THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF BIOBEHAVIORAL HEALTH

Physical Activity as a Moderator of the Effects of Stress Dysregulation on Obesity in Adolescents Experiencing Rural Poverty

CAMRYN A. BUSS
SPRING 2023

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree in
Biobehavioral Health
with honors in Biobehavioral Health

Reviewed and approved* by the following:

Dr. Lori Francis
Associate Professor of Biobehavioral Health
Thesis Supervisor

Dr. Kari Kugler
Assistant Teaching Professor of Biobehavioral Health
Honors Adviser

* Electronic approvals are on file.

ABSTRACT

Adolescent obesity rates are rising higher than ever before; many connections have been drawn in previous literature between stress and obesity. In the present study, we investigated physical activity as a buffer in the relationship between stress and obesity. 253 adolescents experiencing rural poverty answered surveys and had a home visit to collect objective and subjective measures of stress, waist circumference (adiposity), and 7 days of physical activity using an activity monitor. Multiple-group, multiple regression analyses were conducted to examine relationships between the perceived stress scale (PSS), respiratory sinus arrythmia (RSA), waist circumference, physical activity, and demographic information. Results suggest that even 27 minutes (or more) of moderate-to-vigorous physical activity per day may act as a buffer between objective (RSA) and subjective (PSS) stress and adiposity. Additionally, the association between stress and adiposity varied by race; the association was significant only white adolescents and female adolescents. These results suggest that physical activity moderates the relationship between stress and obesity, and that there are differences in the effect of stress and waist circumference by race and sex. Therefore, interventions designed to increase physical activity may improve the obesity epidemic among adolescents.

TABLE OF CONTENTS

Abstract……………………………………………………………………………….i

LIST OF FIGURES iii

LIST OF TABLES v

ACKNOWLEDGEMENT…………………………………………………………vi

Chapter 1: Introduction……………………………………………………………1

Chapter 2: Methods………………………………………………………………..9

Chapter 3: Results…………………………………………………………………16

Chapter 4: Discussion……………………………………………………………..31

REFERENCES…………………………………………………………………….36

LIST OF FIGURES

Figure 1. Ecological model of predictors of childhood overweight……………………………3

Figure 2. Average RSA Across Different Visits……………………………………...……19

Figure 3. Average RSA Across Different Stress Challenges…………………………………20

Figure 4. Sex differences in the association between perceived stress and waist circumference……………………………………………………………………………22

Figure 5. Racial differences in the association between perceived stress and waist circumference……………………………………………………………………………22

Figure 6. Sex differences in the association between RSA during stress and waist circumference……………………………………………………………………………24

Figure 7. Racial differences in the association between RSA during stress and waist circumference…………………………………………………………………………....24

Figure 8. Sex differences in the association between RSA 20 minutes post-stress and waist circumference……………………………………………………………………………25

Figure 9. Racial differences in the association between RSA 20 minutes post-stress and waist circumference……………………………………………………………………………26

Figure 10. Sex differences in the association between RSA 40 minutes post-stress and waist circumference…………………………………………………………………………….27

Figure 11. Racial differences in the association between RSA 40 minutes post-stress and waist circumference…………………………………………………………………….…27

Figure 12. The moderating effect of MVPA on the association between perceived stress and waist circumference……………………………………………………………….……..29

Figure 13. The moderating effect of MVPA on the association between RSA during stress and waist circumference…………………………………………………………………..……29

Figure 14. The moderating effect of MVPA on the association between RSA 20 minutes post-stress and waist circumference…………………………………………………………..30

Figure 15. The moderating effect of MVPA on the association between RSA 40 minutes post-stress and waist circumference…………………………………………………………..30

LIST OF TABLES

Table 1: Sociodemographic Characteristics of Participants at Baseline……………………….16

Table 2: Anthropometric Statistics for Adolescents…………………………………………..17

Table 3: Physical Activity Univariates for Adolescents………………………………….……18

Table 4: Stress Measure Univariates for Adolescents…………………………………………18

Table 5: Correlations among perceived stress and objective measures of stress………………21

ACKNOWLEDGEMENT

A resounding thank you to my amazing mentor, Dr. Lori Francis. Without her kindness, knowledge and guidance this thesis would never have become what it is. Thank you so much to Dr. Kugler for her thoughtful editing and advice throughout this process. And thank you to my family for enabling an incredible education and supporting me every step of the way!

Chapter 1

INTRODUCTION

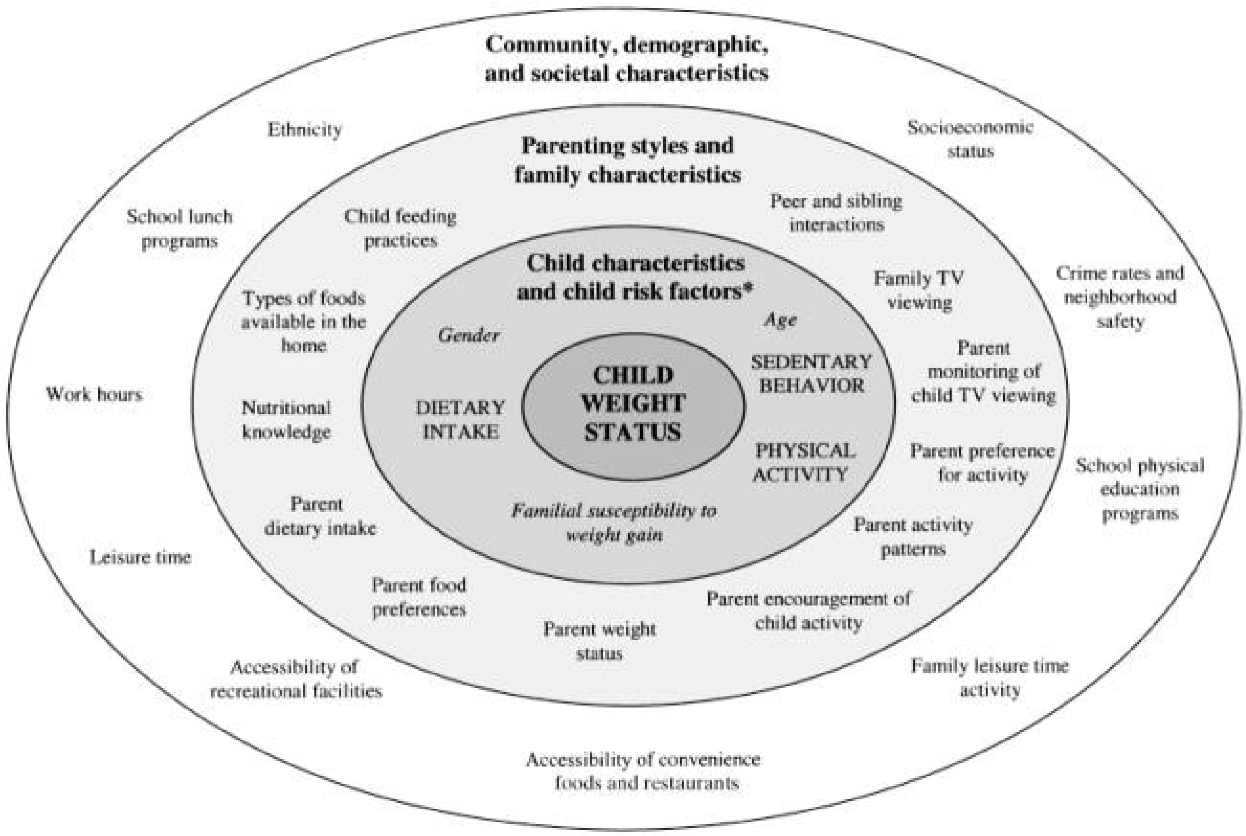
Obesity among adolescents has reached epidemic levels and is associated with a number of concerning health consequences into adulthood (Centers for Disease Control and Prevention [CDC], 2022). Adolescent obesity has been linked to elevated blood pressure, asthma, irregular fasting glucose, high cholesterol, and type 2 diabetes (Barlow, 2007; CDC, 2022), which may increase rates of morbidity and mortality later in life (Jaaskelaine, 2014). Based on findings from the National Health and Nutrition Examination Survey, the prevalence of obesity among children between the ages of 12 and 19 between 2017- March 2020 was 22.2% (Stierman, 2021) and rates increased steadily with age. Further, obesity prevalence was higher among people of color, including 26.2% among Hispanic children and 24.8% among non-Hispanic Black children compared to 16.6% among non-Hispanic white children (Stierman, 2021).

Risk Factors for Obesity

There are many risk factors and explanations for why adolescent obesity rates are on the rise. By nature, obesity develops from an energy imbalance that is the result of diets too high in energy (kilocalories) and/or a lifestyle lacking in energy exertion. The main reasons for these imbalances are 1) consuming too much food/unhealthy food, 2) poor eating habits, and 3) physical activity levels. Firstly, research shows that eating too many foods high in calories, sugar, fat, sodium, as well as not eating enough vegetables, fruits, and whole grains can lead to obesity development (Davison, 2001). Take for example one study that wanted to investigate the effect that sugar-sweetened beverages have on obesity development; it was estimated that a 1% rise in global sugary-drink consumption was associated with an additional 4.8 overweight adults per 100 and 2.3 obese adults per 100 (Basu, 2013). Secondly, dysregulated eating habits such as eating in the absence of hunger, binge eating, and emotional eating, also may lead to obesity development (Davison & Birch, 2001; Rodgers et. al., 2017; Nagata et. al, 2018; Kral, 2018). Research, such as the review conducted by Bryne and colleagues (2019), shows that eating past the point of satiation or binge eating/loss of control (LOC) eating results in excessive energy-dense consumption that exceeds the adolescent's needs and may lead to adiposity. The authors reported that approximately 23% of youth of all weight statuses reported LOC eating in the past month, with almost 10% reporting recurrent episodes (Byrne, 2019). Lastly, not enough physical activity or too much time spent in sedentary activity can also lead to adolescent obesity development (Hong et. al., 2016). Current literature recommends frequent physical activity across every age, but especially during adolescence, which is a crucial time for body and brain development (Lecroy, 2021). Additionally, modern society is increasingly conducive towards excessive time spent sedentary, which is due in part to increasing access to and time spent on electronic screens. For example, one longitudinal cohort study found that as much as 60% of the incidence of overweight could be attributed to time spent watching television (Robinson, 2017). Ultimately, we find that adolescent obesity develops from an energy imbalance.

