A Longitudinal Investigation of the Mental Health Benefits of Physical Activity Among Graduate Students

Trevin Earl Glasgow

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E. Scott Geller, Chair
Charles C. Calderwood
Samantha M. Harden
Roseanne J. Foti

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ABSTRACT

Recent evidence showing graduate students to be at an elevated risk of developing mental health problems has attracted the attention of both researchers and non-researchers (Evans, Bira, Gastelum, Weiss, & Vanderford, 2018; Flatherty, 2018). This increased risk could be attributed to the stressors graduate students routinely experience. However, few studies have examined the negative effects of work stressors among graduate students and ways to protect graduate students from the negative impact of stressors. This research explored the association between work stressors and the mental health of graduate students, while considering the potential protective role of physical activity. Also studied was the potential predictors of physical activity, such as social support for physical activity. Graduate students completed three surveys over a semester. Multilevel structural equation modeling was used to analyze within- and between-person variation. Increased levels of work stressors were associated with increased levels of mental health problems. Physical activity was not associated with improved mental health at both levels of analysis. However, higher levels of physical activity protected graduate students from the negative effects of role conflict and role ambiguity, but not work overload. Social support for physical activity and a mindset that stress is enhancing were both associated with increased physical activity. This is one of the first studies to not only consider the negative effects of work stressors on graduate students’ mental health, but also the protective benefits of physical activity.
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GENERAL AUDIENCE ABSTRACT

Graduate school is a stressful time for many individuals. Graduate students are expected to do well in their classes while juggling other responsibilities, such as teaching, conducting research and/or working full-time to pay for school and living expenses. Although not everyone would consider graduate students to be full-time employees, it is not uncommon for graduate students to have long workdays and weekends that include completing work. Even if a graduate student does not clock into work every day, most are probably working more than the typical hourly employee. Not surprisingly, research has shown that graduate students are at increased risk of developing mental health problems when compared to the general population (Evans, Bira, Gastelum, Weiss, & Vanderford, 2018). These findings have even caught the attention of the national media, with some calling the mental health problem a crisis (Flatherty, 2018).

Work stressors (i.e., parts of a person’s job that lead to feelings of distress) may influence graduate students’ mental health. However, few studies have examined the negative effects of work stressors among graduate students and factors that could protect graduate students from these negative effects. This study assessed the benefits of physical activity among graduate students, given the plethora of studies showing the positive benefits of physical activity. It is possible physical activity can reduce the negative effects of the work stressors experienced by graduate students, such as being overworked with teaching responsibilities or having to conduct multiple research studies at the same time. This study explored factors that might influence graduate students to be more physically active, such as social support for physical activity.
Graduate students completed three surveys over a semester. Increased levels of work stressors were associated with increased levels of mental health problems. Graduate students who exercised more were “protected” from the negative effects of work stressors. In other words, even if graduate students were exposed to high levels of work stressors, they did not experience elevated mental health problems if they regularly exercised. Additionally, being around friends who promoted physical activity and having a mindset that stress is not bad but rather enhancing helped graduate students engage in more physical activity. Overall, the findings indicated that graduate students experience increased mental health problems due to negative work stressors, but by exercising they could reduce the negative effect of these work stressors.
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Introduction

The Physical Activity Guidelines for Americans state that those 18+ years of age should obtain at least 150 minutes of moderate-intensity aerobic physical activity or at least 75 minutes of vigorous-intensity aerobic physical activity, along with at least two days dedicated to muscle-strengthening activities (Piercy et al., 2018; U.S. Department of Health and Human Services, 2018). Additional physical activity and muscle-strengthening activities, intensity, and duration are recommended for additional added health benefits. Half of adults meet the recommendations for aerobic physical activity, but only one out of five meet the recommendations for combined aerobic physical activity and muscle-strengthening activities (U.S. Department of Health and Human Services, 2018). This lack of physical activity is likely one of the driving causes of health problems among Americans (Kohl III et al., 2012; Trost, Blair, & Khan, 2014).

Early research from Morris, Heady, Raffle, Roberts, and Parks (1953), Stunkard (1960) and Kannel (1967) were among the first to explore outcomes of physical activity. Those outcomes included several physical benefits, such as reduced risk of cardiovascular disease (Ignarro, Balestrieri, & Napoli, 2007) and lower levels of obesity (Story, Nanney, & Schwartz, 2009). Physical activity has also been shown to have mental health benefits, including reduced levels of depression (Mammen & Faulkner, 2013; Toker & Biron, 2012) and enhanced positive mood (Wichers et al., 2012). Most of the research that has examined the benefits of physical activity targeted children, adults and college students, leaving out a significant population – graduate students.

Recently, mental health problems experienced by graduate students (e.g., depression, anxiety, and distress) have attracted national attention (Flatherty, 2018). Work stressors, such as long work hours and unclear expectations, have contributed to elevated mental health problems.
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among graduate students (Evans, Bira, Gastelum, Weiss, & Vanderford, 2018). Therefore, graduate programs should be interested in ways to buffer the negative effects of work stressors that likely co-vary with mental health. Prior research that has explored the benefits of intervention programs among graduate students, such as mindfulness or yoga programs, have been limited by cross-sectional research and/or specific samples (e.g., only studying clinical psychology students; Bamonti et al., 2014; Myers et al., 2012). The findings from these studies suggest that self-care behaviors, such as mindfulness and sleep, may be beneficial for graduate students, but cross-sectional studies do not allow for the consideration of within-person differences (i.e., individuals likely report different levels of behavior and health at different points of measurement) and studies limited to specific samples ignore differences that may exist between groups (e.g., PhD vs. master’s students, engineering vs. social sciences students, first year vs. senior-level students). In other words, several methodological shortcomings may limit the validity and/or generalizability of prior findings.

This research explored 1) how common work stressors experienced by graduate students co-vary with mental health, and 2) whether physical activity can protect graduate students from the negative effects of work stressors (i.e., lower the relationship between work stressors and negative mental health outcomes). Additionally, minimal research has addressed the factors that influence the occurrence of physical activity among graduate students. Thus, this research also explored factors that influence engagement in physical activity (e.g., social support for physical activity, life satisfaction, and non-physical activity leisure-time activities).

Graduate students were recruited to participate in a longitudinal study in which physical activity, mental health, work stressors and potential predictors of physical activity were measured at three time points throughout the Fall 2019 semester. Additionally, some of the
measures used in this research contributed to evaluating the generalizability of occupational stress/distress models for graduate students. It is not clear whether occupational stress models, such as the Jobs Demands-Resources model (Bakker & Demerouti, 2007) or the Effort-Reward Imbalance model (Siegrist, 1996), are appropriate models for evaluating the impact of stressors among students (both undergraduate and graduate students). Recent research suggests occupational health theories may not be appropriate for evaluating stress vs. distress among students who work (Calderwood & Gabriel, 2017). Therefore, this research provided preliminary evidence for future related research.

In summary, this research was designed to provide: 1) new domains of research and theory for the study of graduate students’ well-being 2) information regarding the potential benefits of physical activity among graduate students, and 3) information for practitioners who may be interested in developing intervention programs to improve the mental health of graduate students.

Overview of Conceptual Model

The primary conceptual model for this research includes the work stressors (i.e., role conflict, role ambiguity and work overload) influencing mental health problems (i.e., depression, anxiety and distress). Perceptions of productivity are also included as an outcome in this model. Physical activity moderates the relationship between the work stressors and mental health problems, and between the work stressors and productivity. A supplemental model includes physical activity and the predictors of physical activity (i.e., social support for physical activity, life satisfaction and non-physical activity leisure-time activities). The literature review that follows explores each of these variables in further detail. Figure 1 depicts a conceptual diagram of the primary model and Figure 2 shows a conceptual diagram of the supplemental model.
Graduate Students and Mental Health

Graduate students share similar responsibilities as undergraduate students, such as coursework; but graduate programs also include teaching, research responsibilities and/or internships (Offstein, Larson, McNeill, & Mwale, 2004). At moderate-to-well-funded universities, graduate students might receive funding through a research/teaching assistantship, but it is not uncommon for graduate students to feel overworked, as there is little regulation in the number of hours graduate students should work (Rossouw & Niemczyk, 2013). Given the lack of regulation, it is not uncommon for the work hours of graduate students to fluctuate dramatically, which largely depends on the work obligations a graduate student may have over any given week (Mather-L’Huillier, n.d.).

Given a graduate student’s various demands, it is not surprising that recent research shows graduate students report more mental health problems than the general population. Specifically, Evans et al. (2018) found graduate students were at risk of developing mental health problems, with the reporting of moderate to severe levels of depression and anxiety being six times greater than in the general population. Evans et al. (2018) expanded on earlier work by sampling the general graduate student population rather than just focusing on a specific institution (e.g., Garcia-Williams, Moffitt, & Kaslow, 2014; Graduate Student Happiness & Well-Being Report, 2015). Therefore, mental health problems are not just concentrated at specific institutions but are widespread across various graduate programs. The experience of feeling overly stressed (i.e., distressed) is also very common among graduate students, with
Oswalt and Riddock (2007) finding that 65% of graduate students felt overly stressed. The problems highlighted in these studies have even captured the attention of the national media, with some calling it a “crisis” (Berezow, 2018; Flatherty, 2018).

Unless action is taken, the mental health of graduate students will continue to deteriorate, which can have several long-term implications both for the individuals as well as the system that is perpetuating these negative health behaviors and outputs. Employees with higher levels of depression, anxiety and other mental illnesses have shown decreased productivity (McTernan, Dollard, & LaMontagne, 2013), job dissatisfaction (Nadinloyi, Sadeghi, & Hajloo, 2013) and suicidal thoughts (Nakao, Nishikitani, Shima, & Yano, 2007). These associations might already be present among graduate students and could become stronger if mental illnesses continue to rise. Additionally, many graduate students will become leaders in their respective fields of study and will mentor their own graduate students. It is possible they might perceive mental health problems as the norm in graduate education. The cycle of mental health problems may never end simply because mentors see elevated mental health problems as the norm or a “rite of passage.”

To improve the mental health of graduate students, researchers have explored the benefits of self-care behaviors and intervention programs. However, research results have been mixed. For example, Ayala (2015) examined self-care behaviors, including physical activity and eating habits, and found that such self-care behaviors did not moderate the relationship between stressors and quality of life. Venieris (2017) used various positive psychology interventions to improve well-being but did not find improvement among graduate students.

Some graduate programs have even taken action to address mental health concerns. For example, at the University of Minnesota a combination of graduate students in chemistry, the graduate program director and some mental health professionals collaborated to create events to
increase mental health awareness and provide opportunities for graduate students to reduce distress, such as yoga classes and movie nights (Mousavi et al., 2018). These events and opportunities have led to a more open environment allowing for the discussion of mental health among graduate students and faculty members in the department.

However, methodological concerns call the results highlighted above into question. Ayala (2015) used the Health Promotion Lifestyle Profile II (Walker, Sechrist, & Pender, 1987), which contains several physical activity questions, but not at the same level of detail as a more traditional scale, such as the International Physical Activity Questionnaire (Craig et al., 2003). Also, Ayala (2015) used only psychology graduate students studying clinical science or counseling, thereby limiting generalizability. Venieris (2017) included graduate students from a wide range of disciplines, but had participants complete the intervention during the summer. While many graduate students have responsibilities over the summer, such as research assistantships or internships, they typically do not experience the same level of demands as during the academic year. Additionally, the research reports on graduate programs have not measured beneficial changes (e.g., mental health improvements) as the result of the program. When the changes led to changes in behavior, the impact on mental health was not clear.

While the research reported here was not an intervention study, the research attempted to improve on the methodological shortcomings referred to above by using a more generalizable sample of graduate students and taking multiple measures of physical activity and mental health, concomitant with work stressors, over the course of an academic semester.

**Role Conflict and Ambiguity in Graduate Students**

Role theory “explains roles by presuming that persons are members of social positions and hold expectations for their own behaviors and those of other persons” (Biddle, 1986, p. 67).
Role conflict is defined as “the degree of incongruity or incompatibility of expectations associated with the role” (House & Rizzo, 1972, p. 474), whereas role ambiguity has been defined as “the existence of a lack of clarity in the sent roles” (Schuler, Aldag, & Brief, 1977, p. 112). In the workplace, both role conflict and role ambiguity are mostly studied together. Burnout (Papastylianou, Kaila, & Polychronopoulos, 2009) and depression (Schmidt, Roesler, Kusserow, & Rau, 2014) are common experiences of employees who report higher levels of role conflict or role ambiguity.

Some research has measured role conflict and role ambiguity with regard to the demands of graduate students. For example, early research by Baird (1969) and Baird (1972) found that graduate students were bothered when faculty were ambiguous in their expectations, and such role conflict was associated with psychological withdrawal and distress. Baird (1969) pointed out that these findings were similar to foundational research by Kahn, Wolfe, Quinn, Snoek, and Rosenthal (1964) who studied the effects of role conflict and role ambiguity among employees across several organizations.

Theoretically, role conflict and role ambiguity induce strain through feelings of discomfort and anxiety (Rizzo, House, & Lirtzman, 1970), which are likely experienced by graduate students as a result of role conflict and role ambiguity. Therefore, this early research provided justification for studying role conflict and role ambiguity among graduate students, since some of their experiences are analogous to those of traditional employees.

More recent research has corroborated earlier findings, particularly among psychology students in counseling and clinical-science graduate programs, given the multiple responsibilities expected from these students (e.g., classes, practicum, internship). Olk and Friedlander (1992) found that role conflict and role ambiguity were associated with anxiety, job satisfaction, and
displeasure with supervision among counseling and clinical psychology graduate students.

Nelson and Friedlander (2001) interviewed clinical and counseling psychology graduate students who had negative experiences with their supervisor and found that older students had more responsibilities, which led to an increase in their role conflict. Situations in which a senior supervisor was supervising alongside a student’s main supervisor led to confusion that contributed to role conflict. Other research has examined ways to reduce role conflict and role ambiguity. Graduate students in counseling programs experienced less role ambiguity when supervisors established an environment that fostered a strong working alliance between supervisor and graduate student (Ng & Smith, 2012).

Graduate teaching assistants (GTAs) can experience role ambiguity and role conflict since GTAs are typically assigned a faculty advisor for research responsibilities who may have limited communication with the GTA supervisor. Furthermore, a graduate student may work with multiple faculty, making it unclear what tasks should be completed and how the tasks should be prioritized. In fact, this tension of research and teaching responsibilities from different sources can be detrimental to the successful completion of a graduate degree (Park, 2002). Specifically, Park (2002) interviewed graduate students at a university in the United Kingdom and found that GTAs reported slower completion rates compared to graduate students who did not have to teach. Fatima and ur Rehman (2012) measured the role ambiguity and role conflict of GTAs and found that both were associated with job satisfaction and intention to leave the job. Grady, La Touche, Oslawski-Lopez, Powers, and Simacek (2014) held focus groups and found role conflict was a widespread issue, with one graduate student stating that multiple obligations makes it difficult to prioritize assignments.

