (32)	3 (18)
Coworker Support		
Poor	16 (73)	9 (53)
Job Control		
Poor	16 (73)	10 (59)
Job Demand		
High	6 (27)	8 (47)
Job Strain		
High	4 (18)	4 (24)
Work/Life Balance		
Poor	7 (32)	5 (29)
Personal Social Support		
Poor	8 (36)	3 (18)
Sleep Quality		
Poor	11 (50)	5 (29)
Financial Stress		
Above Average[a]	5 (23)	5 (29)

*p<0.05 **p<0.01 ***p<0.001
Fisher's Exact Test for analyses
Higher scores indicate a worse exposure to stressor
Continuous variables dichotomized at the 75th percentile

Stressor and Stress Outcome Associations

Linear regression analyses of the subjective stress measures (perceived stress scale) and objective stress measures (biomarkers of stress) on the psychosocial exposure responses were conducted. Gender discrimination, sexual harassment, heightened vigilance, bullying, and poor social support were significantly associated with higher perceived stress scores (Table 5).

In unadjusted models, individuals who experienced bullying, poor supervisor support, and heightened vigilance had significantly higher perceived stress scores. Those who reported experiencing heightened vigilance had scores that were 3.1 points higher on the PSS than those

who did not (CI: 1.0, 5.1). Participants who reported poor supervisor support also reported perceived stress scores that were 2.9 points higher than those who reported good supervisor support (CI: 0.67, 5.1). Finally, individuals who reported experiencing bullying had scores that were 3.0 points higher on the PSS scale than those that did not report being bullied (CI: 0.50, 5.5).

Gender discrimination and sexual harassment were significantly associated with higher perceived stress scores in both adjusted and unadjusted models. In the adjusted models, participants who experienced gender discrimination reported 2.9 points higher on the perceived stress scale (PSS) than those who did not (CI: 0.31, 5.6), and participants who reported a high level of sexual harassment reported 3.7 points higher on the PSS than those who did not (CI: 1.9, 5.6).

Table 5. Coefficient and 95% confidence interval of association between perceived stress score (dependent variable) and psychosocial stressors (independent variable)

Perceived Stress Score Range: 0 - 12		
Binary Variables	Unadjusted Coefficient (CI)	[1]Adjusted Coefficient (CI)
Variable (reference category)		
PSYCHOSOCIAL EXPOSURES		
Gender Discrimination (no)		
Yes	3.1(0.34, 5.9)*	3.0(0.31, 5.6)*,[2]
Racial Discrimination (no)		
Yes	3.2(-3.6, 10)	4.1 (-2.0, 10)
Age Discrimination (no)		
Yes	2.2(-0.97, 5.4)	1.9(-1.0, 4.8)
Bullying (no)		
Yes	3.0(0.50, 5.5)*	2.3(-0.74, 4.6)
Sleep Quality		
Poor	2.0(-0.18, 4.2)	1.6(-0.44, 3.6)
Overcompensation		
Often	0.63(-1.6, 2.9)	0.86(-1.3, 2.9)
Sexual Harassment		
High	4.4(2.4, 6.3)***	3.7(1.9, 5.6)***
Heightened Vigilance		
High	3.1(1.0, 5.1)**	2.0(-0.29, 4.2)
Isolation		
High	1.2(-0.97, 3.3)	0.32(-1.7, 2.3)
Work/Life Balance		
Poor	1.5(-0.72, 3.8)	1.9(-0.075, 3.9)
Personal Social Support		
Poor	1.8(-0.43, 4.1)	1.2(-0.85, 3.3)
Supervisor Support		
Poor	2.9(0.67, 5.1)*	1.9(-0.42, 4.1)
Coworker Support		
Poor	2.0(-0.063, 4.1)	1.1(-0.94, 3.1)
Job Control		
Low	0.85(-1.4, 3.1)	0.75(-1.3, 2.8)
Job Demands		
High	-1.1(-3.3, 1.0)	-0.60(-2.6, 1.4)
High Strain		
Yes	-0.50(-3.2, 2.2)	-0.15(-2.6, 2.3)

*p<0.05 **p<0.01 ***p<0.001

[1]Adjusted model controlling for age and gender.