As pictured in Fig.1 adapted from Davison and Birch (2001), we can netter understand risk factors for youth obesity using an ecological approach. By examining behavioral, social and genetic factors (family life, socioeconomic culture, sex etc.), we see a web of influence unfold across various domains and contexts that further explains why an energy imbalance may occur in the first place. Aside from diet and activity, additional risk factors include family susceptibility to weight gain, parent nutritional knowledge, school lunch nutritional value, access to recreational facilities, ethnicity, etc. (Davison, 2001).

Figure 1. Ecological model of predictors of childhood overweight from. Reprinted from "Childhood overweight: a contextual model and recommendations for future research" K. Davison, 2001, *Official Journal of the International Association for the Study of Obesity 2*(3), 159–171.



In addition to demographic and sociocultural susceptibility, research shows that stress correlates with obesity development amongst adolescents through multiple avenues (Tomiyama, 2019). High stress may lead to increased intake of food and drink, especially highly palatable foods, as a coping mechanism (Jääskeläinen, 2014) especially because modernity has created an environment in which high calorie, unhealthy foods are increasingly accessible to many populations (Caspi, 2012). Jääskeläinen and colleagues (2014) reported that stress-eating behaviors were more common among adolescent girls than adolescent boys. Consequently, stress-eating also correlated with higher prevalence of overweight, obesity and abdominal adiposity. The authors found, perhaps counter-intuitively, stress-eaters tended to not only binge-eat, but also use strict dieting and heavy exercise for weight control as compared to those who do not stress-eat, further disrupting natural metabolism (Jääskeläinen, 2014).

In addition to stress eating, adverse childhood events (ACEs) have also been shown to be related to increased diastolic blood pressure and heart rate in response to stresses during adolescence, which ultimately may lead to cardiometabolic disease (Jimenez, 2021). Tiwaloluwa and colleagues (2021) found significant relations between adolescents' coping strategies and their α-amylase release during a stress test. Compared to their peers with effective coping strategies, adolescents with historically poor coping strategies released more α-amylase in their saliva post-stress, thus increasing blood glucose (Ajibewa, 2020). Therefore, stressed adolescents with poor coping strategies, such as overeating, were at a higher risk for obesity development. For the purposes of this thesis, I will focus on biobehavioral pathways that may influence how stress contributes to adolescent obesity development.

Stress and Obesity

High levels of perceived stress have been shown to contribute to biological and behavioral reactions conducive to obesity development. Tomiyama (2019) outlines several health pathways that connect stress and obesity: physical, cognitive, and social health. The physical effects of stress include behaviors, such as overeating or inactivity, and biological responses, such as disrupted hormone production and sleep, that encourage weight gain. Stress can also interfere cognitively with impulse control, executive functioning, and reward processing. The state of obesity in and of itself may be perceived as a stressful social experience that creates a damaging positive feedback loop: stress contributes to obesity development, obesity leads to social stigma, which may in turn increase stress (Tomiyama, 2019).

Biological Pathways Linking Stress to Obesity

Aside from dysregulated behaviors, there are also significant biological pathways that lead to obesity development. Researchers have examined respiratory sinus arrhythmia (RSA), a measure of stress reactivity or high-frequency heart rate variability, as an indicator of parasympathetic activity, particularly post-acute stress (Eckberg, 2020). During a normal response to stress, RSA is temporarily suppressed and then recovers; for an individual with emotional dysregulation, the magnitude and rate of recovery may be altered (Gouin et. al., 2014). For example, lower resting RSA and prolonged recovery have been found to be associated with greater stress dysregulation (Friedman, 2007). However, not all researchers have found an association between RSA and obesity. According to Javorka and colleagues (2020), normal RSA function was preserved among adolescents with obesity in response to most stressors, except when participants maneuvered from a supine position to an upright position. Other studies found that among healthy adolescents, physical activity was associated with beneficial intensity-dependent effects on vagal tone, systolic blood pressure, and exercise capacity (Radtke, 2013). While this association may be understudied, RSA may be a useful marker for understanding the relationships between stress, physical activity, and obesity.

Physical Activity, Stress and Obesity

Not only has physical activity been identified as an important behavioral factor for obesity prevention (Zanganeh, 2019), but literature suggests that higher physical activity reduces stress measures as well. In fact, this relationship appears to be bidirectional; lower perceived stress was associated with more physical activity enjoyment among adolescents with overweight or obesity (Tiwaloluwa, 2021). Bagoien and colleagues (2010) observed that upper secondary school students who demonstrated self-motivated physical activity during leisure time also displayed improved psychological well-being. In fact, any physical activity may be more effective in reducing stress than no activity at all; evidence suggests that the stress-reducing effect of physical activity is the same whether one exercises two to three times a week or every day (Moljord, 2011).

One important lens through which we must consider this relationship is that individuals with higher levels of stress may exercise less and consequently develop obesity. Some prospective studies have investigated physical activity levels during times of relatively high stress (exams, parental divorce, etc.) compared to times of relatively low stress for the same individuals. Most find that there is a significant decrease in physical activity during times of stress for adolescents (Stults-Kolehmainen, 2014). Also considering that adolescents in low SES situations experience elevated levels of stress (Chen, 2004), another study found that adolescents in low SES families tended to engage in less physical activity (Kowley, 2017). Assuming that low physical activity leads to increased risk of adolescent obesity (Hills, 2011), an argument could be made for physical activity levels as a mediator, or a pathway, by which stress affects obesity development.

Physical Activity as a Potential Stress Buffer

However, other recent studies, including the present study, look at this relationship a different way; there is evidence that physical activity may moderate, or buffer, the relationship between stress and obesity. Meyer and colleagues (2021) suggested that physical activity alone did not decrease stress levels. Rather, they found that physical activity acted as a buffer for stress, but only in participants with traits of high intrinsic motivation, or pursuit of exercise for pleasure (Meyer, 2021). Perhaps, only those that enjoy physical activity can yield that mediating benefit by way of high self-esteem or autonomy. Additionally, some studies report no benefits at all dependent upon the type of stress (school-based stress vs. social stress) on psychosomatic health (Gerber, 2008). Yin and colleagues (2005) conducted a cross-sectional study with a design similar to the current study that found that among a diverse sample of adolescents, physical activity did in fact act as a buffer for the effects of personal and community stress upon three obesity measures: body-mass index, sum of skinfolds and waist circumference (Yin, 2005). This poses the question; how many adolescents actually meet physical activity recommendations in order to reap the benefits? According to the Physical Activity Guidelines for Americans, 2nd edition (2018), children and adolescents should participate in 60 minutes of moderate to vigorous activity every day in order to stay healthy. However, the same report estimates that only 1 in 5 adolescents actually meet these guidelines (United States, 2018). Given the known health benefits of physical activity, it is important better understand its association with stress and obesity in youth.

The overall aim of this study is to examine whether physical activity (measured objectively using an activity tracker worn over the course of seven days) acts as a buffer, i.e., moderator, of the association between adolescents' stress (RSA responses to a psychosocial stressor and perceived stress) and adolescents' central adiposity (waist circumference). An additional aim is to examine if the association between stress and weight differs by sex and race. Obesity is linked to the development of major long-term health problems such as diabetes, cardiovascular disease and some cancers (Wilson, 2014). Findings from the results of this study may be used to inform the design of physical activity interventions for low-income adolescents that may reduce their risk for obesity and improve health outcomes overall, which may need to be tailored based on race and sex. I hypothesize that the effects of stress on waist circumference will be less with high levels of physical activity and more with lower levels of physical activity for adolescents experiencing poverty.

Chapter 2

METHODS

Participants

Data were drawn from the Family Life Project (FLP), a longitudinal, birth cohort study of predominantly poor youth and families residing in rural communities in the United States. Extensive details about study recruitment and data collection procedures have been published (Vernon-Feagans, Cox, & Investigators, 2013). Pregnant, English-speaking mothers residing in six poor rural counties in eastern North Carolina and Central Pennsylvania were recruited between 2003 and 2004 at the time that they gave birth; low-income families and Black families were oversampled. A total of 1,292 youth were recruited at birth, and more than 1000 were followed through age 12 years. Families were not recruited based on weight status or concern about child weight. A subsample of these families (39.4%) participated in an ancillary Family Healthy Study that was designed to examine exposure to stress and its relation to obesity when youth were 14 years of age. Eligibility criteria for participation in the FLP ancillary study included (1) the absence of severe food allergies or chronic medical problems affecting food intake, and (2) the absence of dietary restrictions involving animal products. This study was approved by the Institutional Review Boards at the University of North Carolina and The Pennsylvania State University (protocol numbers 16-2343 and 2119, respectively). A total of 253 participants participated in the home visit and therefore completed all relevant parts of this study including perceived stress reports, RSA measurements, and activity tracking. Parents and youth provided their informed consent before the study began.