**Work Overload among Graduate Students**
Work overload is defined as “having too many role demands and too little time to fulfill them” (Coverman, 1989, p. 967). From this definition, it is important to point out that an individual could have a lot of work relative to others, but if the individual does not perceive the work as too much, the individual is not overloaded and not over stressed. In the general workforce, work overload is often associated with depression (Weigl et al., 2016), anxiety (Jensen, Patel, & Messersmith, 2013), distress (Bolino & Turnley, 2005) and lower job productivity (Motowidlo, Packard, & Manning, 1986).

Like the research on role conflict and ambiguity, minimal research has been reported on work overload among graduate students. Rummell (2015) found that graduate students in clinical psychology spent an average of 54 hours a week on school-related activities, with these hours allocated to many different activities, including doing homework, working on a thesis or a dissertation and completing assistantship duties. About 70% of psychology graduate students reported that a “lack of time” from work/school demands was a barrier to engagement in wellness activities (El-Ghoroury, Galper, Sawaqdeh, & Bufka, 2012). De Meis, Velloso, Lannes, Carmo, and de Meis (2003) interviewed graduate students in Brazil and found work overload to be a common theme among several interviewees, with excessive demands from academic advisors being one of the causes of this overload.

Maville, Kranz, and Tucker (2004) interviewed 12 nurse practitioner students in a graduate program and found that many of those students experienced work overload through their responsibilities as both students (e.g., retain new knowledge) and as employees at their part-time jobs. Several of the students rated their current level of stress in their graduate program as the “highest ever in my life,” and the students varied in the ways they coped, such as through
vent with family and friends or taking antidepressants. These findings align with the negative effects of work overload found in the general workforce.

Graduate students who experience more work overload experience more physical symptoms, such as headaches and trouble sleeping, and emotional difficulties (Mazzola, Walker, Shockley, & Spector 2011; Rummell, 2015). Several factors could protect against the negative effects of work overload, including role clarity (Bliese & Castro, 2000), social support from supervisors or co-workers (Joiner & Bartram, 2004), and transformational leadership (Fernet, Trépanier, Austin, Gagné, & Forest, 2015). However, it is unknown if these factors or other factors, such as physical activity, could help graduate students deal with work overload.

**Physical Activity**

Physical activity is defined as “any bodily movement produced by skeletal muscle that results in energy expenditure” (Caspersen, Powell, & Christenson, 1985, p. 126). This energy expenditure is linked to diminished health problems, such as coronary heart disease and risk of stroke (Reiner, Niermann, Jekauc, & Woll, 2013). Physical activity is different from exercise, which is considered planned physical activity (Caspersen et al., 1985). Thus, by definition, exercise falls under physical activity, such as organized sports and group exercise. Physical activity that typically does not fall under exercise includes travel to work, movement at work and other incidental opportunities to engage in physical activity (Bauman, Phongsaven, Schoeppe, & Owen, 2006). In most of these cases, the primary objective is to get from one destination to another, with physical activity serving as the transportation medium.

Moderate aerobic physical activity can be defined as activity between three metabolic equivalents (METs) and six METs (Hendelman, Miller, Baggett, Debold, & Freedson, 2000). Moderate aerobic physical activities include brisk walking, bicycling slowly and cleaning
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heavily. To understand how much energy is burned, sitting is one MET. Activities that correspond to around four METs, such as walking briskly, lead to four times as much energy burned compared to sitting; and activities that require six METs lead to six times as much energy burned. Vigorous aerobic physical activity is defined as activity greater than six METs. This includes activities such as jogging, tennis and hiking. Light aerobic physical activity is defined as activity less than three METs and this includes walking slowly, washing dishes and sitting while using the computer.

Research has explored how light, moderate and vigorous aerobic physical activity relate to several physiological and psychological outcomes. Lee and Paffenbarger (2000) looked at mortality among Harvard alumni (all men) and found that different levels of physical activity were associated with mortality. Specifically, vigorous aerobic physical activity predicted the lowest levels of mortality when compared to light and moderate, with moderate still being more beneficial than light physical activity. Likewise, strength training has been shown to reduce mortality from serious diseases, such as cancer and diabetes (Kraschnewski et al., 2016).

On the psychological side, the conclusions supporting the benefits of physical activity are equally impressive. Within ten minutes of physical activity, an individual’s mood can improve (Hansen, Stevens, & Coast, 2001). Individuals who engage in more physical activity report a higher quality of life (Gill et al., 2013). Generally, people are aware of the psychological benefits of being physically active. For example, graduate students were interviewed in focus groups on their activities and many of those students cited mental relaxation as a reason for why they exercised (Longfield, Romas, & Irwin, 2006).

When individuals are not engaging in physical activity, they are likely engaging in sedentary behaviors. Sedentary behavior occurs whenever an individual is sitting or lying and
engaging in activity requiring less than 1.5 METs (Shephard, 2012). Common sedentary behaviors include using a laptop, watching television and playing video games. Over the past few decades, sedentary behavior has become more common as today’s transportation systems and workplace environments require less physical activity. This is especially a potential problem among graduate programs as students spend many hours per day sitting in their classes, offices and laboratories. Increased sedentary behavior is associated with the risk of developing cardiovascular disease (Owen, Healy, Matthews, & Dunstan, 2010), a higher waist circumference (de Rezende, Rey- López, Matsudo, & do Carmo Luiz, 2014), and metabolic syndrome (Ford, Kohl III, Mokdad, & Ajani, 2005).

Even those who are physically active are not safe from the negative effects of sedentary behavior. Those who meet the recommended levels of physical activity but still engage in extensive sedentary behavior are still at risk of developing health problems associated with sedentary behavior (the Active Couch Potato phenomenon; Owen et al., 2010). It is not clear why high levels of activity do not counterbalance the negative effects of sedentary behavior, but it is possible the metabolic consequences of sitting or lying are significant even for those who are physically fit.

Compared to the impact of work stressors on mental health, research on physical activity among graduate students is almost nonexistent. Most of this research focuses on self-care behaviors, which may or may not include physical activity (e.g., Ayala, 2015; Myers et al., 2012). Therefore, more research is needed to better understand the amount and impact of physical activity among graduate students (e.g., “What is the average amount of time graduate students spend being sedentary, compared to moderate and vigorous physical activity?”). Such
findings might not only suggest modifications to graduate programs, but also provide knowledge for understanding how work stressors relate to physical activity among graduate students.

**Physical Activity, Mental Health and Productivity**

Physical activity is a potential treatment method for depression and other mental health problems (i.e., anxiety and distress). Depression is difficult to define but it can be characterized by several symptoms, such as an unhappy mood-state, sleep problems, low energy and feeling hopeless (Derogatis, 1977; Nutt, Wilson, & Patterson, 2008). Depression is one of the most common mental health disorders worldwide, with more than 300 million people suffering from depression (World Health Organization, 2018). Depression is considered a major public health burden as its debilitating effects have major consequences on human well-being, the healthcare system, and employee productivity (Hilton, Scuffham, Vecchio, & Whiteford, 2010; Katon, 2011). As stated earlier, graduate students are at an elevated risk of developing depression and other mental health problems (Evans et al., 2018). Therefore, graduate students are at increased risk of developing a mental health disorder that not only affects their work performance, but also their relationships with friends and family.

**Depression.** Not surprisingly, the treatment of depression has been a major focus of research, with a host of treatment and prevention techniques available. The most common is antidepressant drugs, as these are easy to prescribe once an individual meets all the requirements of being depressed. Antidepressant drugs also require the least amount of effort from clinicians. However, the evidence on the overall and long-term effectiveness of antidepressants is mixed (Pigott, Leventhal, Alter, & Boren, 2010). Other treatment methods include psychotherapy and brain stimulation, but as with antidepressants, effectiveness is mixed with the possibility of adverse impact (Linden, 2013).
The relationship between physical activity and depression is well-established, with decades of research showing increased physical activity associated with decreased levels of depression symptoms among clinical and non-clinical samples, including working populations (Brown, Gilson, Burton, & Brown, 2011; Camacho, Roberts, Lazarus, Kaplan, & Cohen, 1991; Mammen & Faulkner, 2013; Ströhle, 2009). However, there is no consensus on the appropriate amount and type of physical activity needed to prevent and/or treat depression. Reviews of the impact of physical-activity interventions on depression have shown negative correlations between physical activity and depression, but these associations vary as a function of the duration, frequency, and type of physical activity (Mammen & Faulkner, 2013). Additionally, research methodology has varied widely across studies, with between-subjects cross-sectional studies being common, compared to within-subject longitudinal designs. More recently, physical activity has been viewed as a way to prevent depression, which has led to more prospective research (i.e., measuring physical activity prior to measuring depression) (e.g., Rothon et al., 2010; Schuch et al., 2018).

**Distress.** While there is still no consensus on a universal definition of stress, it can be defined as “the nonspecific response to any demand” (Taché, 1978, p. 2). While some situations may be considered to be “universally” stressful, such as having to go through a hurricane (this would actually be the experience of distress, or feeling unprepared for the situation), not everyone perceives the same event as stressful and may even appraise the situation differently (Folkman & Lazarus, 1986). For example, some individuals may view taking an important test as a stressor they prepared for and then only feel stress and not distress. On the other hand, other individuals may experience distress because they may not believe they are in control of the
stressor. This is the key difference between stress and distress: the perception of being in control (Geller, 2020).

Stress has the potential to make a person more self-motivated to do more; distress is harmful and likely reduces feelings of self-motivation (Geller, 2020). However, this distinction is rarely made in the research literature, with “positive” stress and “negative” distress typically combined as a measure of reactions to a stressor, such as in the Perceived Stress Scale (PSS; Cohen, 1988), which contains several items that are not considered distress but rather stress.

Acute stress is common, and most individuals can deal with it in small bouts, but stress (whether it is positive or negative) becomes problematic to health if it is experienced chronically (Juster, McEwen, & Lupien, 2010). Chronic stress is associated with a host of physical and psychological problems, including coronary heart disease (Wirtz & von Känel, 2017), declining immune function (Dhabhar, 2014), and dementia (Peavy et al., 2012). Graduate students experience more stressors than the general population (Helmers, Danoff, Steinert, Leyton, & Young, 1997), meaning they are at increased risk for developing these problems.

The impact of physical activity on distress has been studied rather extensively (Netz, Wu, Becker, & Tenenbaum, 2005). Regardless of study design (e.g., cross-sectional, experimental, longitudinal), increased physical activity has been associated with lower levels of perceived distress (Mouchacca, Abbott, & Ball, 2013; VanKim & Nelson, 2013). College students experience many hassles and stressors due to coursework, jobs and extracurricular activities. Nguyen-Michel, Unger, Hamilton, and Spruijt-Metz (2006) found that weekly leisure-physical activity was negatively associated with perceived distress at school.

Sturm (2017) found that both undergraduate and graduate students in occupational therapy benefited from an eight-week yoga intervention with experiences of reduced distress
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over the course of the intervention. Additionally, physical activity has been shown to be comparable to other stress-reducing strategies. Van der Zwan, de Vente, Huizink, Bögels, and de Bruin (2015) randomly assigned participants to five-weeks of physical activity, mindfulness mediation or heart rate variability biofeedback, and found that all three interventions were equally effective at reducing levels of distress.

Anxiety. The relationship between physical activity and anxiety has also been studied extensively (Asmundson et al., 2013; Ströhle, 2009). In fact, many studies include measures of both anxiety and depression, even if only depression or anxiety is the measure of interest. Anxiety has been defined as the uncontrollable disposition to worry (Akiskal, 1998). Like depression, research connections between anxiety and physical activity has varied between clinical and nonclinical populations (Rebar et al., 2015; Rosenbaum, Tiedemann, Sherrington, Curtis, & Ward, 2014). Physical activity interventions targeting anxiety have been shown to reduce anxiety among both clinical and nonclinical populations, although the findings are mixed (Rebar et al., 2015). The mixed findings for clinical populations could be due to the different ways clinical anxiety can manifest itself (e.g., panic disorders vs. phobias), with physical activity affecting each type of anxiety differently (Asmundson et al., 2013).

Findings on the impact of physical activity interventions on anxiety are also mixed in the workplace, with one review finding yoga interventions to be effective at reducing anxiety, but general physical activity interventions did not lead to any improvements (Chu, Koh, Moy, & Müller-Riemenschneider, 2014). This could be due to yoga not only being a form of physical activity, but also having different components, such as meditation, that add a unique contribution to anxiety reduction. It could also be that the individuals included in the research did not have high levels of anxiety. The results could be different in a work population with elevated levels of
mental health problems, such as graduate students. Sturm (2017)’s eight-week yoga intervention for undergraduate and graduate students studying occupational therapy not only found reductions in distress, but also decreases in anxiety. A physical activity intervention for this population may have also been effective, but future research needs to explore how physical activity relates to anxiety among graduate students specifically.

**Productivity.** Physical activity has been studied extensively as a way to improve job productivity in organizations, with mixed findings (Neuhaus et al., 2014). Whereas some studies found physical activity to improve productivity, other studies did not (Neuhaus et al., 2014). Arguments for improvements in productivity include improved mood and cognition following exercise (Mullane, Buman, Zeigler, Crespo, & Gaesser, 2017). Pereira, Coombes, Comans, and Johnston (2015) reviewed interventions in organizations that promoted physical activity and found positive relationships between physical activity and productivity when compliance to the intervention was high, and when the occupation required physical activity, such as lifting objects.

Improved productivity due to physical activity has been studied with mostly medical school students and graduate students in health-related fields. Physical activity among medical school students was associated with better grades (Al-Drees et al., 2016); however, no association between grades and physical activity was found for graduate students in health science (Gonzalez, Hernandez, Coltrane, & Mancera, 2014). Gonzalez and colleagues argue that a limited range of GPAs was likely the reason for their negative findings, suggesting more sensitive measures of performance are warranted.

**Predictors of Physical Activity**

Factors that predict amount of physical activity include gender (Azevedo et al., 2007), age (Trost et al., 2002) time available to exercise (Reichert, Barros, Domingues, & Hallal, 2007),
and social support (Anderson, Wojcik, Winett, & Williams, 2006). Family and/or friends can provide social support for physical activity through different means: instrumental (e.g., paying for a gym membership for a spouse), informational (e.g., telling a friend about an exercise class that is fun), emotional (e.g., checking in with a friend occasionally to see how his or her new exercise routine is going), and appraisal (e.g., reinforcing exercise behaviors by telling a friend that his or her new exercise routine has made a positive change in his or her attitude or appearance) (Sharma, Sargent, & Stacy, 2005). Social support for physical activity from family and friends have both been shown to be important. Eyler et al. (1999) found the benefits of social support for physical activity to be the same from family and friends, suggesting that the support itself is more important than the source. Social support from coworkers has also been shown to lead to increased levels of physical activity (Tamers et al., 2011), showing that just being around individuals who provide support can influence the frequency of health-related behavior.