[2]Model only controlling for age.

Linear regression used for analyses.

The psychosocial hazards that were significantly associated with higher perceived stress scores (Table 5) were assessed for their association with each of the log-transformed biomarkers of stress. After adjustment by age and gender, those individuals who reported high heightened vigilance had a significant 63% change in CRP (CI: -0.8 %, 170%) compared to those who did not experience heightened vigilance (Table 6). However, it is important to note that the significance value was set an alpha of 0.1 for these regression models.

Table 6. Percent change and 90% confidence interval of association between log-transformed biomarkers (dependent variable) and psychosocial stressors (independent variable)

	DHEAs (ug/mL)	**EBV (U/L)**	**IL-6 (pg/mL)**	**CRP (mg/L)**
Range of Measures *(log-transformed)*:	-0.25, 0.53	0.25, 2.7	-0.060, 1.1	-1.4, 1.3
Variable (reference category)		% Change (CI)		
PSYCHOSOCIAL EXPOSURES				
Gender Discrimination[a]				
Yes	-5.7 (-21, 13)	-2.5 (-41, 60)	-4.3 (-38, 46)	21 (-36, 125)
Heightened Vigilance[b]				
High	1.8 (-15, 14)	8.1 (-32, 72)	21 (-12, 67)	63 (-0.8, $1.7x10^2$)*
Sexual Harassment[b]				
High	4.3 (-9.3, 20)	15 (-26, 77)	3.5 (-24, 41)	16 (-29, 92)
Bullying[b]				
Yes	-2.7 (-17, 13)	26 (-20, 97)	-11 (-36, 22)	-8.2(-46, 54)
Supervisor Support[b]				
Poor	-5.4 (-18, 9.6)	23 (-21, 95)	12 (-20, 54)	1.1 (-40, 72)

*$p<0.1$

[a] Models controlling for age

[b] Models controlling for age and gender

Linear regression used for analyses

Coping Mechanisms

After assessing differences in stress coping mechanisms implemented by each gender group (Table 7), exercise was the coping mechanism that significantly differed (64% of women versus 29% of men). Exercise is known to reduce measures of inflammatory biomarkers of stress (Lark et al., 2018); therefore, log-transformed CRP and IL-6 measures were evaluated for their association with exercise.

Table 7. Implementation of Stress Coping Mechanisms by Gender

Binary Predictors	Women (n=22) n (%)	Men (n=17) n (%)
Coping Mechanisms		
Exercise		
Frequently	14 (64)*	5 (29)
Yoga		
Frequently	1 (4.5)	1 (5.9)
Meditation		
Frequently	2 (9.1)	0 (0)
Talking to a coworker or friend		
Frequently	14 (64)	8 (47)
Distract myself		
Frequently	14 (64)	10 (59)
Being with family		
Frequently	10 (45)	7 (41)
Prayer and other spiritual activities		
Frequently	2 (9.1)	1 (5.9)
Drinking alcohol or using drugs		
Frequently	5 (23)	5 (29)
Try not to think about work		
Frequently	5 (23)	5 (29)

*p<0.05 **p<0.01 ***p<0.001
Fisher's Exact Test for analyses

Exercise was significantly associated with a decrease of CRP and IL-6 measures among all participants after controlling for age and gender. Participants who frequently exercised to manage stress had a -50% change in CRP and -30% change in IL-6 compared to those who infrequently exercised (CI: -67%, -29%; CI: -45%, -10%, respectively).

Table 8. Percent change and 95% confidence interval of association between CRP and IL6 measures (dependent variable) and frequent exercise (independent variable)

	CRP % Change (CI)	IL-6 % Change (CI)
Exercise		
Frequently	-50 (-67, -29)***	-30 (-45, -10)**

*p<0.05 **p<0.01 ***p<0.001
All models control for age and gender.
Linear regression for analyses.