Design and Procedures

Participants completed two 2.5-hour home visits that were ~1 week apart, which varied based on youth exposure to a psychosocial stress task (i.e., one low-stress visit, one high-stress visit). Following the completion of each home visit, links to individual web surveys were sent to youth and primary caregivers (referred to as parents from here on). A total of 308 families completed the home visit, and of these families, 198 parent-adolescent dyads also completed the web-based survey. After removing certain individual cases, we had a final sample of 253 youth (out of 302), referred to as adolescents from here on.

Measures

Independent Variable: Stress Regulation and Perceived Stress

Psychosocial Stress Procedure: Youth reactivity to and recovery from a 15-minute set of psychosocial stressors was assessed in control and stress conditions across identical time increments (Figure 1). A 5-minute baseline included quiet tasks and games for each visit. Home Visit #1 incorporated a control period in place of the stress task protocol. Participants were administered an innocuous computerized executive function task that averaged the same approximate duration of the stress task protocol administered during home visit #2 (~15 minutes). On the low-stress day (control condition), adolescents completed a number of questionnaires thought to be perceived as low-stress (e.g., activity preferences) and executive function tasks thought to elicit low levels of arousal. On the stress day (stress condition), the first task was a Star-Tracing Task, which is a well-established cognitive stressor for youth (Gullikson, 2013). This task required youth to trace a star for 3 minutes, with their non-dominant hand, while viewing the star's reflection in an adjacent mirror. This task has been shown to produce reliable responses to challenges, and performance on the task is linked to externalizing problems in youth. The second task was a 4-minute Impossible Circle Task, modified based on the

Impossibly Perfect Circle Task from the LAB-TAB (Dyson, 2015). In this task, youth are asked to try their best to draw a perfect circle. Throughout the task, the interviewer constantly stopped to interrupt the participant, examined the circle, pointed out imperfections and asked them to try again. The third and final stress task was a five-minute adaptation of the Block Design Test originally developed by Kohs (1923). Participants use red and white patterned blocks to reproduce two dimensional, square, geometric designs. The challenge was modified by starting with relatively easy designs with generous completion times and gradually increasing the design difficulty while decreasing the amount of time allotted, making the patterns extremely difficult to complete within the given time. The interviewer also counted down the seconds remaining to add a level of stress. Adolescents were debriefed immediately following the last challenge (Kohs, 1923).

Cardiac Vagal Regulation: Cardiac data were collected for the adolescent for the duration of both home visits using the Actiwave Cardio Heart Rate Monitor (Camntech, Cambridge, UK). The Actiwave monitor was used to collect ECG signals via two disposable electrodes (Covidien Kendall Disposable Surface EMG/ECG/EKG Electrodes 1 3/8") that were attached to the left side of the child's chest. Research assistants provided a diagram of the correct positioning of the Actiwave and verbally explained the application thoroughly before instructing the target child (TC) to go to another room to attach the monitor in private. Upon return, research assistants instructed participants to stretch their arms up in the air, touch their toes, and pivot at the waist several times to ensure the Actiwave was securely attached. Given issues present with initial noise and messy data from attaching the Actiwave unit, we opted to use the first 5 minutes of continuous editable data to represent baseline measures. For Home Visit #1, the Actiwave was attached approximately 30 minutes into the visit, following consent forms and anthropometrics measurements. For Home Visit #2, the Actiwave was attached approximately 15 minutes into the visit. Inter-beat intervals (IBI) were extracted from the ECG at a sampling rate of 1024 Hz with 10-bit resolution and manually edited for artifacts and arrhythmias by persons reliably certified (Porges, 2007). Data were analyzed for high-frequency heart rate variability (i.e., RSA), low-frequency heart rate variability (LF-HRV), heart rate (HR) and heart period (HP) averaged over each condition. This variable was treated as a continuous variable in our analyses.

Perceived Stress Scale (PSS): The Perceived Stress Scale (PSS-14) is a 14-item questionnaire designed to measure the degree to which global life events are perceived as stressful (Cohen, 1994). Web survey links were sent within 1 week of the second home visit. Participants were encouraged to complete the survey within 1 week of receiving the link. Follow-up emails and phone calls were done to encourage completion if the survey was not completed within one week. PSS responses are given on a 5-point Likert scale ranging from 0 (Never) to 4 (Very Often). A single score was derived for the PSS-14 by first reverse- coding the seven positive items (i.e., 4, 5, 6, 7, 9, 10, and 13) and then summing across all 14 items. Higher scores indicate higher levels of perceived stress. This variable was treated as a continuous variable in our analyses.

Dependent Variable

Adolescent Body Mass Index (BMI) and Waist Circumference: During the home visit, youth weight (nearest 0.01 kg) and height (nearest 0.01 cm) were measured in duplicate by trained research assistants using standardized protocols. Age- and sex-specific BMI indices were generated based on recommended guidelines (34) and were used to generate youth weight status categories for non-overweight (BMI $<85^{th}$ percentile), overweight (BMI $\geq 85^{th}$ percentile), and obesity BMI $\geq 95^{th}$ percentile. This variable was treated as continuous in analysis. Waist circumference was measured in duplicate to the nearest 0.1 cm using a SECA clinical-grade measuring tape during Home Visit #1. Waist circumference was used to obtain estimates of abdominal (central) adiposity and to assess adolescents' obesity-related disease risk. Waist circumference measurements were taken by trained research assistants at the participant's side in order to measure the greatest protuberance of the waist. This variable was treated as continuous in analysis.

Moderating Variable

Physical Activity Tracking (Actigraph): Physical Activity was tracked over the course of seven days using an Actigraph monitor. The Actigraph activity monitor GT3X-BT is a device worn on the body to record and measure daily physical activity. Physical activity was assessed by the intensity, frequency, and total steps taken for each participant by categorizing activity counts in a set time interval (epochs) with predetermined cut points or intensity thresholds (Migueles et al., 2017). The present study opted to have TC wear the ActiGraph on the right hip, thinking this may increase wearer compliance if it was hidden. FHS utilized a 30 Hz sampling frequency, but Migueles et al. (2017) recommended 90 – 100 Hz (Migueles et al., 2017). The Normal filter removed movements that occur at frequencies deemed too low or too high to be consistent with human movement. FHS collected data using an epoch length of 60 seconds. In order to have meaningful data to interpret, ranges of accelerometer counts, or cut points, were used to define varying intensity levels. The classification employed was the Freedson Children (2005). Cut-offs used right hip placement and 60 second epochs. They further employed walking, running, and free-living conditions in the study. Note that there are five cut points for the number of accelerometer counts per minute (CPM):

- Sedentary: 0 – 149 CPM

- Light: 150 – 499 CPM
- Moderate: 500 – 3999 CPM
- Vigorous: 4000 – 7599 CPM
- Very Vigorous: 7600 - ∞ CPM

For the purposes of this study, and based on the literature on youth physical activity, we focused on the average number of daily minutes adolescents spent in sedentary activity and in moderate-vigorous intensity physical activity (MVPA), which refers to time spent in activities that above moderate intensity. Although this variable was measured as continuous (minutes), it was transformed into categorical (high vs. low activity) using a median split at 27 minutes for analysis to allow us to examine regression models separately by physical activity level. In addition, we wanted to make explicit recommendations based on a specific level of activity that was noted in this sample.

Confounding Variables

Sociodemographics: At the 12-year family Life Project home visit, which occurred 3-12 months before the Family Health Study visits, parents reported on household sociodemographics, which included household income, maternal education (years), and state of residence (Pennsylvania or North Carolina). Household income was determined based on any earner who resided in the home. Individuals were considered to be residents of the household if s/he spent 3+ nights/week in the youth's home. Income-to-needs ratio (INR) was calculated using the 2014 poverty threshold values, based on household size and total household income.

Statistical Analysis

Data were available on 253 adolescents. Descriptive statistics were generated to describe all variables and to assess normality. Multiple-group, multiple regression analyses were conducted to examine relationships between the PSS, RSA, waist circumference, physical activity, and demographic information. To examine interaction with race and sex in at the association between stress (PSS and RSA) and waist circumference, an interaction term (*race X stress and sex X stress)* was included in models examining the association between stress and waist circumference, controlling for demographic variables. Regression models were also run separately by sex, race and physical activity level. To examine physical activity as a moderator, a median split at 27 minutes was used to create a categorical variable to characterize adolescents with higher and lower levels of physical activity. In models testing the hypothesis that physical activity is a moderator for relationships between stress and obesity, the following variables were included as covariates: total number of days of physical activity data available, race, sex and household income-to-needs ratio. All analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC).

Chapter 3

RESULTS

Sample Descriptives

Table 1 presents descriptive statistics for the adolescents and parents from the total sample. The sample of adolescents were similarly split between females (44.66%) and males (55.34%) at an average age of 14 years old (SD=0.49). Most adolescents identified as White (73.52%) while 26.09% identified as Black, and one person identified as Other. On average, the majority of mothers reported a high school diploma or less as their highest level of education the (66.67%). The average income-to needs ratio was 2.08 (SD=1.39). By definition, an income-to-needs ratio of 1 is at the poverty line; this average indicates that the sample income was approximately at 200% above of the poverty line, which equates to $47,700 based on the 2014 poverty guidelines. Income-to-needs ratios ranged from 0.113 to 11.582.

Table 1: Sociodemographic Characteristics of Participants at Baseline

Demographic characteristic	*n*	%
Sex		
Female	113	44.66
Male	149	55.34
Race		
White	186	73.52
Black	66	26.09
Other	1	0.40
Maternal Education		
Less than High School	23	9.16
High School/GED	145	57.51
Associates	29	11.55
College or Professional	54	21.52

	n	Mean	SD

Adolescent age in years	251	14.07	0.49
Income-to-needs ratio	253	2.08	1.39

As seen in Table 2, the average BMI across the sample was 24.026 (SD=6.41), which corresponds to an average BMI percentile of 70.83. BMI values ranged from 15.32 to 56.81. The majority of adolescents were classified in the non-overweight BMI category (69.72%), and 1.20% of the adolescents were underweight, 13.55% were overweight, and 15.54% were obese. As an estimate of central adiposity, adolescents' average waist circumference was 77.82 centimeters (30.64 inches); values ranged from 52.00 cm (20.47 in.) to 144.00 cm (56.69 in.)