Life satisfaction (or satisfaction with life) is a measure of how people feel about their life and the direction their life is taking them (Diener, Emmons, Larsen, & Griffin, 1985). Compared to other measures of well-being, life satisfaction is more of an attitudinal/evaluative measure than a hedonic/affective measure. It has been shown to be key to physical and mental health (Siahpush, Spittal, & Singh, 2008), suggesting that it could be a predictor of engagement in physical activity. Research suggests that physical activity is related to life satisfaction. Thome and Espelage (2004) found life satisfaction to be positively associated with physical activity among college students. Likewise, adults who reported higher life satisfaction were more likely to engage in physical activity and other healthy behaviors and were less likely to smoke or drink (Strine, Chapman, Balluz, Moriarty, & Mokdad, 2008).
Additionally, leisure time activities may take away from physical activity opportunities. Adults who watch more television engage in lower levels of physical activity (Mansoubi, Pearson, Biddle, & Cleses, 2014). The development of more advanced technology has provided more choice for non-physical activity. Immigrants to the United States were interviewed in focus groups and many discussed barriers to physical activity, which included time spent with computers, movies and social media (Wieland et al., 2015). Additionally, the more often college students used their smartphones the less often they engaged in physical activity (Kim, Kim, & Jee, 2015). Plus, those students who watched less television engaged in more physical activity (Kwon, Janz, Letuchy, Burns, & Levy, 2015).

**Conceptual Explanations and Hypotheses**

**Work stressors and mental health/productivity relationship.** There are several reasons why role ambiguity, role conflict, and work overload contribute to mental health outcomes. Role theory states that behaviors are driven by expectations (e.g., the typical work expectations for employees; Biddle, 1986). Role ambiguity, role conflict, and work overload can lead employees to engage in behaviors inconsistent with their typical routine, which can be discomfoting and contribute to anxiety (Rizzo et al., 1970). Furthermore, these stressors are a source of uncertainty that can lead to physical strain (e.g., headaches and fatigue; Orpen, 1982), which can lead to depression, distress and anxiety if the physical strain becomes long-term (Capistrant, Moon, Berkman, & Glymour, 2012). The experience of chronic mental health problems alongside work stressors is likely to affect productivity as well, but not beneficially. Based on the research reviewed above, the present research tested the following hypotheses:

**Hypothesis 1:** Role conflict will co-vary positively with 1a) depression, 1b) anxiety, and 1c) distress.
**Hypothesis 2**: Role ambiguity will co-vary positively with 2a) depression, 2b) anxiety, and 2c) distress.

**Hypothesis 3**: Work overload will co-vary positively with 3a) depression, 3b) anxiety, and 3c) distress.

**Hypothesis 4**: Work productivity will co-vary negatively with 4a) role conflict, 4b) role ambiguity, and 4c) work overload.

**Physical activity and mental health/productivity relationship.** Several explanations account for the mental health benefits of physical activity, which likely coincides with improvements in productivity. Some researchers argue that physical activity increases endorphin secretion, which then leads to a reduction in pain and increased sensations of euphoria (Dishman & O’Connor, 2009). Other physiological explanations include: a) the Transient Hypofrontality Hypothesis (Dietrich, 2006), which argues that physical activity decreases neural activity in the prefrontal cortex, a region of the brain responsible for mood and cognition, and b) the Endocannabinoids Hypothesis (Tantimonaco et al., 2014), which argues that physical activity increases the concentration of endocannabinoids, which can lower feelings of pain and decrease negative cognitions.

The Distraction Hypothesis argues that physical activity acts as a distraction to negative stimuli or thoughts an individual may ordinarily have difficulty ignoring (Morgan, 1985). Leisure-time physical activity provides individuals with the opportunity to be active in a context free from work-related or stressful issues that may be on the individual’s mind (Caldwell, 2005). Non-leisure-time physical activity may not allow individuals to ignore these issues as the activity is being completed within the context of the issues or related stressors.
Another explanation considers the environment in which physical activity occurs. The Social Interaction hypothesis argues that physical activity, especially leisure-time physical activity, can take place in a social environment, such as a fitness facility or in a group exercise setting (Malekshahi, Abdoli, Asefirad, & Mohammadi, 2011). Exercising with others provides social support and enables the establishment of personal relationships, which in itself can lower depression (Nezlek, Hampton, & Shean, 2000). Thus, while physical activity itself has physiological benefits, the context in which the physical activity occurs may be just as important. Additionally, physical activity provides a sense of control as the individual is usually choosing to be physically active. This sense of control may lead the individual to appraise stressors as stress (i.e., in his or her control) rather than distress (i.e., out of his or her control). Given these explanations, the following hypotheses were tested:

**Hypothesis 5:** Higher levels of physical activity will co-vary negatively with 5a) depression, 5b) anxiety, and 5c) distress.

**Hypothesis 6:** Higher levels of physical activity will co-vary positively with productivity.

**Physical activity as a buffer against work stressors.** Prior research indicates that physical activity may “protect” employees from the negative effects of work stressors. For example, Burton, Hoobler, and Scheuer (2012) found that the relationship between supervisor distress and abusive supervisor behaviors was diminished by supervisors who engaged in moderate levels of physical activity. In other words, when supervisors experienced high levels of distress, if they engaged in high levels of physical activity, they were less likely to engage in abusive behaviors towards their supervisees compared to supervisors who engaged in low levels of physical activity. Burton et al. (2012) speculated physical activity may be a coping strategy
for supervisors who experience high levels of distress, which leads them to be less abusive toward their supervisees.

Toker and Biron (2012) measured depression and burnout among employees over three time-points and found that an increase in depression and burnout was weaker for those employees who engaged in physical activity compared to those who did not. Additionally, Sliter, Sinclair, Cheung, and McFadden (2014) found physical activity among nurses moderated the relationship between work stressors (e.g., high workload and stressors from patients) and mental health outcomes, including depression and life satisfaction. The relationship between the work stressors and mental health outcomes was attenuated for those nurses who engaged in more physical activity. Given the consistent findings of physical activity being a positive buffer between work stressors and mental health outcomes, the following hypothesis was tested.

**Hypothesis 7**: Physical activity will moderate the relationships between work stressors and mental health/productivity, such that the relationships will be smaller for those who engage in more physical activity.

**Predictors of physical activity.** Social interaction has been shown to enhance physical activity, suggesting that exercising with others can motivate individuals to continue exercising (Al Ayubi, Parmanto, Branch, & Ding, 2014). Anderson, Wojcik, Winett, and Williams (2006) found social support to affect physical activity directly, but they also found self-efficacy and self-regulation to be potential mediators of the relationship. Ayotte, Margrett, and Hicks-Patrick (2010) also found support for self-efficacy and self-regulation to possibly explain the association between social support and physical activity, suggesting that social support could enhance one’s beliefs that they have the potential to be physically active, leading to the regulation of behaviors necessary to engage in physical activity.
Regarding leisure-time activities, if one engages in more non-physical activity leisure time activities (e.g., watching television, using a computer, using social media), then it is likely the individual will not engage in physical activity. Individuals may appreciate physical activity but may prefer other activities that interfere with opportunities to exercise (Floyd, Shinew, McGuire, & Noe, 1994).

In terms of life satisfaction, individuals who feel more satisfied with their lives may want to improve their well-being (Strine et al., 2008). A meta-analysis found life satisfaction and other related constructs were positively associated with long-term health outcomes, such as general health and cardiovascular functioning (Howell, Kern, & Lyubormirsky, 2007). Those individuals who experienced higher life satisfaction likely engaged in several healthy behaviors such as physical activity, which ultimately lead to better long-term health outcomes. Thus, the following hypotheses were tested:

**Hypothesis 8**: Physical activity will co-vary positively with 8a) social support for physical activity and 8b) life satisfaction.

**Hypothesis 9**: Non-physical activity leisure time activities (e.g., watching movies, reading books, talking on the phone) will co-vary negatively with physical activity.

Several trait-like variables might influence one’s engagement in physical activity behaviors. A meta-analysis by Rhodes and Smith (2006) found several personality traits to be positively associated with engagement in physical activity: extraversion and conscientiousness. Conscientiousness is a relevant personality trait to consider among graduate students as it is likely many graduate students score relatively high on conscientiousness because it is a measure of one’s discipline and desire to do well in activities pursued. Individuals who score high on conscientiousness are more likely to act on their intentions and engage in physical activity.
Autonomy is a basic psychological need derived from self-determination theory (Ryan & Deci, 2000). It can be described as one’s perception of choice and free-will and has been associated with engagement and enjoyment in physical activity. Vazou-Ekkekakis and Ekkekakis (2009) found that loss of perceived autonomy in an experimental setting led participants to enjoy physical activity less than those who did not experience a loss in autonomy. The authors further speculated that the negative experience could lead to less physical activity adherence in the future. Additionally, Gunnell, Bélanger, and Brunet (2016) conducted a longitudinal study to assess the relationship between basic psychological needs and health behaviors and found autonomy and physical activity to have a bidirectional relationship (i.e., both engagement in physical activity and autonomy were antecedents and outcomes of the other).

As mentioned throughout this review, graduate students experience higher levels of distress than the general population (e.g., Evans et al., 2018; Oswalt & Riddock, 2007). However, some individuals can handle stress better as they may have a stress-is-enhancing mindset (Crum, Salovey & Achor, 2013). Rather than perceiving stress as debilitating, these individuals may see stress as a challenge and as an opportunity for personal growth. In fact, stress has been shown to lead to several positive outcomes, such as increased mental toughness and an increased sense of meaningfulness (Crum et al., 2013). Although distress has been shown to be negatively associated with engagement in physical activity, individuals with a positive mindset toward stress may not ruminate about stressful events that may otherwise interfere with opportunities to be physically active.
The following research questions were developed to consider the effects of trait-like variables on physical activity among graduate students:

**Research Question 1**: Does conscientiousness co-vary positively with physical activity?

**Research Question 2**: Does autonomy co-vary positively with physical activity?

**Research Question 3**: Does having a perception of stress being enhancing rather than debilitating co-vary positively with physical activity?

**Method**

**Participants**

Participants were graduate students at a large public land-grant university in the Southeastern United States. In order to participate, graduate students had to be full-time students (enrolled in either a masters or PhD program), had a 20-hour assistantship and be 18 years or older. The assistantship could be a graduate research assistantship (GRA), graduate teaching assistantship (GTA), or fellowship funding. Using Hox (2013) as a reference to determine an appropriate sample size, a minimum of 100 participants was an appropriate number of participants to recruit, with the goal to recruit as many participants as possible.

A total of 218 graduate students were recruited and completed at least one survey and were included in all analyses. The mean age of participants was 26.10 (SD = 4.09) and the mean duration of graduate study was 2.68 years (SD = 1.60). Female participants comprised of 63.3% of the sample (n = 138), with one participant not indicating gender. Master’s students comprised of 32.6% of the sample, with the remainder mostly being doctoral students (n = 139) or students in dual degree programs (n = 8). At Virginia Tech, 47% of graduate students are in a doctoral program and 53% in a master’s program (Graduate Education by the Numbers, n.d.). Participants were asked if they had any significant milestones over the semester (i.e., preliminary exam,
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qualifying exams, thesis/dissertation proposal and thesis/dissertation defense). A total of 103 participants had at least one significant milestone, with most of those having just one milestone, although 17 graduate students had more than one milestone to complete over the semester.

Regarding ethnicity/race, 56.0% of the participants reported White, 25.2% reported Asian, 5.0% reported Black or African American, 3.2% reported Hispanic or Latino, and the remainder of participants reported “Other” or multiple ethnicities/races. Participants came from a diverse range of disciplines, with 44.0% reporting they were in an Engineering program (e.g., Aerospace Engineering, Mechanical Engineering, Civil Engineering, Biomedical Engineering), 23.4% reporting they were in a Social Sciences or Humanities program (e.g., Psychology, English, Economics, Sociology), and the remaining participants reporting they were in a natural/life sciences program (e.g., Animal and Poultry Sciences, Dairy Science, Biology, Chemistry). At Virginia Tech, 37% of graduate students are in an Engineering program, 28% are in a Social Sciences or Humanities program, 19% are in a natural/life sciences program while the remainder are part of online/nontraditional programs, such as Information Technology and Graduate Studies (Graduate Education by the Numbers, n.d.).

Measurement of Physical Activity, Depression and Stress

Before outlining the study procedure, it is important to discuss the measurement of physical activity, depression and stress – the three most controversial measures included in this study. First, the debate on subjective vs. objective measures of physical activity sometimes overshadows the research itself. Advances in technology have allowed for the use of more objective measures of physical activity (e.g., Fitbits and ActiGraph watches). While research generally supports the use of objective over subjective measures (Reilly et al., 2008), researchers still use subjective measures because of the reduced cost and ease of using subjective
assessments, especially with a large number of participants (Richardson, Leon, Jacobs, Ainsworth, & Serfass, 1994).

Also, most objective measures have difficulty assessing more complex types of physical activity beyond walking, running or bicycling (e.g., organized sports that may require many lower and upper body movements, such as tennis). Knowing the specific types of physical activity in which individuals engage, such as yoga or dance classes, is important. This important information is typically unavailable with objective measures (Kelly, Ritzsimons, & Baker, 2016; Skender et al., 2016).

Several self-report scales have been developed to measure physical activity, with mixed evidence supporting their utility. Some of the most popular scales include: a) the Global Physical Activity Questionnaire (GPAQ; Armstrong & Bull, 2006), b) the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003), and c) the Minnesota Leisure Time Physical Activity (LTPA) Questionnaire (Taylor et al., 1978). Research has shown adequate reliability in many cases, but evidence for validity tends to be less convincing (Bull, Maslin, & Armstrong, 2009). Individuals tend to underestimate or overestimate their physical activity in surveys, which contributes to validity issues (Klesges et al., 1990; Knox, Musson, & Adams, 2015).