DISCUSSION

To our knowledge, this pilot study is the first of its kind to evaluate objective measures of stress among tradeswomen in construction. The primary goal was to establish the groundwork for a future larger study by assessing the feasibility of conducting this project on a pilot-scale. Additionally, the study aimed to evaluate work and non-work stressors experienced by participants, determine the differences in these exposures and stress outcomes between gender groups, and explore associations between the stressors and both subjective and objective stress outcomes. While the results of this research are exploratory in nature due to the size of the study population and cross sectional design, analyses suggest that a future larger project is worthwhile and practicable.

Women reported higher average measures of perceived stress than men, which was also reflected in the SHEWT study and among women from the representative sample in U.S. overall. Women in this study also had significantly lower levels of DHEAs. As described in the background of this paper, while current literature suggests that lower levels of DHEAs is the expected stress response, studies have also associated higher levels of this hormone biomarker with higher levels of perceived stress and experience of stressors. Furthermore, DHEAs is also lower among women and older individuals (Lennartsson et al., 2015); the women in this study were older than their male counterparts, so this lower level of DHEAs in women must be interpreted cautiously, particularly since the linear regression analyses did not demonstrate significant associations between DHEAs and psychosocial stressors after adjustment for age and gender.

All study participants had measurable levels of EBV, and the mean level of EBV among women was higher than the measure for men in this study. Greater measures of EBV is the expected response to higher levels of stress, but mean differences between gender groups were not significant. The inflammatory biomarkers, CRP and IL-6, did not demonstrate significant mean differences between men and women. However, after assessing differences in stress coping mechanisms implemented by men compared to women, exercise was the coping mechanism that significantly differed (64% of women versus 29% of men). Exercise is known to reduce measures of these inflammatory biomarkers among individuals in physically demanding jobs and in the general population (Lark et al., 2018; Lakka et al., 2005), and exercise was significantly associated with a decrease in log-transformed measures of CRP among women and men when controlling for age. A significant decrease in log-transformed IL-6 measures was also associated with exercise among women. Therefore, although women had higher perceived stress scores and experienced greater gendered stressors, these exploratory analyses suggest that exercise could be a factor in why these inflammatory biomarkers were not also demonstrating expected responses for experiencing greater levels of chronic stressors among women.

Exploratory linear regression analyses presented significant associations between work-related psychosocial stressors and both objective and subjective stress outcomes. Experiences of

sexual harassment and gender discrimination at work were significantly associated with higher perceived stress scores (subjective stress outcome). These results somewhat reflect those found in the SHEWT study; gender discrimination among the entire study population and sexual harassment among women were associated with higher perceived stress in SHEWT, but they also found significant associations between higher perceived stress scores and poor work/life balance, age discrimination, and bullying. The SHEWT research team also observed that physical overcompensation was significantly associated with an increased number of work related injuries, but it was not associated with higher perceived stress.

Differences in the associations between these exposures (psychosocial stressors) and perceived stress found in the SHEWT study and this project may be partially due to our limitations in recruitment. While women in our study did experience higher levels of bullying than men, they did not report worse work/life balance, overcompensation, or age discrimination. Our convenience sample of the workforce may have resulted in recruiting mainly those individuals who had enough time to participate and those who had potentially the lowest experiences of these psychosocial exposures. This suggests that the observed associations may be greater among a representative sample of this workforce.

Heightened vigilance was the third psychosocial stressor significantly associated with higher perceived stress scores, and it was also associated with higher log-transformed CRP measures (objective stress outcome). Heightened vigilance has traditionally been studied as a maladaptive coping mechanism used to evaluate how someone prepares to face adversity in the event of racial discrimination (Hicken et al., 2013). To my knowledge, this is the first study to use heightened vigilance as a standalone psychosocial stressor when evaluating occupational stress differences between genders in construction. Two other studies have evaluated heightened vigilance outside the racial context outside of occupational settings; one evaluated heightened vigilance as an effect modifier in the relationship between healthcare mistreatment among Trans individuals and healthcare avoidance (Hughto et al., 2018). The other study explored how heightened vigilance modified the effect of racial discrimination on stress between gender groups (Himmelstein et al., 2014), and both studies found that heightened vigilance significantly modified these relationships, which resulted in an increase of the adverse outcome.