Table 2: Anthropometric Statistics for Adolescents

Weight Status		
	n	%
Non-Overweight	175	69.72
Overweight	34	13.55
Obese	39	15.54
Underweight	3	1.20

Adiposity			
	n	Mean	SD
Body Mass Index (BMI)	251	24.03	6.41
Waist Circumference (cm)	251	77.82	1.00

Adolescent Physical Activity

During the week that adolescents were instructed to wear the Actigraph monitor, activity was recorded, on average, for 6 days (SD=1.93). Of the time spent wearing the tracker, adolescents spent an average of 64.00% (SD=10) of their time in sedentary activity, 4.21% (SD=0.04) in moderate-vigorous intensity physical activity (MVPA), 4.0% on moderate activity, and the least percentage of time on vigorous physical activity (0.1%). Adolescents spent 19.78 minutes, on average, in MVPA per day.

Table 3: Physical Activity Univariate Analysis for Adolescents

Activity Level	*n*	Mean	SD
Total Physical Activity (Days)	253	6.059	1.93
Percent Time Sedentary	253	0.640	0.10
Percent Time MVPA	253	0.042	0.04
Percent Time Moderate PA	253	0.04	0.004
Percent Time Vigorous PA	253	0.001	0.0002
Average MVPA/day (minutes)	253	19.777	18.42
Note: MVPA= Moderate-Vigorous Physical Activity; PA=physical activity; percentages reported in decimal format (i.e. 0.640=64.0%).			

Perceived Stress

On average, adolescents reported perceived stress score was 22.65 (SD= 8.15, n=191) on a scale from 0-40, with 40 being extremely high perceived stress. Average RSA during block design averaged 6.29 ln $(\text{msec})^2$ with a minimum of 3.40 and a maximum of 9.17. Average RSA 20 minutes after block design averaged 6.54 ln $(\text{msec})^2$ with a minimum of 3.88 and a maximum of 9.29. Average RSA 40 minutes after block design averaged 6.67 ln $(\text{msec})^2$ with a minimum of 4.34 and a maximum of 9.28 (Table 4).

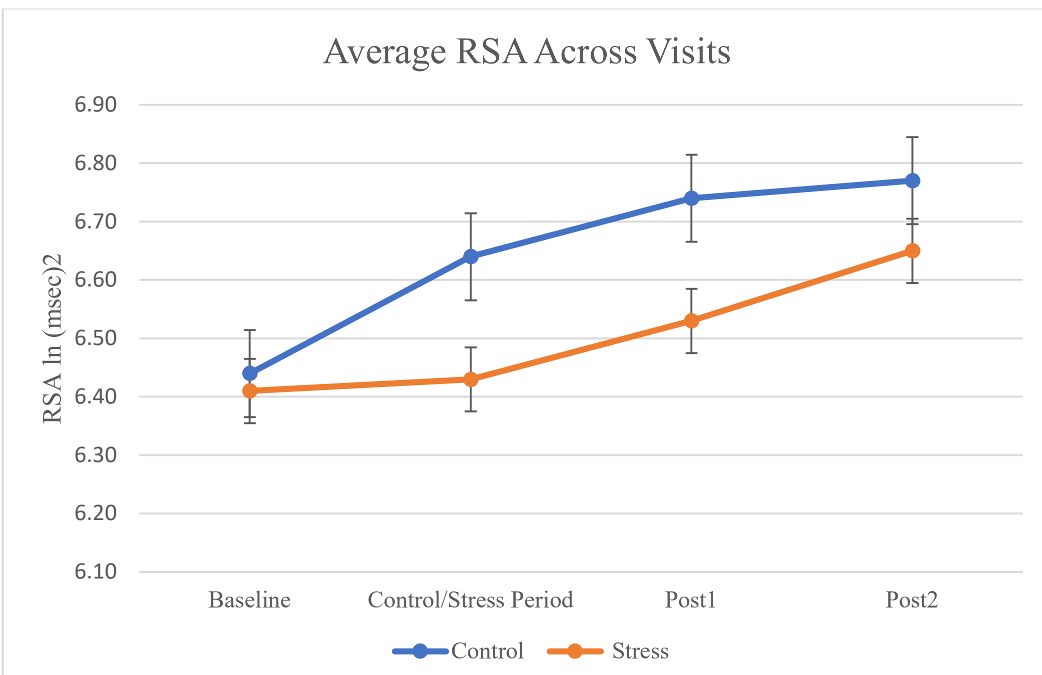
Table 4: Stress Measure Univariates for Adolescents

	n	Mean	SD
Perceived Stress Score	191	22.654	8.15
Block Design RSA	214	6.29	1.09
RSA 20-Min Post-Stress	196	6.54	0.99
RSA 40-Min Post-Stress	194	6.67	0.98

Stress Reactivity

Figure 2 demonstrates RSA measures throughout the control (blue line) and stress (orange line) conditions. Repeated measures mixed modeling revealed evidence of a significant day X time effect (p = 0.002). There was no significant difference in RSA at baseline between conditions (*p* = 0.980). Average RSA levels were lower at 20 minutes post-stress than they were at the same period in the control condition (p = 0.056), but this difference became insignificant after adjusting for age and sex. RSA levels did not differ between conditions at 40 minutes post-stress/control (p=.199). These findings indicate that adolescents' RSA was slightly suppressed under stress.

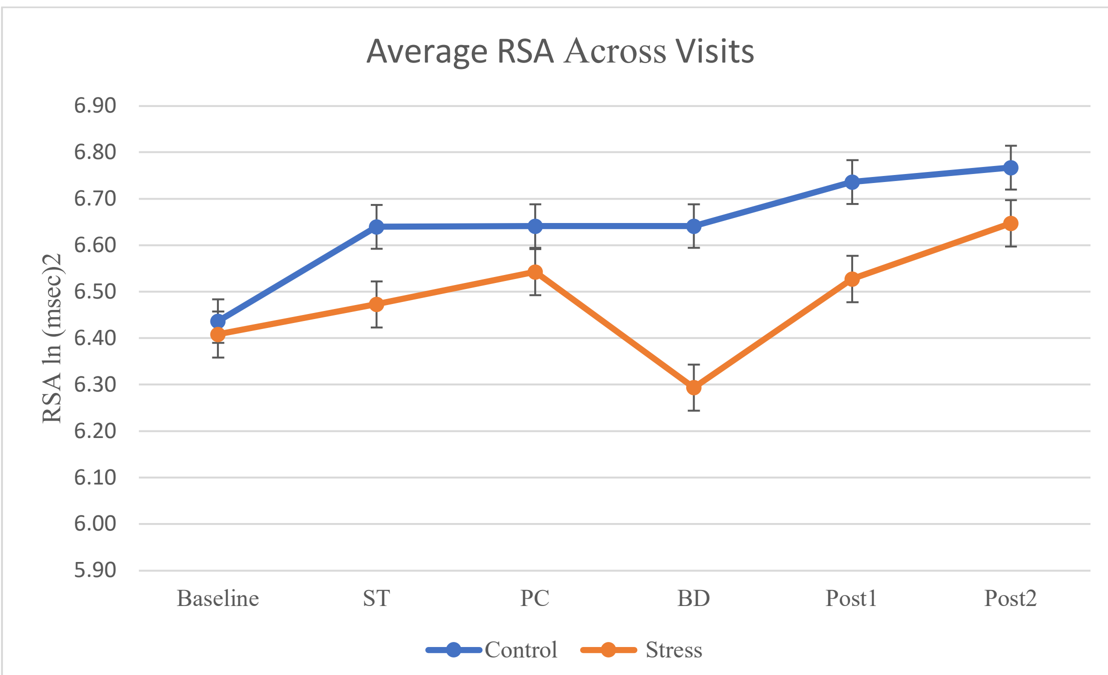
Figure 2: Average RSA Across Different Visits



Note: Post1= Average RSA 20 minutes post-stress; Post2= Average RSA 40 minutes post-stress.

When RSA levels were plotted across different challenges in the stress condition (Figure 3), it was revealed that the block design challenge resulted in the greatest RSA suppression. These results indicated that on average adolescents exhibited the greatest biological response to the block design challenge. Therefore, we will focus on RSA during the block design challenge as our main indicator of stress reactivity and refer to this challenge as this study's main stress test going forward. We also included RSA measures at 20- and 40-minutes post-stress to demonstrate stress recovery and as additional indicators of stress regulation.

Figure 3. Average RSA Across Different Stress Challenges



Note: ST = star tracing challenge; PC – perfect circle challenge; BD = block design challenge; Post1= Average RSA 20 minutes post-stress; Post2= Average RSA 40 minutes post-stress

Correlations Among Perceived and Objectively Measured Stress

Zero-order correlations revealed that perceived stress was not significantly correlated with biological stress measures (Table 5). However, all biological measures were significantly correlated to each other. RSA during stress was related to average RSA 20 minutes post-stress (r=0.8798, p=<.001) and average RSA 40 minutes post-stress (r=0.8366, p<.001). Average RSA 20 minutes post-stress was also significantly correlated to average RSA 40 minutes post-stress (r=0.9068, p<.001).