This study collected multiple measures of physical activity over time which may help reduce validity issues. The Concise Physical Activity Questionnaire (CPAQ; Sliter & Sliter, 2014) was tested in a working population and appears to be an adequate measure of physical activity as it captures multiple types of physical activity: aerobic physical activity and muscle-strengthening activities, such as resistance training and yoga. It has also been used in recent organizational studies (e.g., Boyd, Sliter, & Chatfield, 2016; Frone & Blais, 2019). Thus, the CPAQ was used to measure physical activity.
Like physical activity, many depression scales are available. The scales most commonly used include the Hospital Anxiety and Depression scale (HADS; Zigmond & Snaith, 1983), the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977), the Patient Health Questionnaire 9 (PHQ-9; Kroenke, Spitzer, Williams, & 2001), and the Hamilton Depression Rating Scale (HAM-D; Hamilton, 1986). Some scales are more appropriate for general settings, such as the CES-D, while other scales are more appropriate for clinical populations, such as the HADS.

Not all researchers use the most appropriate depression scale for their study, potentially influencing the detection of depressive symptoms. For example, a scale that is more appropriate for clinically diagnosed patients in the general population may not capture the varying subclinical levels of depression among people. This could lead to a “floor effect” in which most participants are at the lower extremes of the clinical scale, making it difficult to capture relevant variance, and leading to underestimating the relationship between depression and physical activity. Therefore, for this study it was important to use a scale appropriate for a non-clinical population. The Depression, Anxiety, and Stress Scales (DASS: Lovibond & Lovibond, 1993) is an appropriate set of measures to use in a non-clinical population. The DASS was chosen to measure not only depression, but also distress and anxiety.

The most commonly used measure of stress is the Perceived Stress Scale (PSS; Cohen, 1988). However, it is mostly used to measure distress. The Stress Mindset Scale (SMS; Crum et al., 2013) has been used to measure how an individual perceives stress (i.e., is it enhancing or debilitating?). Although the PSS was one of two measures of stress alongside the DASS’s distress subscale, one’s perception of stress is likely to influence one’s health behaviors (i.e.,
physical activity). Therefore, the SMS was included in the supplemental model to consider how one’s perception of stress (i.e., enhancing vs. debilitating) influences his/her physical activity.

**Materials**

Each assessment period included a battery of surveys, with demographic questions included in the first assessment. The list of surveys given are listed in Table 1. All surveys except the productivity and leisure activities surveys have been previously used and have demonstrated adequate validity and reliability. All of these surveys are included in Appendix A.

When completing the CPAQ, participants received a score of 0 if they did not engage in the type of physical activity asked, a 1 if they did the activity one day per week or less, a 2 if they did the activity 2 – 3 days per week, a 3 if they did the activity 4 – 5 days per week, or a 4 if they did the activity 6 – 7 days per week. Participants’ responses to Item 3 of the questionnaire, “Vigorous aerobic activity (Ex: Jogging/running, swimming, laps, jumping rope)”, were multiplied by 2.5 (e.g., a score of 3 would be 3*2.5 = 7.5), as advised by Sliter and Sliter (2014).

Productivity was measured on a 0 to 10 scale, with 0 being “not productive at all”, 5 being “somewhat productive” and 10 being as “productive as can be.” Although other measures of productivity were collected (e.g., time spent responding to email, time spent writing manuscripts, time spent reading articles), these were excluded as they did not correlate with any other measures. This included an overall composite score in which time spent on each activity was added together to create an overall “productivity” score. Explanations for issues with the productivity measures are discussed later in the “Discussion” section.

When completing the social support for physical activity scale, graduate students were asked whether they lived with someone (e.g., roommate, spouse, children) or lived alone. If they lived with someone, participants completed an additional scale with identical questions, except
they were asked to consider the people they lived with rather than their friends. Almost a third of the sample did not complete this supplemental scale. Since Eyler et al. (1999) showed friend and family social support for physical activity to have similar effects on engagement in physical activity, only the friends’ social support for physical activity scale was included in the analyses.

[insert Table 1 here]

Procedure

At the beginning of the Fall 2019 academic semester, graduate students were recruited through the graduate student listserv and select departmental listservs (e.g., Psychology, Aerospace Engineering, Biological Sciences) in which permission was obtained. Recruitment started after the first week of classes. All recruitment materials included a link to the first survey. Participants were told that the survey would take 30 to 45 minutes to complete and that the survey included questions about physical activity, work characteristics and psychological well-being. Participants had the opportunity to sign-up and complete the first survey within two weeks. They provided their email addresses in order to receive two follow up surveys throughout the semester. Only individuals who completed the entire first survey were considered for further participation in the study as only those who provided their email at the end of the study were able to be contacted.

Throughout the remainder of the semester, participants completed two more surveys at approximately one-month intervals (i.e., in mid-October and mid-November). The additional surveys included all the same questionnaires from the first survey, excluding the demographic questions. Participants were assigned a study code to use for each follow up survey. Participants had a week to complete the surveys after the initial email and were sent up to two reminder emails to complete the survey. Participants were told they would be compensated with a $5
Amazon e-gift card for each survey they completed (i.e., $15 for completion of all surveys). At the conclusion of the study, participants were emailed either a $5, $10 or $15 Amazon e-gift card, depending on how many surveys they completed. Several graduate students (n = 6) were asked if $5 was an appropriate amount for compensation and all students agreed. The study procedures and materials were approved by the Virginia Tech Institutional Review Board. The approval letter can be found in Appendix B.

**Analytic Approach**

Given the nature of the data (i.e., three measurement points per individual) and the plan to test multiple dependent variables at once, multi-level structural equation modeling (MSEM) was used to conduct all main analyses. All variables at the month-level (i.e., Level-1) were person-mean centered, while all continuous variables at the participant-level (i.e., Level-2) were grand-mean centered. Mean-centering allows for easier interpretation of the predictor variables in the models. Prior to conducting the MSEM models, a confirmatory factor analysis (CFA) using the analysis type “complex” in Mplus (Muthén & Muthén, 1998 – 2017) was conducted with the four mental health measures (i.e., the three DASS measures and the PSS). The analysis type “complex” takes into account the dependency in data (Muthén & Muthén, 1998 – 2017).

Fit was evaluated using normed $\chi^2$ (i.e., $\chi^2/df$), Comparative Fit Index (CFI), Standardized Root Mean Square Residual (SRMR) and Root Mean Square Error of Approximation (RMSEA). Using cutoff values from Hu and Bentler (1999), a CFI value of .95, a SRMR value of .05 and RMSEA value of .06 was used to evaluate the fit of the models. For normed $\chi^2$, values < 3 are considered acceptable (Ullman, 2001). Parceling of the variables was accomplished by aggregating items in the whole scale for all measurements except for measurements from the DASS, which contains subscales of depression, anxiety and distress. Mplus Version 8.3 was used
Results

Descriptive Statistics

Although 218 participants completed the first survey, not all participants completed the second and third surveys. Two hundred and three participants (93 % response rate) completed the second survey, while 188 participants completed the third survey (86 % response rate). Individuals who completed all three surveys were compared to those who only completed one or two surveys. There were almost no differences between those who completed all surveys vs. those who only completed one or two surveys, except for the proportion of students who were of minority status. A higher proportion of participants from minority populations only completed one or two surveys, \( t(216) = -2.47, p = .02 \).

First, the reliability of the scales was measured at each time point, using Cronbach’s \( \alpha \) (Cronbach, 1951). Almost all scales demonstrated acceptable reliability at each time point (i.e., .70; Tavakol & Dennick, 2011), with only autonomy having a reliability of .69 at time one. Given the level of reliability demonstrated across all measurement scales, items were not removed from any of the scales. Reliability scores per scale and point of measurement are provided in Table 2.

[insert Table 2 here]

Next, means and correlations were calculated for each variable included in the analyses. Excluding the DASS, PSS, life satisfaction, CPAQ and self-report measure of productivity scales, scores for each construct were calculated by summing up the scores from each item and
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computing the average in order to create a composite score (e.g., the eight items of role conflict were summed together and the average was computed to create a composite role conflict score). Excluding the DASS, CPAQ and self-report measure of productivity scales, all responses were on a 1 to 5 scale. The items for the role ambiguity scale were all reverse coded as the original items measured lower role ambiguity. Each sub-score from the DASS was calculated by summing together the responses from the 14 items of each subscale. Scores from each item could range from 0 (“Did not apply to me at all”) to 3 (“Applied to me very much, or most of the time”). The score for the CPAQ was calculated by summing together the responses of each of the four items since it is a formative indicator (Sliter & Sliter, 2014).

The mean scores from the DASS distress, anxiety and depression subscales were 12.99 (SD = 8.38), 6.71 (SD = 5.89) and 8.83 (SD = 8.35), respectively. A higher score reflects more distress, anxiety or depression. Crawford and Henry (2003) evaluated the DASS with a large non-clinical population and found the means of the distress, anxiety and depression subscales to be 9.27, 3.56 and 5.55, respectively, which were lower than the scores obtained from the graduate students in this study. This is in line with research showing that graduate students are at heightened risk of developing mental health problems (Evans et al., 2018).

Mean scores for role conflict and role ambiguity were 2.48 (SD = 0.69) and 2.30 (SD = 0.67), respectively. This suggested that on average graduate students experienced role conflict and role ambiguity between “almost never” and “sometimes.” The mean score for work overload was 3.58 (SD = 0.78), suggesting that on average graduate students experienced work overload between “sometimes” and “fairly often.” The average productivity score for graduate students was 6.44 (SD = 1.87). Given that the range of possible scores was 0 to 10, this suggests graduate students generally thought they were at least a little over “somewhat productive.”
Graduate students participated in non-physical activity leisure activities between “almost never” and “sometimes” (overall mean score on time spent on 17 activities was 2.67, SD = 0.43). The mean life satisfaction score was 16.84 (out of a possible 25, $SD = 4.22$). The average graduate student did not experience much social support for physical activity from friends, with the mean being 2.40 (out of a 5 on a 5-point scale, SD = 0.73). To better identify the type of physical activity in which graduate students engaged, the percentage of each type of physical activity was calculated. For light aerobic physical activity, 2.3% of responses reflected no light aerobic physical activity, 14.9% for one day or less a week, 36.6% for 2 – 3 days a week, 24.3% for 4 – 5 days a week and 21.9% for 6 – 7 days a week. For moderate aerobic physical activity, 19.0 % of responses reflected no moderate aerobic physical activity, 30.9% for one day or less a week, 33.3% for 2 – 3 days a week, 12.0% for 4 – 5 days a week and 4.8% for 6 – 7 days a week. For vigorous aerobic physical activity, 29.4% of responses reflected no vigorous aerobic physical activity, 30.2% for one day or less a week, 24.3% for 2 – 3 days a week, 12.5% for 4 – 5 days a week and 3.6% for 6 – 7 days a week. For muscle-strengthening activity, 32.0% of responses reflected no muscle-strengthening activity, 31.8% for one day or less a week, 22.9% for 2 – 3 days a week, 11.1% for 4 – 5 days a week and 2.1% for 6 – 7 days a week. The mean scores and standard deviations of all these variables are given in Table 3.

[insert Table 3 here]

At the between-person level, the work stressors correlated significantly with the mental health outcomes, with higher reported work stressors co-varying with more mental health problems ($rs$ ranging from .13 to .51, all $ps < .05$). Self-reported ratings of overall productivity co-varied negatively with role conflict and role ambiguity ($rs$ -.22 and -.47, respectively, both $p < .05$), but not with work overload. Physical activity did not correlate with any of the work
stressors, but co-varied negatively with anxiety and distress measured from the PSS ($r_s$ -.15 and -.20, respectively, both $ps < .05$) and positively co-varied with life satisfaction and social support for physical activity ($r_s$ .26 and .42, respectively, both $ps < .05$). Results were almost identical at the within-person level, with a few differences. Notably, physical activity co-varied negatively with all of the work stressors, but co-varied negatively only with depression and none of the other mental health measures. Self-report ratings of overall productivity co-varied positively with work overload but did not co-vary significantly with the other work stressors. The between-person and within-person correlations are given in Table 4.

[insert Table 4 here]

**Multilevel SEM Analyses**

Prior to conducting the MSEM, a CFA was conducted, due to the strong correlations between the measures and the interest in creating a latent variable using all the mental health variables. Given the dependency associated with the data, a CFA using the analysis type “complex” was conducted in Mplus. The analysis type “complex” is used to account for dependency among data (i.e., the mental health variables taken multiple times from the same individuals). The model fit for the latent factor was good excluding $\chi^2/df$ and RMSEA: $\chi^2/df = 6.99$, CFI = .98, RMSEA = .10 and SRMR = .02. However, Kenny, Kaniskan, and McCoach (2015) showed issues with RMSEA when dfs are low (for this CFA, df equaled 2). Thus, the mental health variables were modeled under one overall latent variable (henceforth referred to as “mental health”) given the SRMR and CFI had acceptable values. All other variables were included as observed variables in the models. Thus, all MSEM models reported are hybrid models (i.e., includes both a latent construct and observed variables), with the supplemental model being a multilevel path model due to the inclusion of only observed variables.
Additionally, notable differences in correlations occurred at the within- and between-person level. Excluding the relationships between the work stressors and the mental health variables, differences in relationships were found across the levels. Given these differences, models were specified at both the within- and person-level. The between-person specifications were identical to the within-person specifications but were aggregated to the person-level (e.g., the role conflict scores were aggregated for each participant used at the between-level).

The first model included the work stressor variables (i.e., role conflict, role ambiguity, and work overload) as predictors of mental health simultaneously (i.e., depression, anxiety, distress and work productivity). The second model included physical activity as a predictor. The final model included all elements of the second model but considered physical activity as a moderator of the relationship between the work stressors and mental health, as well as the work stressors and productivity.

A supplemental model was tested, with the three predictor variables of physical activity (i.e., life satisfaction, social support for physical activity and non-physical activity leisure-time activities) predicting engagement in physical activity. Conscientiousness, autonomy and perceptions of stress were also included in this model as predictors of physical activity. The results of the first three models are presented in Table 5, with mental health as the outcome. The results of the first three models are presented in Table 6, with productivity as the outcome. The results of the supplementary model are presented in Table 7.
Model 1: Work stressors predicting mental health and productivity. Overall fit of this model was good: $\chi^2/df = 3.71$, CFI$^1 = .92$, SRMR$_{\text{within}} = .05$, SRMR$_{\text{between}} = .05$, RMSEA = .07. At the within-person level, role conflict ($b = 2.07, p < .001$), role ambiguity ($b = 1.82, p < .01$) and work overload ($b = 1.30, p = .05$) were significant predictors of mental health. Role conflict ($b = -0.15, p = .44$) and role ambiguity ($b = 0.00, p = .99$) were not significant predictors of productivity, but work overload positively co-varied with self-report ratings of productivity ($b = 0.36, p = .02$). Thus, those who reported being more overloaded with work rated their productivity higher than those who were less overloaded with work.