Assessing the relationship between heightened vigilance as a gender-related psychosocial stressor and both perceived stress and biomarkers of stress among construction workers is novel. To my knowledge, this is the first study to explore and demonstrate an association between elevated levels of CRP and heightened vigilance; however, this association must also be interpreted with caution. This value was significant for a 90% confidence interval, which may increase type I error. Additionally, there is no correction for multiple comparisons, so given the number of comparisons being made, there may be significant relationships observed due to chance alone. However, this pilot study had a small sample size, so capturing associations with an outcome that may have a small effect size is not likely feasible. Therefore, the alpha value

was increased for these exploratory regression analyses to indicate what might be most important to evaluate in future research.

As illustrated in the background, methods, and in Appendix B, many covariates can have an effect on the relationship between the psychosocial exposures of interest and all stress biomarkers. Appendix C includes linear regression models that each separately control for age, gender, and one additional covariate for each biomarker. These analyses aimed to detect a change of greater than 20% in the biomarker beta coefficient by including each covariate in separate models, and significance was assessed at an alpha value of 0.05. The models that included experiencing a significant life event, accounting for aliments or medications associated with CRP, and frequent exercise each demonstrated a significant relationship between elevated CRP measures and heightened vigilance at a lower alpha than my primary analyses. However, the model that adjusted for high BMI made the association between heightened vigilance and the CRP measures insignificant.

While interpretation of these results needs to be careful, another pilot study among women experiencing similar work-related psychosocial exposures showed an association between high job strain and increased allostatic load index measures; moreover, there were also associations between high allostatic load measures and chronic diseases (Rosemberg et al., 2018). One of the biomarkers used to quantify allostatic load in this study was CRP, and Rosemberg et al. notes that the clinical cutoff point for normal CRP measures is 3.0 mg/L. Approximately 40% of our participants had non-log transformed CRP measures that were above this cutoff point, which may increase risk of cardiovascular diseases (Cozela et al., 2013).

As discussed previously, a covariate that was significantly associated with lower levels of the inflammatory stress biomarkers in this study was exercise. Coping mechanisms did not differ significantly between gender groups with the exception of exercise. However, both gender groups reported implementing additional positive coping mechanisms to combat stress, including "talking to a coworker or friend" and "being with family". Similar proportions of each gender group reported that they drank alcohol or used drugs to negatively cope with stress, as well as trying not to think about work and distracting oneself. The latter negative results are similar to those reported by Langdon et al. who found that construction workers reported acceptance, blame, disengagement, humor, and substance use as methods to cope with work-related stress; however, their sample population only included one woman, so this was more indicative of how men coped with occupational stress in this industry (2018).

In addition to the implementation of stress-related coping strategies, individual resilience factors and covariates like genetics may be contributing to the inter-individual variables that attenuate the associations between exposure to psychosocial stressors and stress biomarker levels. Personal resilience that make one more "hardy" may affect how an individual appraises a psychosocial stressor, thus affecting their perceived stress and stress biomarker levels in response to the stressor. Genetic variables may also affect how stress response systems such as

the HPA axis operate when experiencing a stressor or perceiving stress (Ising et al., 2006). An individual can have a harder time returning to homeostasis after being in allostasis, or their expected physiological response to stress may be less affective or subdued. While these factors were not captured in this study, they are important to consider in understanding variability in stress response between people.

Limitations

One limitation of this study stems from the design itself. The cross-sectional study design makes temporality hard to establish, which means that we cannot say with certainty that exposure to psychosocial stressors preceded perceived stress or the stress biomarker measures. Furthermore, one of the stress biomarker measures used to assess stress differences across genders, DHEAs, is itself known to be associated with gender. Also, the small sample size makes accounting for inter-individual differences and a small effect size in the outcome difficult. Finally, using a convenience sample of participants in this study may have only included those individuals who had the lowest levels of stress and experiences of stressors.