Table 5. Correlations among perceived stress and objective measures of stress

	Perceived Stress	RSA during stress	Avg. RSA 20-min post-stress
RSA during stress	-0.0642 (p=0.3957) n=177		
Avg. RSA 20-min post-stress	-0.0326 (p=0.6647) n=179	0.8798 (p=<.001) n=229	
Avg. RSA 40-min post-stress	-0.0356 (p=0.6358) n=179	0.8366 (p<.001) n=229	0.9068 (p<.001) n=232

Is Perceived Stress Associated with Adolescents' Adiposity?

A Pearson correlation coefficients test revealed a significant correlation across the sample between perceived stress and waist circumference, referred to as adiposity from here on (r= 0.20, p=.065). The interaction between perceived stress and sex was not significant (β= 0.10, p= 0.256) When we examined this association separately by gender, the association was no longer significant for males (β= 0.27, p= 0.163), but remained significant for females (β=0.50, p= 0.013) as seen in Fig. 4. Thus, for every 1-unit change in perceived stress, there was a .50 cm increase in waist circumference in females. Although the interaction between perceived stress and race was not significant (β= 0.12, p= 0.234), differences emerged when we stratified by race; the association between perceived stress and adiposity was marginally significantly for white adolescents (β=0.26, p= 0.081), and for Black adolescents (β=0.65, p=0.081) as seen in Fig. 5.

Figure 4. Sex differences in the association between perceived stress and waist circumference

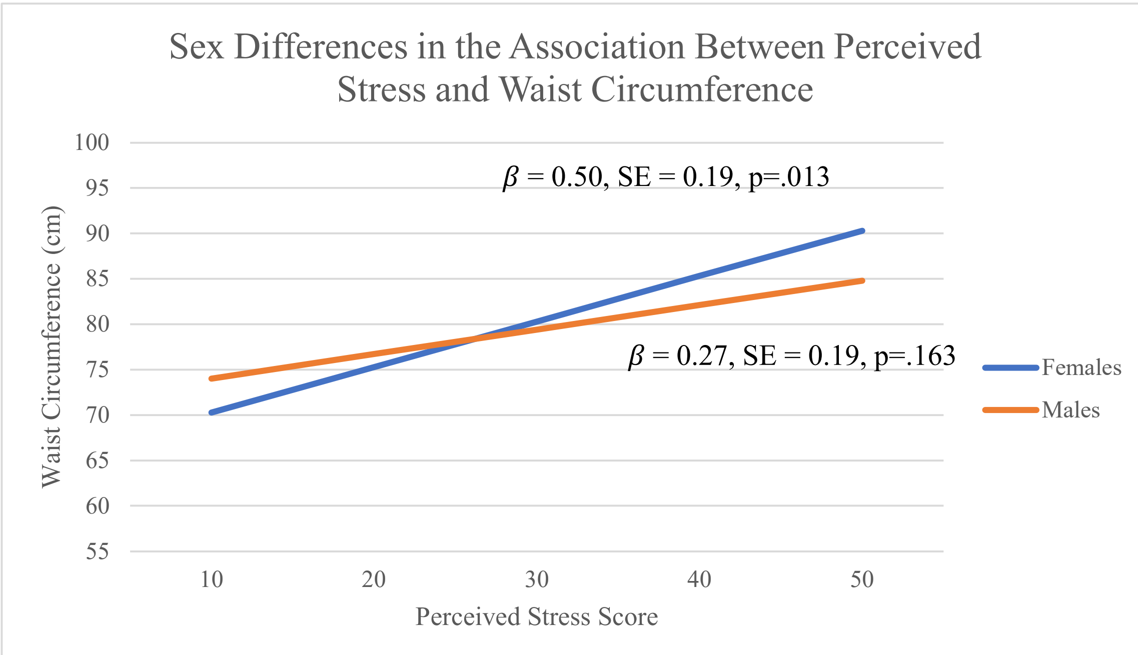
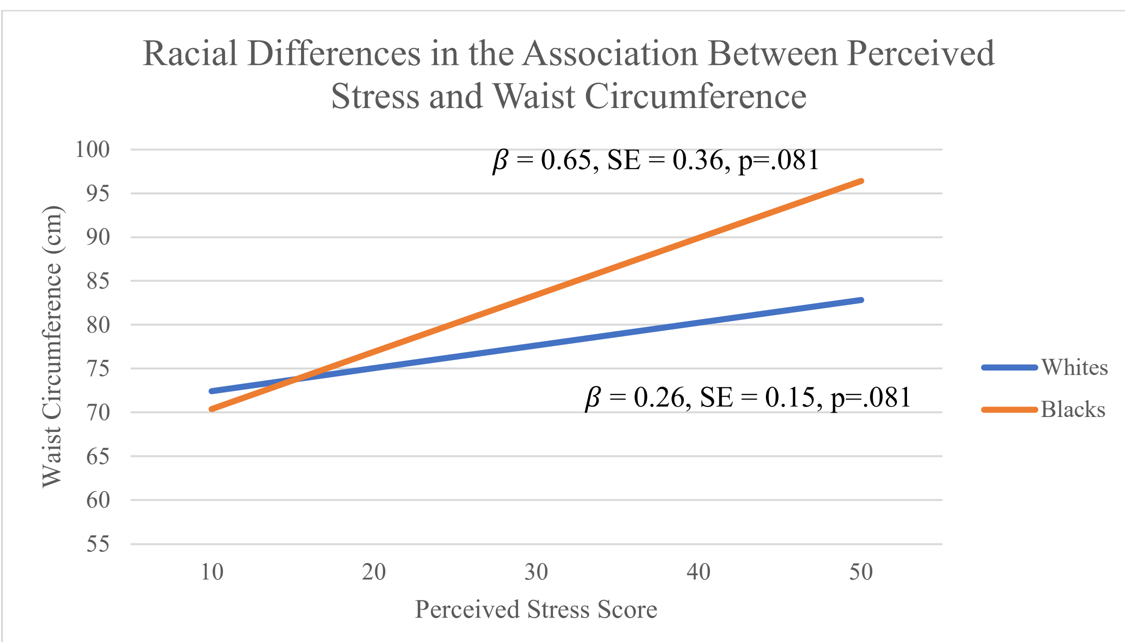


Figure 5. Racial differences in the association between perceived stress and waist circumference



Is RSA Associated with Adolescents' Adiposity?

RSA During Stress

In order to answer this question, we conducted a Pearson correlation coefficients test that revealed a significant correlation across the sample between RSA during stress and adiposity (r=-0.16, p=0.016). The interaction between RSA during stress and sex was significant (β= 0.64, p= 0.040). Results revealed a significant association between RSA during stress and adiposity for females (β=-4.05, p< 0.001), but not for males (β=-0.17, p=0.91) (Fig. 6). For every 1-unit decrease in RSA during stress, there was a 4.05 cm increase in waist circumference in females. The interaction between RSA during stress and race was not significant (β= 0.30, p= 0.412). We observed significant differences when the sample was stratified by race (Fig. 7); RSA during stress and adiposity were significantly correlated for Black participants (β =0.037, p=0.099), but not significantly correlated for white adolescents (β=-1.59, p=0.132). Thus, for every 1-unit decrease in RSA during stress, there was a 1.59 cm increase in waist circumference in white adolescents.

Figure 6. Sex differences in the association between RSA during stress and waist circumference

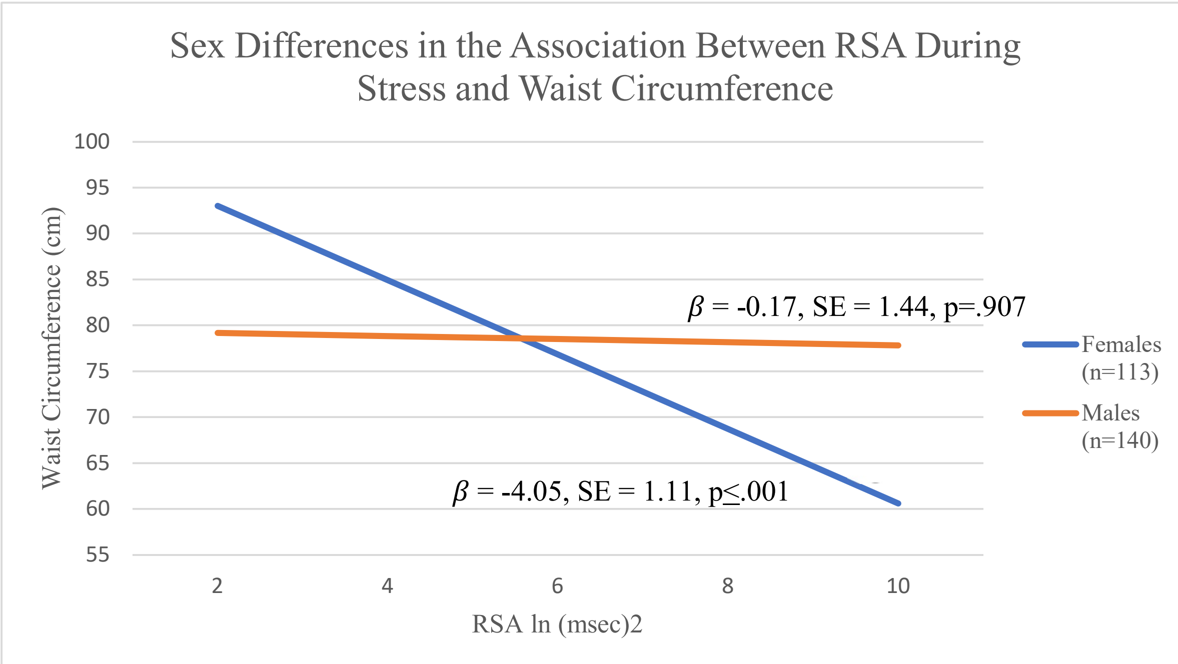
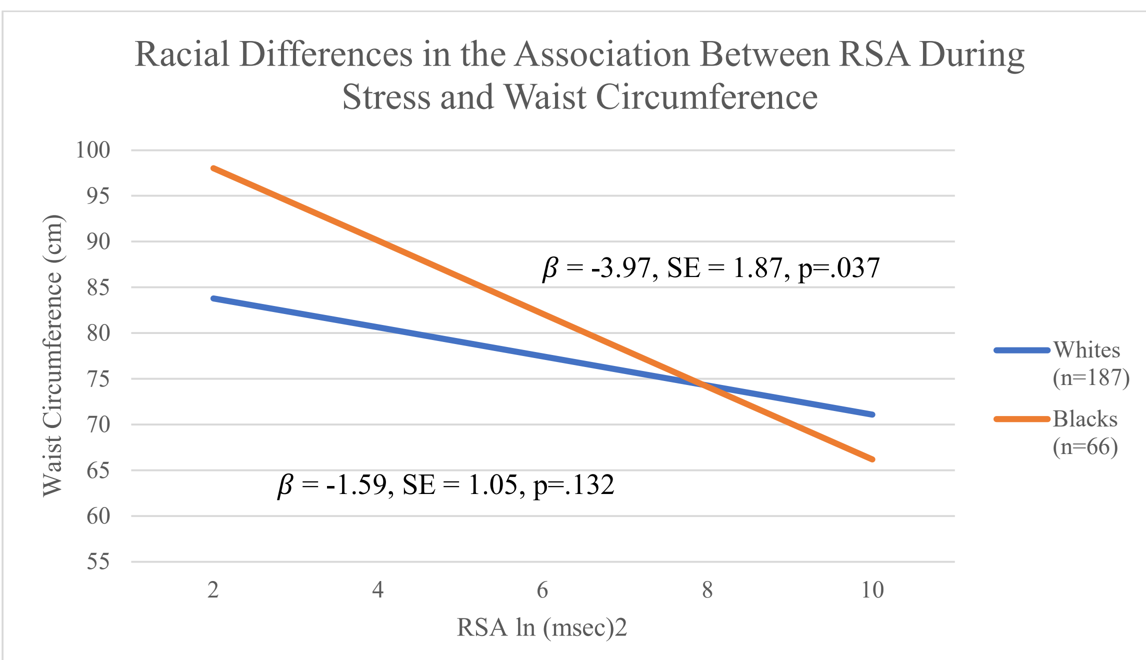