At the between-person level, role conflict ($b = 2.12, p < .001$), role ambiguity ($b = 4.60, p < .01$) and work overload ($b = 1.70, p = .03$) were significant predictors of mental health. Role conflict ($b = -0.47, p = .03$), role ambiguity ($b = -1.07, p < .001$) and work overload ($b = 0.37, p = .03$) were significant predictors of productivity. Those who reported experiencing more role conflict and role ambiguity reported lower levels of productivity, whereas those who experienced more work overload reported higher levels or productivity.

Hypotheses 1 – 3 were supported, as positive associations between the mental health outcomes and role conflict, role ambiguity and work overload were hypothesized. **Hypothesis 4** was partially supported: at the within-person level there were no negative associations between the work stressors and productivity, with the work overload and productivity association being in the opposite direction hypothesized. However, at the between-person level role conflict and role ambiguity were positively associated with mental health problems, even though the work overload association at the between-person level was also in the opposite direction hypothesized.

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$^1$ Taasoobshirazi and Wang (2016) showed that CFI is influenced by sample size, with smaller sample sizes associated with lower CFI values.
Model 2: Work stressors and physical activity predicting mental health and productivity. Overall fit of this model was good: $\chi^2/df = 3.41$, CFI = .92, SRMR\textsubscript{within} = .05, SRMR\textsubscript{between} = .05, RMSEA = .06. At the within-person level, role conflict ($b = 2.09, p < .001$), role ambiguity ($b = 1.83, p < .01$) and work overload ($b = 1.31, p = .05$) were significant predictors of mental health. Role conflict ($b = -0.16, p = .42$) and role ambiguity ($b = 0.00, p = .98$) were not significant predictors of productivity, but work overload co-varied positively with self-report ratings of productivity ($b = 0.36, p = .02$). Physical activity was not associated with mental health ($b = 0.03, p = .77$) nor with productivity ($b = -0.01, p = .66$).

At the between-person level, role conflict ($b = 2.09, p = .02$), role ambiguity ($b = 4.49, p < .001$) and work overload ($b = 1.65, p = .03$) were significant predictors of mental health. Role conflict ($b = -0.46, p = .03$), role ambiguity ($b = -1.04, p < .001$) and work overload ($b = 0.38, p = .03$) were significant predictors of productivity. Physical activity was not associated with mental health ($b = -.18, p = .10$) nor with productivity ($b = 0.05, p = .08$). Thus, Hypotheses 5 and 6 were not supported since physical activity did not co-vary with mental health nor productivity, respectively.

Final model: Physical activity as a moderator of the work stressors and mental health and productivity relationships. Initially, an interaction term was created for each of the work stressors with physical activity at the within and between-person levels. However, the only two interactions found to be significant were those between 1) role ambiguity and physical activity with mental health as the outcome at the within-person level, and 2) role conflict and physical activity with mental health as the outcome at the between-person level. All other non-significant interaction terms were removed for model parsimony. Thus, the final model included all three work stressors and physical activity, but only included the interactions between physical
activity and role ambiguity at the within-person level and physical activity and role conflict at the between-person level. Overall fit of this model was good: $\chi^2/df = 3.09$, CFI = .92, SRMR\text{within} = .05, SRMR\text{between} = .05, RMSEA = .06.

At the within-person level, role conflict ($b = 2.06, p < .001$), role ambiguity ($b = 1.99, p < .01$) and work overload ($b = 1.32, p = .04$) were significant predictors of mental health. Physical activity ($b = 0.03, p = .79$) was not a significant predictor of mental health. The interaction between physical activity and role ambiguity was significant ($b = -1.20, p < .01$). Role conflict ($b = -0.16, p = .42$) and role ambiguity ($b = -0.01, p = .98$) were not significant predictors of productivity, but work overload co-varied positively with self-report ratings of productivity ($b = 0.36, p = .02$). Physical activity did not co-vary with self-report ratings of productivity ($b = -0.01, p = .66$).

At the between-person level, role conflict ($b = 2.33, p = .01$), role ambiguity ($b = 4.51, p < .001$) and work overload ($b = 1.62, p = .03$) were significant predictors of mental health. Physical activity ($b = -0.19, p = .07$) was not a significant predictor of mental health. The interaction between physical activity and role conflict was significant ($b = -0.32, p = .03$). Role conflict ($b = -0.46, p = .04$), role ambiguity ($b = -1.05, p < .001$) and work overload ($b = 0.38, p = .03$) were significant predictors of productivity. Physical activity did not co-vary significantly with self-report ratings of productivity ($b = 0.05, p = .09$).

To better interpret the interactions, simple slopes were calculated for the moderator variable (i.e., physical activity) at one $SD$ below the mean, the mean and one $SD$ above the mean using Mplus. This was first calculated for the within-person interaction (i.e., physical activity moderating the relationship between role ambiguity and mental health). The slope values at one $SD$ below the mean and at the mean were 3.96 and 1.99, respectively (both $ps < .01$). The simple
slope at one $SD$ above the mean was 0.02 ($p = .98$). In other words, when individuals engaged in low-to-moderate levels of physical activity during any given month, higher levels of role ambiguity also co-varied with high levels of mental health problems. However, when individuals engaged in high levels of physical activity during any given month, role ambiguity had no relationship with mental health problems, even if the individual experienced high levels of role ambiguity.

The same process was repeated for the between-person interaction (i.e., physical activity moderating the relationship between role conflict and mental health). The slope values at one $SD$ below the mean and at the mean were 3.65 and 2.33, respectively (both $ps < .01$). The simple slope at one $SD$ above the mean was 1.02 ($p = .30$). In other words, individuals who generally engaged in low-to-moderate levels of physical activity generally experienced higher levels of mental health problems due to role conflict. However, individuals who generally engaged in high levels of physical activity did not experience higher levels of mental health problems, even if they experienced high levels of role conflict. Overall, Hypothesis 7 was partially supported since physical activity moderated the association between role ambiguity and mental health at the within-person level and between role conflict and mental health at the between-person level, but physical activity did not moderate any relationships that included productivity or work overload.

**Exploratory model.** Since demographic questions were included in the first survey, an exploratory model included the demographic variables at the participant-level. These variables were gender, age, area of graduate study, year in graduate school, degree-type (i.e., master’s vs. PhD), graduate student milestones and ethnicity. Their addition was justified, since several of these variables have been shown to co-vary with mental health. However, the only significant
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covariate found was gender. Thus, following the suggestions of Carlson and Wu (2012), only
gender was retained for further analyses.

Overall model fit of the final model with gender included as a covariate was good: $\chi^2/df = 3.07$, CFI = .91, SRMR_{within} = .05, SRMR_{between} = .05, RMSEA = .06. At the within-person level, role conflict ($b = 2.06$, $p < .001$), role ambiguity ($b = 1.99$, $p < .01$) and work overload ($b = 1.32$, $p = .04$) were significant predictors of mental health. Physical activity ($b = 0.03$, $p = .78$) was not a significant predictor of mental health. The interaction between physical activity and role ambiguity was still significant ($b = -1.03$, $p < .01$).

At the between-person level, role conflict ($b = 2.50$, $p < .01$) and role ambiguity ($b = 4.23$, $p < .001$) were significant predictors of mental health. Work overload ($b = 1.29$, $p = .07$) was no longer a significant predictor of mental health. Physical activity ($b = -0.18$, $p = .08$) was not a significant predictor of mental health. The interaction between physical activity and role conflict was still significant ($b = -0.30$, $p = .03$). Gender co-varied significantly with mental health ($b = 2.87$, $p < .001$). Since male participants were coded as 0 and female participants were coded as 1, female graduate students reported more mental health problems than male graduate students.

To better understand the gender differences, the mean scores between female and male graduate students were compared. The overall mean DASS scores for depression, anxiety and stress for male participants during the study were 9.88 ($SD = 6.73$), 5.56 ($SD = 5.23$) and 7.18 ($SD = 6.81$), respectively. The overall mean DASS scores for depression, anxiety and stress for female participants during the study were 14.92 ($SD = 7.63$), 7.64 ($SD = 5.69$) and 9.95 ($SD = 8.05$), respectively. Men had a mean PSS score of 25.89 ($SD = 5.54$), whereas women had a mean PSS score of 30.03 ($SD = 6.19$). All mean differences were significant (i.e., $ps < .05$).
Supplemental model: Three predictors of physical activity predicting physical activity engagement. In the supplemental model there were no latent variables since only physical activity was the outcome of interest (i.e., the supplemental model was a multilevel path analysis model). Life satisfaction, social support for physical activity, non-physical activity leisure-time activities, conscientiousness, autonomy and stress mindset were all included as within- and between-person predictors of physical activity.

The model was saturated (df = 0), so model fit could not be evaluated. At the within-person level, life satisfaction ($b = 0.07, p = .34$), non-physical activity leisure-time activities ($b = 0.48, p = .36$), stress mindset ($b = -0.35, p = .51$), conscientiousness ($b = 0.07, p = .34$) and autonomy ($b = 0.00, p = 1.00$) were not significant predictors of physical activity. Social support for physical activity ($b = 1.11, p < .01$) was a significant predictor of physical activity. At the between-person level, life satisfaction ($b = 0.12, p = .11$), non-physical activity leisure time activities ($b = -0.42, p = .56$), conscientiousness ($b = 0.62, p = .18$) and autonomy ($b = -0.45, p = .50$) were not significant predictors of physical activity. Social support for physical activity ($b = 2.46, p < .001$) and stress mindset ($b = 0.97, p = .01$) were significant predictors of physical activity.

Hypothesis 8 was partially supported since social support for physical activity was positively associated with physical activity at the within- and between person levels, but life satisfaction was not associated with physical activity. Hypothesis 9 was not supported: non-physical activity leisure time activities did not co-vary negatively with physical activity. The answer to the first two Research Questions: conscientiousness and autonomy did not co-vary with physical activity. The answer to the third Research Question: stress mindset co-varied with physical activity at the between-person level.
Exploratory model. An exploratory model including the demographic variables at the participant-level was also conducted for the supplemental model. Since several of these variables have been shown to co-vary with physical activity, their inclusion was justified. However, none of the covariates were significantly associated with engagement in physical activity. Therefore, the original model with no covariates was kept.

Discussion

Summary of the Findings

Overall, the findings showed role conflict, role ambiguity and work overload to co-vary positively with mental health problems among graduate students. The findings for productivity were more mixed at the within-person level. When considering within-person differences, graduate students who perceived they had more work to complete (i.e., work overload) were more likely to report that they were more productive. This finding was in the opposite direction than originally hypothesized. However, this finding is not surprising because it could be expected that students who are working a lot would feel more productive, even if they perceive the deadlines are too short or they have too much to do. It is possible graduate students who feel overloaded with work also feel productive, even if they do not produce a tangible output at the end of the day. However, it was surprising to find that role conflict and role ambiguity were not associated with perceptions of productivity at the within-person level. This meant when graduate students had a month in which they experienced higher levels of role conflict or role ambiguity, they did not report lower levels of perceived productivity.

At the between-person level, the findings for the work stressors and productivity were more consistent with findings from prior research (e.g., Malik et al., 2013; Motowidlo et al., 1986), with higher levels of role conflict and role ambiguity associated with lower perceptions of
productivity. Higher levels of work overload were associated with higher perceptions of productivity, which replicated the within-person finding, but the former two associations were not significant at the within-person level. It is not uncommon for associations between variables to differ when considering them at multiple levels (e.g., Wardell, Ramchandani, & Hendershot, 2015). One possible explanation could be that work stressors have an accumulating effect on productivity. In other words, one bad month is not enough to influence perceptions of productivity. Consistently experiencing negative work stressors over the course of the semester might be necessary for productivity to be significantly influenced.

Physical activity did not co-vary with mental health (except for several of the correlations at the within- and between-person levels). This is surprising given the array of research over the past several decades showing the positive benefits of physical activity (Brown et al., 2011; Camacho et al., 1991; Mammen & Faulkner, 2013; Ströhle, 2009). Although evidence of the generalizability of the benefits of physical activity has been shown (Mammen & Faulkner, 2013), the overall effectiveness of physical activity on human welfare have been mixed. An earlier meta-analysis (Schlicht, 1994) found physical activity only led to a very small reduction in anxiety.

Rebar et al. (2015) conducted a meta-analysis of meta-analyses (i.e., meta-meta-analysis), and found physical activity had a moderate anti-depressive effect and a small anti-anxiety effect among nonclinical populations. In other words, physical activity is beneficial, but the effects are not as substantial as expected when considered at the meta-analytic level of analysis. Additionally, Myers et al. (2012) evaluated the effects of several self-care behaviors among graduate students and found physical activity was not associated with lower levels of perceived distress. Perhaps a positive relationship between physical activity and mental health is dependent
on boundary conditions (e.g., whether a graduate student has a good social support system, engages in group or individual physical activity, and is physically fit).

Additionally, physical activity did not co-vary significantly with productivity. Although positive associations have been found between physical activity and productivity, the overall findings have been mixed (Neuhaus et al., 2014; Pereira et al., 2015). This research was not the first to find no association between physical activity and productivity. Gonzalez el. (2014) found that physical activity did not improve academic performance among health science graduate students. It is possible an underlying personality trait explains why the findings for the relationship between physical activity and productivity is poorly established. Perhaps those who view physical activity as beneficial adopt a mindset that allows them to work harder and feel more productive. On the other hand, those who view physical activity indifferently or even negatively, may have a mindset or attitude that physical activity interferes with work, thereby lowering their overall perception of personal productivity.

The “buffering” hypothesis of physical activity was partially supported. Specifically, physical activity buffered against the negative effects of role ambiguity at the within-person level but did not buffer against role conflict and work overload. At the between-person level, physical activity moderated the relationship between role conflict and mental health. Physical activity did not moderate any of the work stressors or productivity relationships. Although no main effects for physical activity were found, the moderation findings suggest physical activity provides benefits, but possibly only when it occurs at relatively high levels (i.e., low and moderate levels of physical activity are not enough to reduce the negative effects of work stressors). There are several explanations for these findings.
Role ambiguity deals with understanding one's actual job responsibilities (e.g., what is required for the person to do on a daily or weekly basis). For graduate students, this could be understanding their responsibilities in the research lab (e.g., should they be in the lab for a set period of time during the week, should they hold office hours for a certain amount of time during the week, how much time should be allocated to research and teaching?). Even when graduate students are done with their work for the day, they may go home and think about what they could have done during the day or what they could be doing at night because their advisor was not clear about their daily responsibilities. In other words, graduate students may engage in rumination as they repeatedly think about their work issues but are not able to develop a concrete plan to address those issues. Rumination has been shown to be associated with higher levels of depression, anxiety and distress (McLaughlin & Nolen-Hoeksema, 2011).