Conclusions

Although exploratory, these analyses demonstrated significant differences in the experience of psychosocial stressors between women in men in the pipe, sheet metal, and carpentry trades within the construction industry. To my knowledge, using heightened vigilance as it relates to gender discrimination in this population is novel, and this is the first study to assess stress biomarkers in particular among women in this field. Additionally, this is the first to find associations between higher CRP measures and heightened vigilance; although these associations must be interpreted cautiously considering the confidence interval, covariates and individual factors that may affect this relationship.

This pilot study contributes to the body of research about women in nontraditional occupations, and it provides insight on the ways in which women cope at an individual level to deal with stress; however, these women may be those that are least stressed and have the lowest experiences of stressors compared to the general population of this workforce based on the convenience sampling strategy.

The results of this pilot study indicate a need for additional research through a larger study, particularly one that implements a sampling strategy that aims to ascertain a more representative sample of this workforce. Furthermore, future research may consider using allostatic load to quantify an objective burden of physiologic stress instead of individual stress biomarkers each as a separate outcome, especially considering that individual level factors each may have different effects on each of the biomarkers.

Overall, the assessment of workplace exposures to factors beyond physical, biological, or chemical agents is important, especially when an exposure such as psychosocial stressors may

also be contributing to the burden of disease and adversely affect the mental and physical wellbeing of a workforce. Continued assessment of psychosocial stressors experienced more by women in the trades compared to men through this study indicated that women are still experiencing higher levels of harassment and discrimination. This finding is concerning given Title VII of the civil rights act, a growing need for more skilled trades workers in the United States, and the hardships faced by women trying to enter and stay within the trades. Improvements in organizational level stress coping strategies and identifying ways to prevent gender-specific, work-related psychosocial stressors can lead to a healthier workforce and potentially improved recruitment and retention of women in the construction industry.

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APPENDIX A

Table 6 includes regression analyses of the psychosocial exposures that were significantly associated with perceived stress to determine their association with each stress biomarker. All regression models control for the effects of age and gender when evaluating the association between the psychosocial exposures of interest and each stress biomarker; additional confounders were each assessed in separate regression models to determine whether they had a greater than 20% effect on the log-transformed biomarker coefficient values as compared to the initial regression models. The models that demonstrated this effect are noted in Table 6, and tables containing the exploratory analyses of these effects are in Appendix C. The table below includes a list of the covariates that were analyzed for their effect on the relationship between the selected psychosocial variables and each stress biomarker:

Stress Biomarkers	**Covariates considered for each biomarker regression model in Table 6[a]**
All Biomarkers	- Life Events - Sleep Quality - BMI (Overweight vs Not Overweight)
DHEAs	*Ailments/Medications*[b] - NSAID use - Oral Steroid use
EBV	*Ailments/Medications* - Fever - Cold, Flu, or Sore Throat - Sinus Infection or Sinusitis - Bronchitis
CRP	*Ailments/Medications* - Fever - Cold, Flu, or Sore Throat - Sinus Infection or Sinusitis - Bronchitis - NSAID use - Oral Steroid use *Other* - Exercise
IL-6	*Ailments/Medications* - Fever - Cold, Flu, or Sore Throat - Sinus Infection or Sinusitis - Bronchitis - NSAID use - Oral Steroid use *Other* - Exercise

[a]A binary "Yes/No" response was recorded for use of one or more of the ailments/medications included in each list to create one "Ailment/Medication" variable for each model

APPENDIX B

^p<0.1, *p<0.05, **p<0.01, ***p<0.001

"Original Biomarker β" derived from model controlling for age and gender, where applicable

"AMEBV", "AMIL6", "AMCRP", and "AMDHEAs" is a binary yes/no variable that denotes whether a participant is taking ailments and/or medications that could potentially affect each specific biomarker measure

Covariate effects on log-transformed biomarker β per regression

DHEAs

Gender Discrimination

	Log DHEAs		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**-0.059**	-0.09	Yes
BMI [Final]		-0.051	No
Sleep Rating		-0.066	No
AMDHEAs		-0.093	Yes

Sexual Harassment

	Log DHEAs		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**-0.042**	-0.038	No
BMI [Final]		-0.043	No
Sleep Rating		-0.045	No
AMDHEAs		-0.02	Yes