Figure 7. Racial differences in the association between RSA during stress and waist circumference



RSA Recovery 20 Minutes Post-Challenge

A Pearson correlation coefficients test revealed no significant correlation across the sample between average RSA 20 minutes post-stress and adiposity (r=-0.10, p=0.13), although the interaction between RSA 20-minutes post-stress and sex was significant (β= 0.68, p= 0.029). Once again, when this association was separated by gender (Fig. 7), there was no significant association for males (β=0.45, p=0.784) and a significance negative association for females (β = -3.77, p= 0.004). For every 1-unit decrease in RSA 20-minutes post-stress, there was a 3.77 cm increase in waist circumference. We saw no significant interactions with race, and no differences when the sample was split by race (Figure 9).

Figure 8. Sex differences in the association between RSA 20 minutes post-stress and waist circumference

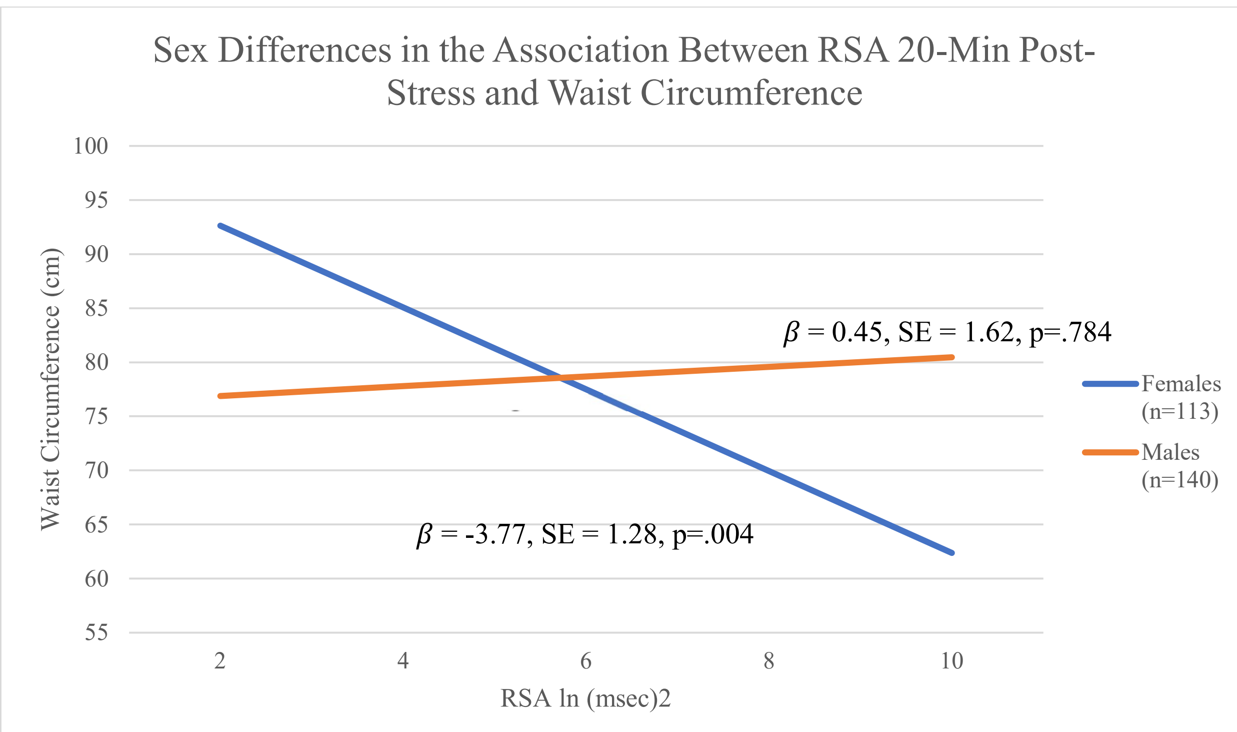
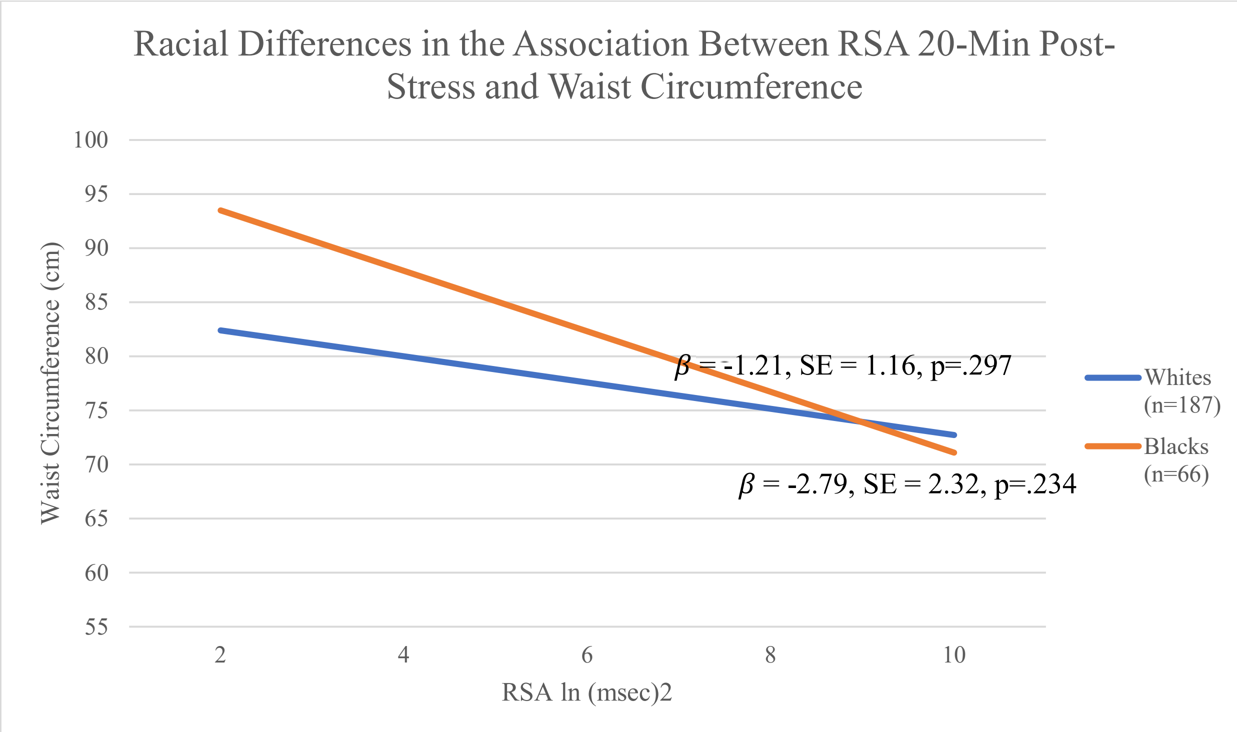


Figure 9. Racial differences in the association between RSA 20 minutes post-stress and waist circumference



RSA Recovery 40 Minutes Post-Challenge

There was a significant, negative correlation between RSA 40 minutes after the stress test and adiposity across the sample (r=-0.16, p=0.014), and the interaction between RSA 40-minutes post-stress and sex was marginally significant (β= 0.57, p= 0.051); the interaction with race was not significant (β= -4.02, p= 0.003). However, this association was only significant for female adolescents as seen in Fig. 10. (β= 0.27, p= 0.443) and Black participants as seen in Fig. 11 (β = -4.62, p=0.028). For every 1-unit decrease in RSA 40-minutes post-stress, there was a 4.02 cm increase in waist circumference in females and a 4.62 cm increase in waist circumference in Black adolescents.