Even if graduate students are extremely unsure of their responsibilities, regular physical activity provides welcomed certainty or personal control within a context of uncertainty and role ambiguity. Perhaps this is why the association between role ambiguity and mental health was non-significant when individuals exercised more. However, it is not clear why the moderation effect was not replicated at the between-person level. It is possible that physical activity only temporarily alleviates the negative effects of role ambiguity. In other words, physical activity may help buffer the effects during a difficult month, but for graduate students who regularly experience role ambiguity, regular physical activity may not be enough.

Physical activity did not moderate the association between role conflict and mental health at the within-person level, but it did moderate the association at the between-person level. While role ambiguity relates to uncertainly, role conflict reflects competing roles graduate students may experience, such as deciding how much time to allocate toward teaching vs. research and
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scholarship. Olk and Friedlander (1992) found that role ambiguity among graduate students decreased as graduate students learned more about their daily responsibilities. The stress from role ambiguity could occur intermittently, rather than accumulate over the course of the semester. Role ambiguity has more short-term effects that might come and go as a function of periodic change.

On the other hand, role conflict might not vary or decrease to the same extent as role ambiguity. Graduate students are always experiencing role conflict, no matter their year in graduate school. In fact, more advanced graduate students are expected to experience more role conflict than beginning graduate students (Olk & Friedlander, 1992). Even if graduate students have gotten used to their work responsibilities, they may always experience conflict, especially during semesters when they teach or have a job outside of their academic department. Therefore, graduate students need to be physically active to avoid the negative effects of role conflict. Being more physically active for a short period of time may not be enough to buffer against role conflict.

Additionally, the only significant covariate included in the final model was gender. Women reported more mental health problems than men. The gender difference supports prior research that found women to be at higher risk of developing depressive and anxiety disorders (e.g., Afifi, 2007; Halonen, Koskinen, Varje, Kouvonen, Hakanen, & Väänänen, 2018; Seedat et al., 2009). There are a couple explanations for why women experience higher levels of mental health problems. Compared to men, women tend to ruminate more (Johnson & Whisman, 2013). Women may also be more likely to report higher levels of psychological problems and seek help for these problems than men (Piccinelli & Wilkinson, 2000). Since graduate students are already
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at an elevated risk of developing depression and anxiety disorders, this finding suggests the risk for female graduate students could be even higher.

The findings for the supplemental model were mixed, but two clear predictors of physical activity emerged: social support for physical activity and a mindset that stress is enhancing. The former finding has been demonstrated across different populations (Beets, Cardinal, & Alderman, 2010; Eyler et al., 1999), so replicating the finding among graduate students strengthens the importance of social support for influencing engagement in physical activity. Even after including several demographic covariates, such as completing a significant milestone or being in a PhD or master’s program, the association was still significant. This suggests that even if graduate students are having a busy semester or are part of an intensive program of study, they are more likely to engage in physical activity if their friends provide motivation or help plan and support an exercise routine. Future research may also want to consider the role of the university (e.g., how well-being programs at universities advertise opportunities for graduate students to engage in physical activity).

Although the connection between a mindset or expectation that stress is enhancing and engagement in physical activity was not as clear as the association with social support for physical activity, it is still an important connection to consider. Those with a mindset that stress is enhancing are likely to also be more resilient and mentally tough (Crum et al., 2013), dispositions that can help individuals deal with stressful events. They may also be more optimistic, enabling them to look forward to a positive future. Rather than let a rejection letter from a submitted manuscript or a failed lab experiment lead to distress and potential rumination or engagement in unhealthy behavior, those graduate students who embrace stress as a motivator might be more likely to seek out healthy behaviors as a way to stifle distress. Physical activity
could be one of several other activities these individuals perform in order to prevent distress from ruining their day.

The non-significant relationships were surprising, notably between physical activity and life satisfaction, given consistent findings of a positive association between physical activity and life satisfaction (Thome & Espelage, 2004; Wiese, Kuykendall, & Tay, 2018). Although the within-person correlation between physical activity and life satisfaction was nonsignificant, the between-person correlation was significant. However, when all variables were considered, the relationship between physical activity and life satisfaction became nonsignificant. In general, life satisfaction may be a useful predictor of physical activity when not taking other variables into account, but when including other variables such as social support for physical activity and perception of stress as enhancing, it becomes less important.

Conscientiousness, autonomy and non-physical activity leisure-time activity were also found to have non-significant relationships with physical activity at the within- and between-person levels. High conscientiousness among graduate students may just lead to a greater focus on work, rather than an increase in physical activity that has been found with other samples. Although the relationship between conscientiousness and productivity was not examined explicitly, the correlation at the between-person level was $r = .38$ and at the within-person level it was $r = .17$, both $p < .001$. This supports research showing that conscientiousness is a valid predictor of productivity in the workplace (e.g., Barrick & Mount, 1991).

Autonomy did not correlate with physical activity at the between- or within-person levels. As with conscientiousness, autonomy significantly correlated with productivity, suggesting graduate students who feel they have more choice may choose to do extra work rather than increase their amount of physical activity. The alternative activities in which graduate
students engage in did not predict their engagement in physical activity. Graduate students who engage in many activities may still be able to find time to exercise, while those who do not engage in many activities (including physical activity) may be more focused on their graduate work.

**Strengths and Limitations**

The inclusion of three measurement periods enabled the consideration of within-person differences. Given how graduate student demands could change from the beginning to the end of a semester, it is important to take into account fluctuations in work stressors and health over several months. This study found many similarities at the within- and between-person levels, but there were also several differences across the two levels that could only have been accounted for with a longitudinal data approach.

The sample of graduate students included in the study was diverse. A third of the participants were master’s students with the remainder being PhD students or in a dual degree program. Thus, the results of the study apply to both PhD- and master’s-level students. Prior research on graduate students had participants limited to either PhD or master’s level. However, it is important to note the percentages were not truly representative of the number of graduate students in master’s and PhD programs at Virginia Tech since 53% are in master’s programs and the remainder are in PhD programs. Nevertheless, including graduate students from both master’s and PhD programs strengthens generalizability.

The graduate students in the present research represented a wide range of disciplines, ranging from English to Aerospace Engineering. This is an improvement from studies that limited their participants to one discipline. The percentage of students in each discipline did not align perfectly with the overall Virginia Tech percentage, but arguments for generalizability are
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stronger than most prior research. The participants were also at various stages in their graduate education, from first-semester students to some in their 7th year. Thus, even a more senior-level student is not immune to the negative effects of work stressors and could benefit from engaging in physical activity.

Additionally, weather and seasonal factors were controlled for by collecting data over the same time period for each participant. Specifically, data were collected over the Fall semester for everyone, rather than collecting a subset during the Fall and Spring academic semesters. Type of season has an influence on the development of depression (i.e., seasonal affective disorder; Rosenthal et al., 1984). By only collecting data during the Fall, it is possible to rule out the effects of season on mental health. Lastly, by only collecting data from Virginia Tech graduate students, it was possible to control for access to physical activity opportunities, such as fitness facilities and outdoor activities.

A few limitations of this research should be noted. First, all measures were from subjective self-report surveys. Participants are subjected to recall bias if they are asked to report their feelings or events that occurred in the past (Levine & Safer, 2002). Participants were asked to report how they felt over the past week when completing the DASS and over the past month for the PSS. The original scales used these time intervals and the decision was made to not modify the original instructions. Even though the time periods differed, the PSS was strongly correlated with the subscales of DASS, suggesting it did not matter if the time period was the same or different for the surveys. Additionally, given that individuals have been shown to overestimate or underestimate their levels of physical activity in prior research (Knox et al., 2015), it is possible participants overreported or underreported their level of physical activity engagement.
Although the CPAQ was selected due to its inclusion of various types of physical activity, two major limitations of the survey are noteworthy: 1) it only considers consecutive physical activity of 20 minutes and 2) it does not consider extreme levels of physical activity. Some individuals may take walk breaks during the day, but these walk breaks may only last 15 consecutive minutes. These walk breaks would not count for participants, even if they went on multiple walks during the day. Even brief periods of physical activity (i.e., less than 15 minutes) have been shown to provide benefits (Hansen et al., 2001), so those 15 minutes should not be ignored. Given that the Physical Guidelines for Americans counts all minutes of physical activity regardless of duration, it is impossible to assess how many graduate students truly met the recommended level of physical activity.

At the other extreme, the CPAQ does not distinguish between physical activity sessions over 20 minutes, so it is possible respondents in the study exercised for only 20 minutes per session, while other respondents exercised for an hour or more per session. These respondents were treated the same in the analyses. La Gerche and Prior (2007) argued that physical activity and well-being resembles the inverted U-curve commonly seen in different areas of research (e.g., stress and performance, Westman & Eden, 1996). In other words, there are risks for low levels of physical activity, but also similar risks for high levels of physical activity (e.g., increased risk of physical health problems, lowered mental health, higher mortality rate). It would have been beneficial to separate the extreme exercisers from the less extreme ones.

Also, individuals are not very accurate at providing self-reports of productivity (Donaldson & Grant-Vallone, 2002). This is possibly why the productivity measures (excluding the overall rating of perceived productivity) did not correlate with any of the variables of interest and were not considered in any of the models. Given the multitude of demands graduate students
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experience, it is difficult for graduate students to provide a reliable estimate of how much time they spend reading articles, completing homework and writing manuscripts because there is likely significant overlap in the time spent on these activities. This is possibly why these items could not be included in the analyses: graduate students do not keep track of the specific amount of time they spend on various activities, with overlap possibly occurring between several of the activities (e.g., graduate students may include reading articles as part of writing a manuscript, with responding/reading email occurring intermittently during the process).

However, graduate students are a unique work sample in which it would have been very difficult (but not impossible) to collect reliable measures of productivity from other sources (e.g., a friend, advisor, roommate or spouse). The mean reported time spent doing work at home per week was 11.05 hours ($SD = 9.87$), with a range of 0 to 60 hours. This means graduate students are spending a significant amount of time doing academic work at home, with some possibly only going to their department building or lab for meetings. If these students live with roommates, partners or family members, it would be possible to get an estimate of how much time these students spend doing their schoolwork. But how could they be sure a graduate student is actually doing the required work rather than non-work activities (e.g., playing video games, watching Netflix, shopping online), especially if the graduate student has a private room for work?

This same problem exists in an office or lab setting since many graduate students have designated areas to work where it is possible to avoid interaction with colleagues or advisors for many hours. Unless the person providing the other-report is checking in on the graduate student hourly, it is possible they are overestimating the amount of work a graduate student is
completing, especially if no tangible product is produced at the end of the day (which is likely a common occurrence for many graduate students).

Several other variables could have been considered as a determinant of mental health or work stress. Whether a graduate student has a family and/or a partner/spouse is likely to influence his or her levels of work stress and/or mental health. The intense academic and research demands on a graduate student can make family-life challenging for those with a spouse and children. Work-family conflict has been shown to co-vary with many of the variables examined in this study, such as mental health, work stressors and even physical activity (Allen & Armstrong, 2006).

Income, type of assistantship, overall physical health and primary mode of transportation could have also been considered. Myers et al. (2012) found that graduate students with lower income reported more distress. Graduate students do not make a lot of money compared to full-time employees. However, stipend amount varies across disciplines due to departmental funding. Even taking yearly income into account may not be enough as some graduate students might receive aid from their parents while other graduate students do not receive such financial assistance and might have to take out loans.

Furthermore, the type of assistantship (i.e., GTA, GRA or fellowship was not considered). Participants were asked if they had an assistantship, but they did not have to provide their specific assistantship. Given many graduate students are responsible for conducting research, it is possible graduate students with a GTA work longer hours than graduate students who have a GRA or fellowship as GTA’s have the added responsibility of teaching. If GTAs have more responsibilities, it is likely they may report experiencing more work stressors.
Moreover, an individual’s physical health is likely to influence his or her engagement in physical activity. A graduate student may wish to exercise but might have to limit the amount of time or intensity of his or her workouts due to a chronic health condition. In fact, the physical health condition likely has its own effects on mental health (Hare, Toukhasti, Johansson, & Jaarsma, 2014).

Active travel is a form of transportation in which physical activity is used to travel from one destination to another. For example, individuals who walk or ride a bicycle to work are engaging in active travel. Active travel improves psychological health outcomes, such as mood and depression (Glasgow, Le, Geller, Fan, & Hankey, 2019; Insall, 2013). Graduate students who engage in more active travel may arrive to work in a better mood, which may act as a buffer against a negative work stressor. Likewise, engaging in active travel after work may help graduate students detach from their work demands and replenish their resources. It is possible some graduate students engage in active travel on a regular basis, but without being explicitly asked, they may not have considered active travel in the context of the CPAQ.

Additionally, the study sample was limited to one university, which impacts the generalizability of the findings. Location has been shown to be an important co-variate of mental health, with mental health problems being more pronounced in cities when compared to rural environments (Paykel, Abbott, Jenkins, Brugha, & Meltzer, 2000). Given the graduate students in this sample attend a university in a more rural environment, the findings could be different at universities in urban settings. The factors associated with living in an urban environment, such as increased noise, pollution and population density, are possible explanations for the association between increased mental health problems and urbanization (Gruebner et al., 2017). Even though graduate students at other universities are likely to experience similar levels of work stressors as
many programs have similar expectations for graduate students, a graduate student who must live with four other roommates to afford rent and commute by train daily might have a different perception of daily stressors than a graduate student who lives on their own and can drive to work every day.

**Implications and Future Directions**

The results of this study provide several directions for future research, along with implications for research examining work stress within and outside the context of graduate programs. Calderwood and Gabriel (2017) have argued that work stress models, such as the job demands-control model (Karasek, 1979), may not be appropriate for student samples. Although none of the major models were directly tested in this research, the findings showing that role conflict, role ambiguity and work overload had negative effects on mental health support a plethora of research showing that work stressors negatively influence employee health (Ganster & Rosen, 2013). The associations revealed in this research provide evidence that graduate students are probably more closely related to traditional employees than with undergraduate students, and work stress researchers may want to consider testing their models with graduate students.

Physical activity is not the only health behavior that is likely to influence the mental health of graduate students. Since graduate school is a stressful time for many individuals, other health behaviors, such as alcohol consumption, is likely to be more prevalent among some graduate students than others. Alcohol could possibly exacerbate the negative effects of work stressors, with the association between work stressors and mental health being stronger for graduate students who consume higher levels of alcohol. Indeed, higher levels of alcohol consumption have been associated with increased mental health problems among employees.
PHYSICAL ACTIVITY AMONG GRADUATE STUDENTS

(Koopman, Wanat, Whitsell, Westrup, & Matano, 2003), which could also be true for graduate students who are heavy and/or binge drinkers.

However, alcohol consumption in moderation may buffer the negative effects of the work stressors graduate students experience. Quintana, Guastella, McGregor, Hickie, and Kemp (2013) found individuals who consumed alcohol in moderation had increased heart rate variability (HRV). Increased HRV is associated with lower levels of depressive and anxious symptoms (Kemp & Quintana, 2013). Thus, alcohol may be a protective factor for graduate students, but only when it is consumed in moderation.