Heightened Vigilance

	Log DHEAs		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**-0.018**	0.0022	Yes
BMI [Final]		-0.03	No
Sleep Rating		-0.015	Yes
AMDHEAs		0.019	Yes

Bullying

	Log DHEAs		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**-0.027**	-0.046	Yes
BMI [Final]		-0.022	No
Sleep Rating		-0.041	Yes
AMDHEAs		-0.036	Yes

Supervisor Support

	Log DHEAs		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**-0.055**	-0.059	No
BMI [Final]		-0.049	Yes
Sleep Rating		-0.078	Yes
AMDHEAs		-0.067	Yes

EBV

Gender Discrimination

	Log EBV		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**-0.025**	-0.025	No
BMI [Final]		-0.023	No
Sleep Rating		-0.039	Yes
AMEBV		-0.028	No

Sexual Harassment

	Log EBV		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**0.14**	0.13	No
BMI [Final]		0.13	No
Sleep Rating		0.17	Yes
AMEBV		0.16	No

Heightened Vigilance

	Log EBV		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**0.078**	0.045	Yes
BMI [Final]		0.037	Yes
Sleep Rating		0.041	Yes
AMEBV		0.084	No

Bullying

	Log EBV		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**0.23**	0,21	Yes
BMI [Final]		0.21	No
Sleep Rating		0.38	Yes
AMEBV		0.018	Yes

Supervisor Support

Log EBV

	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event		0.021	No
BMI [Final]	**0.021**	0.18	No
Sleep Rating		0.38	Yes
AMDHEAs		0.22	No

CRP

Gender Discrimination

Log CRP

	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event		0.23	Yes
BMI [Final] **		0.082	Yes
Sleep Rating	**0.19**	0.16	No
AMCRP		0.26	Yes
Exercise *		0.17	No

Sexual Harassment

Log CRP

	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event		0.17	No
BMI [Final]***		0.13	No
Sleep Rating	**0.15**	0.16	No
AMCRP		0.24	Yes
Exercise ***		0.21	Yes

Heightened Vigilance

Log CRP

	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event ^		0.063*	Yes
BMI [Final] ***		0.27	Yes
Sleep Rating	0.50^	0.49^	No
AMCRP		0.57*	No
Exercise ***		0.44*	No

Bullying

	Log CRP		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**-0.086**	-0.022	Yes
BMI [Final]		-0.026	Yes
Sleep Rating		-0.16	Yes
AMCRP		0.014	Yes
Exercise		0.0042	Yes

Supervisor Support

	Log CRP		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**0.011**	0.023	Yes
BMI [Final]		-0.029	Yes
Sleep Rating		-0.059	Yes
AMCRP		0.026	Yes
Exercise		0.084	Yes

IL6

Gender Discrimination

	Log IL6		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**-0.044**	0.02	Yes
BMI [Final] **		-0.1	Yes
Sleep Rating		-0.06	Yes
AMIL6		-0.054	Yes
Exercise *		-0.053	Yes

Sexual Harassment

	Log IL6		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**0.034**	0.047	Yes
BMI [Final] (0.39, 0.12)**		0.021	Yes
Sleep Rating		0.032	No
AMIL6		0.03	No
Exercise**		0.064	Yes

Heightened Vigilance

	Log IL6		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event ^	**0.19**	0.27^	Yes
BMI [Final] **		0.064	Yes
Sleep Rating		0.19	No
AMIL6 ^		0.18	No
Exercise**		0.16	No

Bullying

	Log IL6		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**-0.12**	-0.070	Yes
BMI [Final]		-0.21	Yes
Sleep Rating		-0.20	Yes
AMIL6		-0.12	No
Exercise		-0.075	Yes

Supervisor Support

	Log IL6		
	Original Biomarker β	**New Coefficient**	**> 20% Change?**
Life Event	**0.10**	0.11	No
BMI [Final]		-0.47	Yes
Sleep Rating		0.072	Yes
AMIL6		0.12	No
Exercise		0.14	No