Figure 10. Sex differences in the association between RSA 40 minutes post-stress and waist circumference

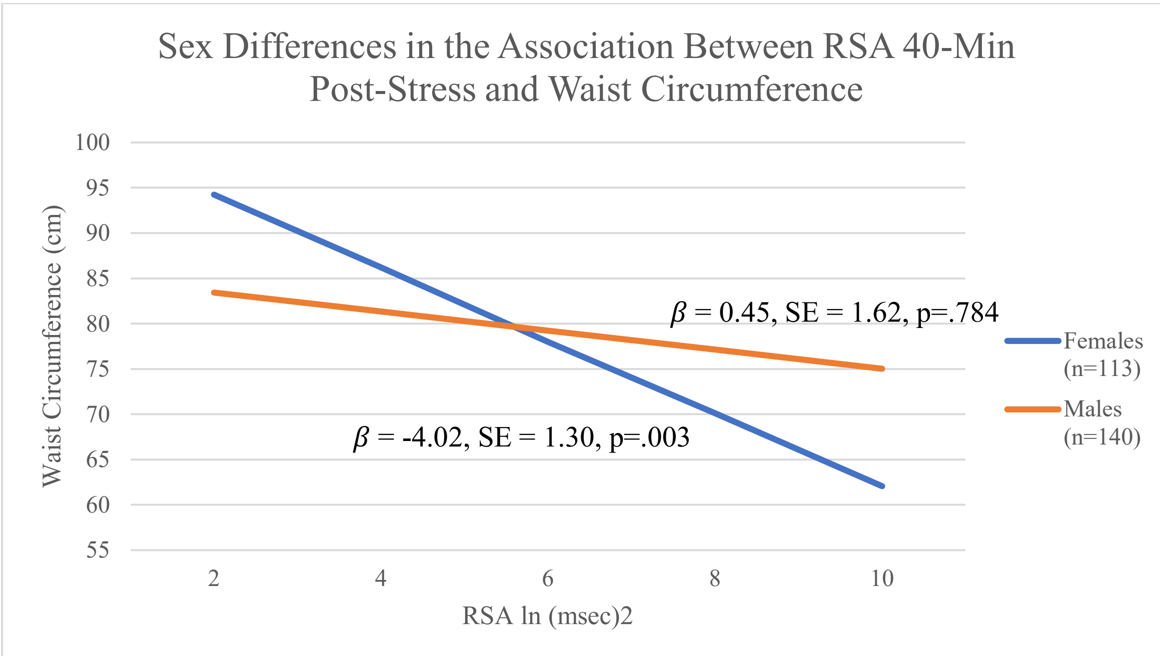
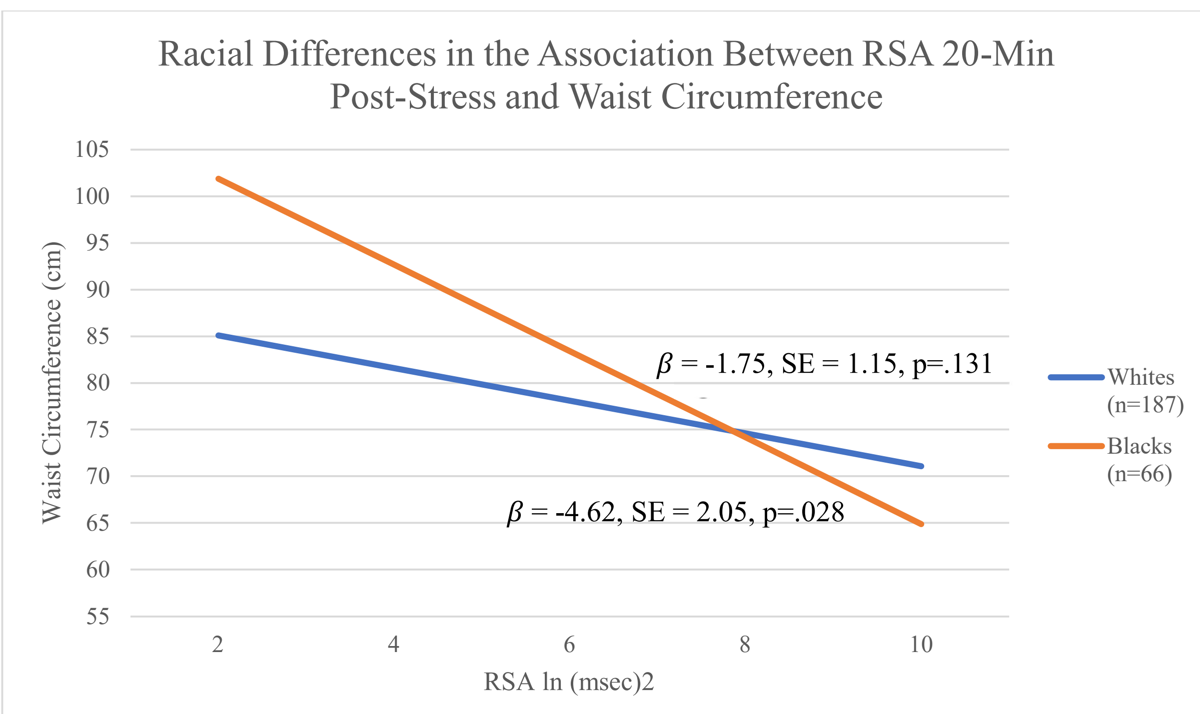


Figure 11. Racial differences in the association between RSA 40 minutes post-stress and waist circumference



Does Physical Activity Act as a Buffer Between Stress and Adiposity?

Using the median cutoff between high and low physical activity categories was as follows:

Lower Physical Activity (Low PA): Average of <27 minutes of MVPA per day

Higher Physical Activity (High PA): Average of ≥ 27 minutes of MVPA per day

Given threats to power due to small sample sizes once the sample was stratified by physical activity level, we did not run any additional models by race or sex. Rather, these variables were included as covariates in models examining physical activity as a moderator.

There were no significant interactions between the continuous measure of MVPA and perceived stress (β= -0.14, p= 0.291), RSA during stress (β= -0.08, p= 0.884), RSA 20-minutes post-stress (β= -0.17, p= 0.753), or RSA 40-minutes post-stress (β= -0.09, p= 0.856). As depicted in Fig. 12, the association between stress measures and adiposity was moderated by levels of physical activity, such that perceived stress was significantly correlated to adiposity for those who engaged with less than 27 minutes of physical activity (β=0.413, p=.013), but not for those who engaged with more than 27 minutes of daily physical activity (β=0.363, p=.152). We observed a similar moderated relationship in Fig. 13 between RSA during stress and adiposity with no association in adolescents with higher levels of physical (β=-0.31, p=.857) and a significant correlation in adolescents with lower levels of physical activity (β=-2.52, p=.025). No significant moderating effect from physical activity was observed for the relationships between RSA 20 minutes post-stress and adiposity (Fig. 14). There was a slight moderating effect from physical activity for RSA 40 minutes post-stress and adiposity (Higher levels: β=1.73, p=0.372, Lower levels: β=-2.40, p=0.052) (Fig. 15).

Figure 12. The moderating effect of MVPA on the association between perceived stress and waist circumference

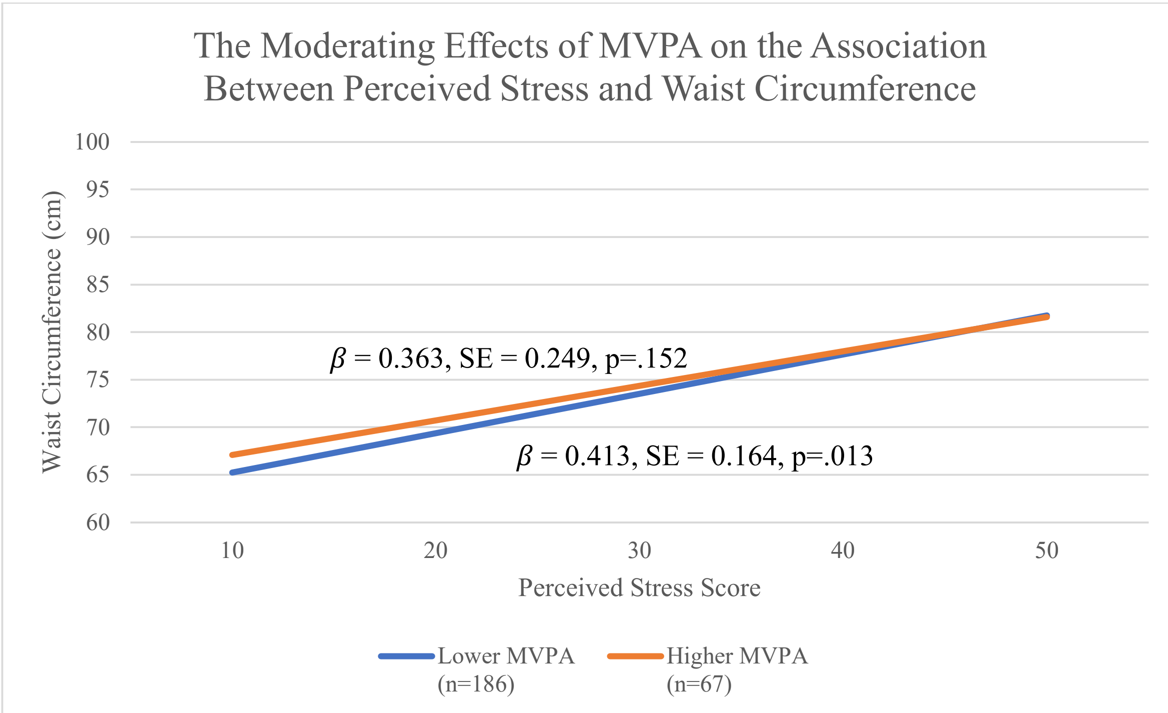


Figure 13. The moderating effect of MVPA on the association between RSA during stress and waist circumference