Although social support for physical activity was considered, more general social support was not considered. Friends and family can influence many aspects of life for graduate students. Given the purpose of this research, it made sense to only consider social support for physical activity. However, future research should explore the potential benefits of general social support. Hefner and Eisenberg (2009) measured social support among college students and found that those who perceived their social support as being lower quality were more likely to experience mental health problems compared to those who perceived a higher quality of social support. Like physical activity, higher quality social support may buffer against the negative effects of work stressors.

Lastly, graduate programs should be interested in the findings of this study. Graduate programs have a stake in both the psychological well-being and the performance of graduate students, as issues in one or both are likely to affect the recruitment and retention of students. Learning what factors could prevent work stressors from turning positive stress into negative distress can inform the development of effective intervention programs to improve the mental health and productivity of graduate programs. Given that high levels of physical activity were
shown to protect graduate students from high levels of role conflict and role ambiguity, graduate programs should seriously consider developing physical activity interventions for their graduate students.

**Conclusion**

Prior research of work stress has largely ignored a population of employees: graduate students. The findings of this research showed graduate students should be considered full-time employees and should not be ignored by work stress researchers: graduate students experience work stressors and these stressors influence their mental health. Although some inconsistencies occurred in the model results, increased physical activity emerged as a potential buffer to the negative effects of work stressors among graduate students. One possible explanation for the buffering effect of physical activity is the distraction hypothesis, since physical activity provides an opportunity for graduate students to take a break from their “24/7” workday. Graduate students are also influenced by those around them: being around those who promote regular physical activity influences graduate students to engage in physical activity. Additionally, having a mindset that stress is enhancing increases engagement in physical activity. The findings suggest several follow-up studies for researchers interested in developing interventions to target graduate student health and well-being.


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doi:10.1016/j.jenvp.2019.101345


doi:10.3928/15394492-20140714-01


PHYSICAL ACTIVITY AMONG GRADUATE STUDENTS


PHYSICAL ACTIVITY AMONG GRADUATE STUDENTS


doi:10.1016/j.paid.2013.03.019


PHYSICAL ACTIVITY AMONG GRADUATE STUDENTS


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doi: [10.1097/WAD.0b013e3182389a9c](https://doi.org/10.1097/WAD.0b013e3182389a9c)


doi:10.1111/psyp.12134

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PHYSICAL ACTIVITY AMONG GRADUATE STUDENTS


The final conceptual model with physical activity moderating the relationship between the work stressors and mental health and the work stressors and productivity.
Figure 2

The supplemental model with the predictors of physical activity

- Social support for physical activity
- Non-physical activity leisure time activities
- Life satisfaction

Physical activity
### Tables

**Table 1**

*Surveys used in the study to assess the variables of interest*

<table>
<thead>
<tr>
<th>Construct</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depression</td>
<td>Depression, Anxiety, and Stress Scale (DASS; Lovibond &amp; Lovibond, 1993)</td>
</tr>
<tr>
<td>Stress</td>
<td>Perceived Stress Scale (Cohen, 1988) and DASS</td>
</tr>
<tr>
<td>Anxiety</td>
<td>DASS</td>
</tr>
<tr>
<td>Productivity</td>
<td>Survey developed for the purpose of study</td>
</tr>
<tr>
<td>Role conflict</td>
<td>Role Conflict Scale (Rizzo et al., 1970)</td>
</tr>
<tr>
<td>Role ambiguity</td>
<td>Role Ambiguity Scale (Rizzo et al., 1970)</td>
</tr>
<tr>
<td>Work overload</td>
<td>Quantitative Workload Inventory (Spector &amp; Jex, 1998)</td>
</tr>
<tr>
<td>Physical activity</td>
<td>Concise Physical Activity Questionnaire (Sliter &amp; Sliter, 2014)</td>
</tr>
<tr>
<td>Life satisfaction</td>
<td>Satisfaction with Life Scale (Diener et al., 1985)</td>
</tr>
<tr>
<td>Social support for physical activity</td>
<td>Survey from Anderson et al. (2016)</td>
</tr>
<tr>
<td>Non-physical activity leisure time</td>
<td>Survey from QuestionPro (18 Leisure Time Activities Survey Questions Sample Questionnaire Template, 2019)</td>
</tr>
<tr>
<td>Conscientiousness</td>
<td>Conscientiousness subscale from the Big Five Inventory (John &amp; Srivastava, 1999)</td>
</tr>
<tr>
<td>Autonomy</td>
<td>Index of Autonomous Control (Weinstein, Przybylski, &amp; Ryan, 2012)</td>
</tr>
<tr>
<td>Perceived control over stress</td>
<td>Stress Mindset Scale (Crum, Salovey, &amp; Achor, 2013)</td>
</tr>
</tbody>
</table>
Table 2

*Reliability scores over the three time points of the study*

<table>
<thead>
<tr>
<th>Scale</th>
<th>α (Time 1)</th>
<th>α (Time 2)</th>
<th>α (Time 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role conflict</td>
<td>.84</td>
<td>.82</td>
<td>.85</td>
</tr>
<tr>
<td>Role ambiguity</td>
<td>.85</td>
<td>.87</td>
<td>.87</td>
</tr>
<tr>
<td>Work overload</td>
<td>.86</td>
<td>.85</td>
<td>.86</td>
</tr>
<tr>
<td>Depression (DASS)*</td>
<td>.94</td>
<td>.95</td>
<td>.95</td>
</tr>
<tr>
<td>Anxiety (DASS)*</td>
<td>.85</td>
<td>.85</td>
<td>.88</td>
</tr>
<tr>
<td>Stress (DASS)*</td>
<td>.93</td>
<td>.92</td>
<td>.92</td>
</tr>
<tr>
<td>PSS*</td>
<td>.87</td>
<td>.89</td>
<td>.88</td>
</tr>
<tr>
<td>Life satisfaction</td>
<td>.85</td>
<td>.86</td>
<td>.88</td>
</tr>
<tr>
<td>Social support for physical activity</td>
<td>.90</td>
<td>.90</td>
<td>.90</td>
</tr>
<tr>
<td>Conscientiousness</td>
<td>.83</td>
<td>.84</td>
<td>.81</td>
</tr>
<tr>
<td>Autonomy</td>
<td>.69</td>
<td>.74</td>
<td>.73</td>
</tr>
<tr>
<td>SMS*</td>
<td>.87</td>
<td>.90</td>
<td>.88</td>
</tr>
</tbody>
</table>

Note: DASS = Depression, Anxiety, and Depression Scales; PSS: Perceived Stress Scale; SMS = Stress Mindset Scale
Table 3

*Means and standard deviations of the variables of interest*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depression (DASS)*</td>
<td>8.83</td>
<td>8.35</td>
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<tr>
<td>Stress (DASS)*</td>
<td>12.99</td>
<td>8.38</td>
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<tr>
<td>Anxiety (DASS)*</td>
<td>6.71</td>
<td>5.89</td>
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<tr>
<td>Productivity</td>
<td>6.44</td>
<td>1.87</td>
</tr>
<tr>
<td>Role conflict</td>
<td>2.48</td>
<td>0.69</td>
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<tr>
<td>Role ambiguity</td>
<td>2.30</td>
<td>0.67</td>
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<tr>
<td>Work overload</td>
<td>3.58</td>
<td>0.78</td>
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<tr>
<td>Physical activity</td>
<td>8.48</td>
<td>4.49</td>
</tr>
<tr>
<td>Life satisfaction</td>
<td>16.84</td>
<td>4.22</td>
</tr>
<tr>
<td>Social support for physical activity</td>
<td>2.40</td>
<td>0.73</td>
</tr>
<tr>
<td>Non-physical activity leisure time</td>
<td>2.67</td>
<td>0.43</td>
</tr>
<tr>
<td>Conscientiousness</td>
<td>3.74</td>
<td>0.61</td>
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<tr>
<td>Autonomy</td>
<td>3.50</td>
<td>0.47</td>
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<tr>
<td>PSS</td>
<td>28.51</td>
<td>6.81</td>
</tr>
<tr>
<td>SMS</td>
<td>2.80</td>
<td>0.75</td>
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</table>

Note: DASS = Depression, Anxiety, and Depression Scales; PSS: Perceived Stress Scale; SMS = Stress Mindset Scale
Table 4

Within- and between-person correlations of the variables included in the analyses

<table>
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<th>Measure</th>
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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Depression</td>
<td>.52**</td>
<td>.50**</td>
<td>-.12**</td>
<td>.19**</td>
<td>.25**</td>
<td>.13**</td>
<td>-.11**</td>
<td>-.35**</td>
<td>-.06</td>
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<tr>
<td>2. Stress</td>
<td>.70**</td>
<td>.67**</td>
<td>.02</td>
<td>.23**</td>
<td>.19**</td>
<td>.17**</td>
<td>-.01</td>
<td>-.23**</td>
<td>-.11**</td>
<td>-.06</td>
</tr>
<tr>
<td>3. Anxiety</td>
<td>.69**</td>
<td>.78**</td>
<td>-.10</td>
<td>.17**</td>
<td>.14**</td>
<td>.14**</td>
<td>.02</td>
<td>-.19**</td>
<td>-.06</td>
<td></td>
</tr>
<tr>
<td>4. Productivity</td>
<td>-.43**</td>
<td>-.26**</td>
<td>-.25**</td>
<td>-.02</td>
<td>.00</td>
<td>.12**</td>
<td>-.02</td>
<td>.03</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>5. Role conflict</td>
<td>.30**</td>
<td>.42**</td>
<td>.32**</td>
<td>-.23**</td>
<td>.23**</td>
<td>.24**</td>
<td>-.11**</td>
<td>-.06</td>
<td>-.16**</td>
<td>-.06</td>
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<tr>
<td>6. Role ambiguity</td>
<td>.42**</td>
<td>.38**</td>
<td>.30**</td>
<td>-.46**</td>
<td>.36**</td>
<td>.10*</td>
<td>-.10*</td>
<td>-.141</td>
<td>-.109</td>
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<tr>
<td>7. Work overload</td>
<td>.13</td>
<td>.34**</td>
<td>.21**</td>
<td>.04</td>
<td>.55**</td>
<td>.07</td>
<td>.10*</td>
<td>.10*</td>
<td>.04</td>
<td></td>
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<tr>
<td>8. Physical activity</td>
<td>-.10</td>
<td>-.13</td>
<td>-.15*</td>
<td>.16*</td>
<td>-.07</td>
<td>-.10</td>
<td>-.06</td>
<td>.06</td>
<td>.21**</td>
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</tr>
<tr>
<td>9. Life satisfaction</td>
<td>-.60**</td>
<td>-.44**</td>
<td>-.44**</td>
<td>.34**</td>
<td>-.25**</td>
<td>-.43**</td>
<td>-.15*</td>
<td>.25**</td>
<td>.04</td>
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<td>10. Social support</td>
<td>-.13</td>
<td>-.03</td>
<td>-.04</td>
<td>.16*</td>
<td>.08</td>
<td>-.04</td>
<td>-.05</td>
<td>.42**</td>
<td>.23**</td>
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<td>11. Leisure activities</td>
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<td>-.10</td>
<td>-.07</td>
<td>.01</td>
<td>-.01</td>
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<td>.08</td>
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<td>12. Conscientiousness</td>
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<td>.04</td>
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<td>.38**</td>
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<td>-.31**</td>
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<td>.24**</td>
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<td>13. Autonomy</td>
<td>-.38</td>
<td>-.22**</td>
<td>-.32**</td>
<td>.28**</td>
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<td>-.35**</td>
<td>.01</td>
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<td>.42</td>
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<tr>
<td>14. Perceived Stress Scale</td>
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<td>.77**</td>
<td>.65**</td>
<td>-.42**</td>
<td>.42**</td>
<td>.51**</td>
<td>.31**</td>
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<td>-.66**</td>
<td>.01</td>
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<td>15. Stress Mindset Scale</td>
<td>-.19</td>
<td>-.24**</td>
<td>-.23**</td>
<td>.04</td>
<td>-.02</td>
<td>-.08</td>
<td>.03</td>
<td>.26**</td>
<td>.36**</td>
<td>.16**</td>
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<td>16. Age</td>
<td>-.10</td>
<td>-.05</td>
<td>-.10</td>
<td>-.07</td>
<td>-.05</td>
<td>-.03</td>
<td>.03</td>
<td>-.08</td>
<td>-.01</td>
<td>-.10</td>
</tr>
<tr>
<td>17. Genderc</td>
<td>.17*</td>
<td>.32**</td>
<td>.18**</td>
<td>-.09</td>
<td>.05</td>
<td>.10</td>
<td>.14</td>
<td>-.07</td>
<td>-.05</td>
<td>.08</td>
</tr>
<tr>
<td>18. Year in Graduate School</td>
<td>-.08</td>
<td>.05</td>
<td>-.09</td>
<td>-.06</td>
<td>.17*</td>
<td>.05</td>
<td>.21**</td>
<td>.05</td>
<td>.05</td>
<td>.03</td>
</tr>
<tr>
<td>19. Type of degreeb</td>
<td>-.12</td>
<td>-.03</td>
<td>-.13</td>
<td>.04</td>
<td>.01</td>
<td>-.04</td>
<td>.25**</td>
<td>.08</td>
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<td>.06</td>
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<td>20. Graduate School Milestones</td>
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<td>.09</td>
<td>-.10</td>
<td>.07</td>
<td>-.03</td>
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<td>.032</td>
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<td>21. Ethnicityd</td>
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<td>.14*</td>
<td>-.10</td>
<td>.03</td>
<td>-.07</td>
<td>-.08</td>
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<td>-.27**</td>
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</tr>
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<td>22. Social Sciences/Humanities</td>
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<td>.10</td>
<td>-.03</td>
<td>-.05</td>
<td>-.01</td>
<td>-.02</td>
<td>-.13</td>
<td>.01</td>
<td>-.17*</td>
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</tr>
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<td>23. Engineeringe</td>
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<td>.01</td>
<td>-.05</td>
<td>-.02</td>
<td>-.14**</td>
<td>.04</td>
<td>.034</td>
<td>.14*</td>
<td></td>
</tr>
</tbody>
</table>

Note: *p < .05, **p < .01; aGender: 0 = male, female = 1; bType of degree: 0 = Master’s program, 1 = PhD or dual degree program; cGraduate School Milestones: 0 = none, 1 = at least one; dEthnicity: 0 = white, 1 = all other races/ethnicity; eAll other science programs is the reference for Social Sciences/Humanities and Engineering; between-person correlations are below the diagonal and within-person correlations are above the diagonal; n = 601-603 at the within-person level and N = 217-218 at the between-person level
Table 4 (continued)

<table>
<thead>
<tr>
<th>Measure</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
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<tbody>
<tr>
<td>1. Depression</td>
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<td>-.08</td>
<td>-.24**</td>
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</table>

Note: * \(p < .05\), ** \(p < .01\); \(^a\)Gender: 0 = male, female = 1; \(^b\)Type of degree: 0 = Master’s program, 1 = PhD or dual degree program; \(^c\)Graduate School Milestones: 0 = none, 1 = at least one; \(^d\)Ethnicity: 0 = white, 1 = all other races/ethnicity; \(^e\)All other science programs is the reference for Social Sciences/Humanities and Engineering; between-person correlations are below the diagonal and within-person correlations are above the diagonal; \(n = 601-603\) at the within-person level and \(N = 217-218\) at the between-person level.
Table 5

*Model 1, 2 and final model results with mental health as the outcome variable*

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<th>Model 2</th>
<th>Final model</th>
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<td>(b)</td>
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<td>1.83**</td>
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<td>1.31*</td>
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<tr>
<td>PA x RA***</td>
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<td>Role conflict</td>
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<td>Role ambiguity</td>
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<tr>
<td>(\chi^2)(df)</td>
<td>103.77(28)</td>
<td>116.03(34)</td>
<td>141.10(46)</td>
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<td>RMSEA</td>
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<td>CFI</td>
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<td>.91</td>
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<tr>
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<tr>
<td>SRMR(_{\text{between}})</td>
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<td>.46**</td>
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Note: *\(p < .05\), **\(p < .01\), ***Interaction terms for physical activity and role ambiguity (PA x RA) and physical activity and role conflict (PA x RC)
Table 6

Models 1, 2 and final model results with productivity as the outcome variable

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<th>Final model</th>
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**Fit Statistics**

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<td>103.77(28)</td>
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Note: *$p < .05$, **$p < .01$
Table 7

**Supplemental model results**

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**Fit Statistics**

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Note: *$p < .05$, **$p < .01$
Role Conflict Scale
Below is a list of things that may describe your work environment. Please select how often you have felt this way during the past month.

I have to do things that should be done differently under different conditions.
I receive an assignment without the manpower to complete it.
I have to buck a rule or policy in order to carry out an assignment.
I work with two or more groups who operate quite differently.
I receive incompatible requests from two or more people.
I do things that are apt to be accepted by one person and not by others.
I receive an assignment without adequate resources and materials to execute it.
I work on unnecessary things.

Never (1)
Almost never (2)
Sometimes (3)
Fairly often (4)
Very often (5)
Role Ambiguity Scale
Below is a list of things that may describe your work environment. Please select how often you have felt this way during the past month.

I have clear, planned goals and objectives for my job. (reversed)
I know that I have divided my time properly. (reversed)
I know what my responsibilities are. (reversed)
I know exactly what is expected of me. (reversed)
I feel certain about how much authority I have on the job. (reversed)
Explanation is clear of what has to be done. (reversed)

Never (1)
Almost never (2)
Sometimes (3)
Fairly often (4)
Very often (5)
Quantitative Workload Inventory
Below is a list of things that may describe your work environment. Please select how often you have felt this way during the past month.

How often does your job require you to work very fast?
How often does your job require you to work very hard?
How often does your job leave you with little time to get things done?
How often is there a great deal to be done?
How often do you have to do more work than you can do?

Never (1)
Almost never (2)
Sometimes (3)
Fairly often (4)
Very often (5)
Concise Physical Activity Questionnaire
Please think about the past month. During that time, approximately how many days per week did you engage in each of the following types of physical activity for at least 20 consecutive minutes?

Example 1. If you walk to work and it takes you 10 minutes each way, that would NOT count because the minutes were not consecutive.
Example 2. If you walk to work and it takes you 20 minutes each way, then that would count as performing light physical activity that day. You walked for at least 20 consecutive minutes that day.

1. Light aerobic activity (Ex: Shopping, housework, leisurely walking)
2. Moderate aerobic activity (Ex: Brisk walking, bicycling, tennis)
3. Vigorous aerobic activity (Ex: Jogging/running, swimming laps, jumping rope)
4. Muscle-strengthening activity (Ex: Lifting weights, Pilates, yoga)

Physically unable/not medically allowed to do this (0)
Chose not to do this (0)
1 day per week or less (1)
2–3 days per week (2)
4–5 days per week (3)
6–7 days per week (4)
Depression Anxiety Stress Scales
Please read each statement and indicate how much the statement applied to you over the past week. There are not right or wrong answers. Do not spend too much time on any statement.

*The rating scale is as follows:*
Did not apply to me at all (0)
Applied to me to some degree, or some of the time (1)
Applied to me to a considerable degree, or a good part of the time (2)
Applied to me very much, or most of the time (3)

I found myself getting upset by quite trivial things
I was aware of dryness of my mouth
I couldn't seem to experience any positive feeling at all
I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)
I just couldn't seem to get going
I tended to over-react to situations
I had a feeling of shakiness (eg, legs going to give way)
I found it difficult to relax
I found myself in situations that made me so anxious I was most relieved when they ended
I felt that I had nothing to look forward to
I found myself getting upset rather easily
I felt that I was using a lot of nervous energy
I felt sad and depressed
I found myself getting impatient when I was delayed in any way (eg, elevators, traffic lights, being kept waiting)
I had a feeling of faintness
I felt that I had lost interest in just about everything
I felt I wasn't worth much as a person
I felt that I was rather touchy
I perspired noticeably (eg, hands sweaty) in the absence of high temperatures or physical exertion
I felt scared without any good reason
I felt that life wasn't worthwhile
I found it hard to wind down
I had difficulty in swallowing
I couldn't seem to get any enjoyment out of the things I did
I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)
I felt down-hearted and blue
I found that I was very irritable
I felt I was close to panic
I found it hard to calm down after something upset me
I feared that I would be "thrown" by some trivial but unfamiliar task
I was unable to become enthusiastic about anything
I found it difficult to tolerate interruptions to what I was doing
I was in a state of nervous tension
I felt I was pretty worthless
I was intolerant of anything that kept me from getting on with what I was doing
I felt terrified
I could see nothing in the future to be hopeful about
I felt that life was meaningless
I found myself getting agitated
I was worried about situations in which I might panic and make a fool of myself
I experienced trembling (eg, in the hands)
I found it difficult to work up the initiative to do things
Perceived Stress Scale
The questions in this scale ask about your feelings and thoughts during the last month. In each case, you will be asked to 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 fairly quickly. That is, don’t try to count up the number of times you felt a particular way; rather indicate the alternative that seems like a reasonable estimate.

In the last month, how often have you been upset because of something that happened unexpectedly?
In the last month, how often have you felt that you were unable to control the important things in your life?
In the last month, how often have you felt nervous and stressed?
In the last month, how often have you felt confident about your ability to handle your personal problems? (reversed)
In the last month, how often have you felt that things were going your way? (reversed)
In the last month, how often have you found that you could not cope with all the things that you had to do?
In the last month, how often have you been able to control irritations in your life? (reversed)
In the last month, how often have you felt that you were on top of things? (reversed)
In the last month, how often have you been angered because of things that happened that were outside of your control?
In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

Never (1)
Almost never (2)
Sometimes (3)
Fairly often (4)
Very often (5)
Satisfaction with Life Scale
Below are five statements with which you may agree or disagree. Please be open and honest in your responding.

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.

Strongly Disagree (1)
Disagree (2)
Neither Agree nor Disagree (3)
Agree (4)
Strongly Agree (5)
Stress Mindset Scale
Rate the extent to which you agree or disagree with the following questions:
The effects of stress are negative and should be avoided. (reversed)
Experiencing stress facilitates my learning and growth.
Experiencing stress depletes my health and vitality. (reversed)
Experiencing stress enhances my performance and productivity.
Experiencing stress inhibits my learning and growth. (reversed)
Experiencing stress improves my health and vitality.
Experiencing stress debilitates my performance and productivity. (reversed)
The effects of stress are positive and should be utilized.

Strongly Disagree (1)
Disagree (2)
Neither Agree nor Disagree (3)
Agree (4)
Strongly Agree (5)
Self-report productivity
The next few questions ask about perceptions of your academic work. Please select the choice that best answers the question over the past month (Note: participants were given a dropdown choice for most of the questions in increments of one).

On average, how many hours per week do you spend working on your research? If you have a graduate research assistantship that requires you to do research outside of your lab, do not count this. Now, if you have a graduate research assistantship that requires you to do research outside of your lab responsibilities, how many hours on average do you spend working on the research? If you do not have a graduate research assistantship or job that requires this please choose N/A. How many labs do you work in (include your primary lab with your main advisor)?

On average, how many hours a week do you spend reading academic material? On average, how many hours a week do you spend reading and responding to emails? On average, how many hours a week do you spend writing (e.g., writing manuscripts, abstracts for conference submissions, grants, etc)? On average, how many hours a week do you spend at lab/research meetings? On average, how many hours a week do you spend on coursework? On average, how many hours a week do you spend in your department building (e.g., Williams Hall for Psychology) doing work? On average, how many hours a week do you spend at home doing academic work? On average, how many hours a week do you spend at another building affiliated with your department or with your graduate assistantship?

Rate your overall feeling of productiveness, with 0 being not productive at all, 5 being somewhat productive and 10 being as productive as can be.

0 1 2 3 4 5 6 7 8 9 10

Now comparing yourself to your fellow graduate students, rate how productive you are compared to them, with 0 being not productive at all, 5 being somewhat productive and 10 being as productive as can be.

0 1 2 3 4 5 6 7 8 9 10
Leisure Time Scale
Please select the frequency in which you engaged in the following activities in the past month.

Check only one answer for each possible leisure activity.
- Watching television (e.g., not just cable television, but also streaming services like Netflix, either on laptop, television or another device)
- Playing adult games (e.g., playing cards)
- Walking for pleasure
- Competing in team sports (e.g., soccer, baseball, basketball)
- Going on a family outing
- Competing in individual sports (e.g., tennis, ping pong)
- Going out for the evening for drinks and entertainment
- Bicycling
- Going to the movies
- Reading books for pleasure
- Visiting art galleries and museums
- Collecting or making something (e.g., crafts, baseball cards)
- Swimming
- Attending sports events
- Attending opera, ballet or dance performances
- Surfing the web
- Working on the computer
- Listening to music
- Playing video games (e.g., on any gaming console, laptop, phone)
- Spent time on social media (e.g., on phone, laptop, or another device)
- Spent time on phone sending text messages
- Spent time on phone making calls

Never (1)
Almost never (2)
Sometimes (3)
Fairly often (4)
Very often (5)
Social support for physical activity
During the past month, my friends:

- Exercised with me.
- Offered to exercise with me.
- Gave me encouragement to stick with my exercise program.
- Changed their schedule so we could exercise together.
- Discussed exercise with me.
- Complained about the time I spent exercising. (reversed)
- Criticized me or made fun of me for exercising. (reversed)
- Gave me rewards for exercising (e.g., brought me something or gave me something I like).
- Planned for exercise on recreational outings.
- Helped plan activities around my exercise.
- Asked me for ideas on how they can get more exercise.
- Talked about how much they like to exercise.

Never (1)
Almost never (2)
Sometimes (3)
Fairly often (4)
Very often (5)
Conscientiousness Scale
Rate the extent to which you agree or disagree with the following questions.

I see myself as someone who does a thorough job.
I see myself as someone who can be somewhat careless. (reversed)
I see myself as someone who is a reliable worker.
I see myself as someone who tends to be disorganized. (reversed)
I see myself as someone who tends to be lazy. (reversed)
I see myself as someone who perseveres until the task is finished.
I see myself as someone who does things efficiently.
I see myself as someone who makes plans and follows through with them.
I see myself as someone who is easily distracted. (reversed)

Strongly Disagree (1)
Disagree (2)
Neither Agree nor Disagree (3)
Agree (4)
Strongly Agree (5)
Index of Autonomous Functioning
Below is a collection of statements about your general experiences. Please indicate how true each statement is of your experiences on the whole. Remember that there are not right or wrong answers. Please answer according to what really reflects your experiences rather than what you think your experiences should be.

My decisions represent my most important values and feelings.
I do things in order to avoid feeling badly about myself. (reversed)
I often reflect on why I react the way I do.
I strongly identify with the things that I do.
I am deeply curious when I react with fear or anxiety to events in my life. (reversed)
I do a lot of things to avoid feeling ashamed. (reversed)
I try to manipulate myself into doing certain things. (reversed)
My actions are congruent with who I really am.
I am interested in understanding the reasons for my actions.
My whole self stands behind the important decisions I make.
I believe certain things so that others will like me. (reversed)
I am interested in why I act the way I do.
I like to investigate my feelings.
I often pressure myself. (reversed)
My decisions are steadily informed by things I want or care about.

Not at all true (1)
A bit true (2)
Somewhat true (3)
Mostly true (4)
Completely true (5)
Demographic Questions
What is your age?

What is your biological sex?
Male
Female
Other
Prefer not to respond

What is your year in graduate school?
First Year
Second Year
Third Year
Four Year
Fifth Year
Sixth Year
Seventh Year or above

Which graduate program best describes you?
Master's program
PhD program
Dual degree program (e.g., MBA/PhD, MD/PhD, etc.)
Other (please specify)

Please indicate if you are completing any of the following this academic semester:
Preliminary exam
Thesis/dissertation proposal
Qualifying exam
Thesis/dissertation defense

What is your ethnic origin (or race)?
White
Black or African American
Asian
American/Pacific Islander
Hispanic or Latino
Native American or American Indian
Other

Please enter the area of study that you are getting your degree in (e.g., Biomedical Engineering, Clinical Psychology, Biology, etc.)
Appendix B – IRB Approval Letter

Memorandum

Date: August 22, 2019

To: Scott Geller, Trevin Earl Glasgow

From: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

Protocol Title: Physical activity as a buffer to mental health problems in graduate students

IRB Number: 19-633

Effective August 22, 2019, the Virginia Tech Human Research Protection Program (HRPP) and Institutional Review Board (IRB) determined that this protocol meets the criteria for exemption from IRB review under 45 CFR 46.104(d) category(ies) 2(ii).

Ongoing IRB review and approval by this organization is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities impact the exempt determination, please submit a new request to the IRB for a determination.

This exempt determination does not apply to any collaborating institution(s). The Virginia Tech HRPP and IRB cannot provide an exemption that overrides the jurisdiction of a local IRB or other institutional mechanism for determining exemptions.

All investigators (listed above) are required to comply with the researcher requirements outlined at:
https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

Protocol Information:

Determined As: Exempt, under 45 CFR 46.104(d) category(ies) 2(ii)
Protocol Determination Date: August 22, 2019

Associated Funding:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.