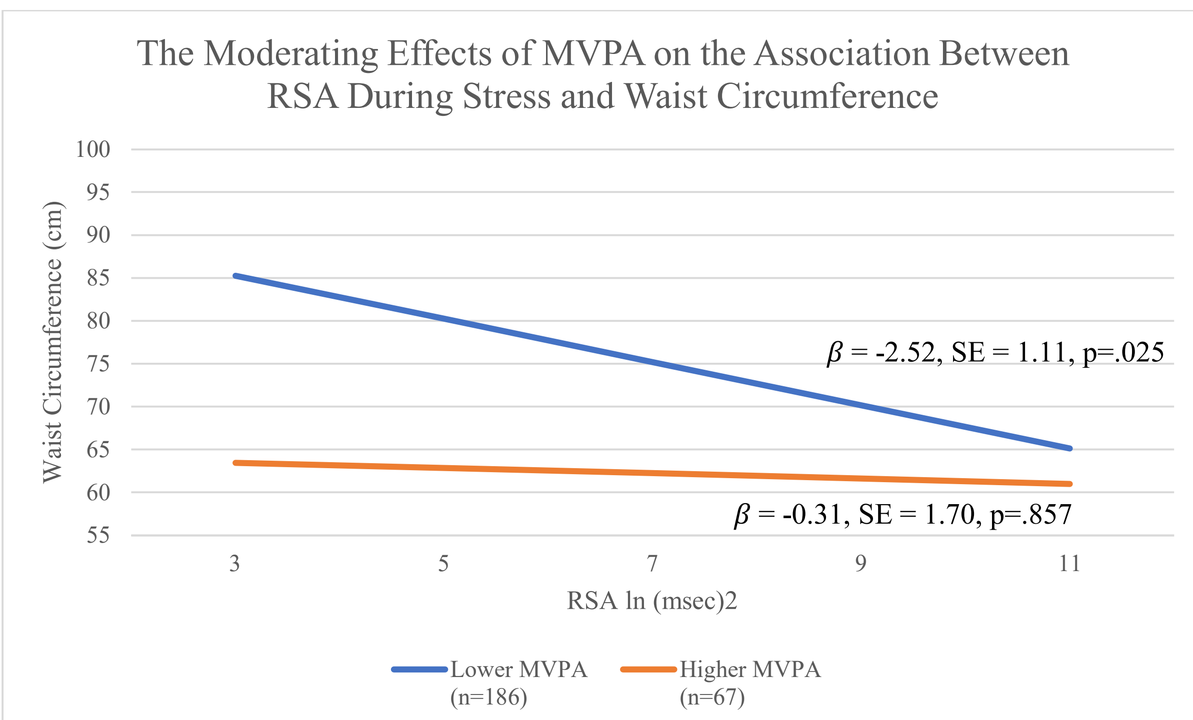


Figure 14. The moderating effect of MVPA on the association between RSA 20 minutes post-stress and waist circumference

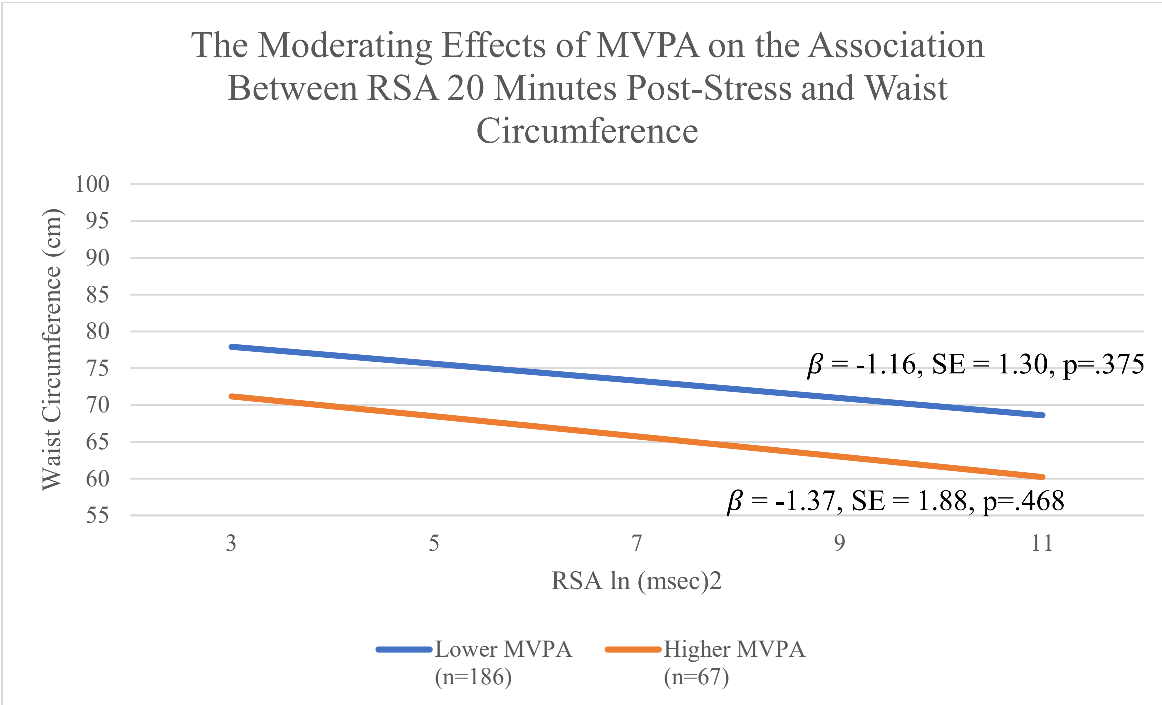
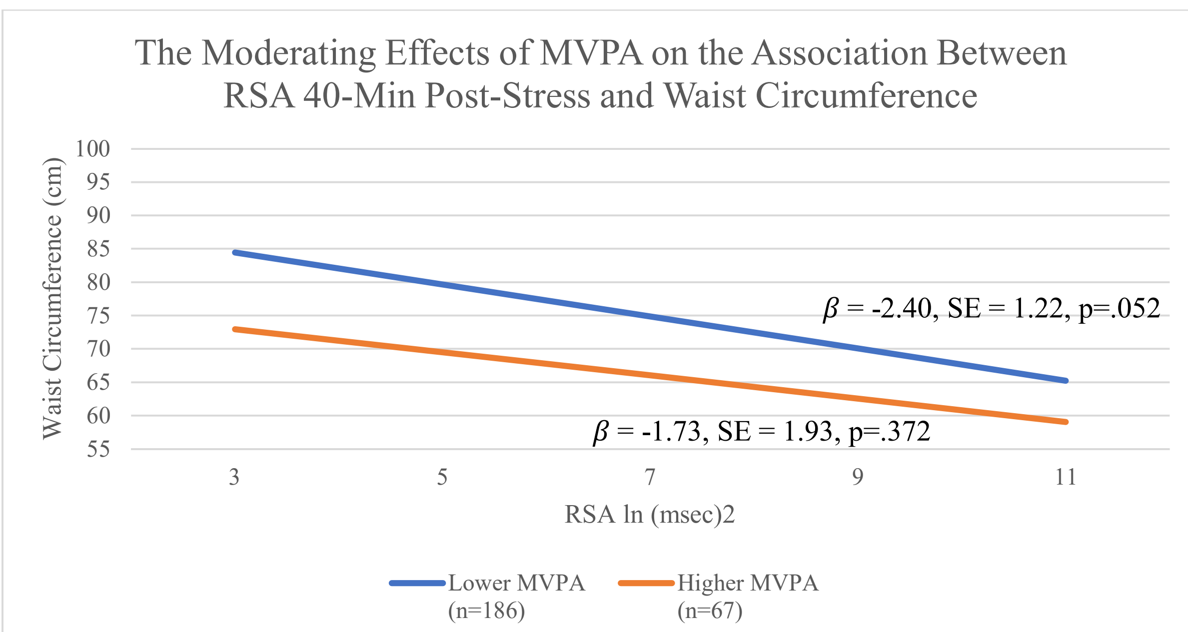


Figure 15. The moderating effect of MVPA on the association between RSA 40 minutes post-stress and waist circumference



Chapter 4

DISCUSSION

Overview of Results

The present study sought to address the hypothesis that physical activity acted as a moderator for the relationship between stress and obesity among adolescents experiencing poverty. In other words, higher physical activity may have reduced the potential effects of stress on adolescents' obesity. Our results were mostly consistent with this hypothesis. Firstly, both perceived stress scores (subjective) and RSA during a stress challenge (objective) were significantly correlated to central adiposity, but only for adolescents with lower physical activity levels (Figures 11 and 12). These findings suggested evidence of a moderating effect from physical activity in the relationship between stress (both biological and subjective) and obesity. Secondly, our results provided evidence that stress measures such as perceived stress, RSA during stress, and average RSA 20 minutes after the stress challenge were all significantly correlated to central adiposity. These results suggested that if adolescents engaged with even just 27 minutes of MVPA per day, they may have warded off obesity by way of stress moderation.

This relationship was partially moderated by sex and race. Overwhelmingly all stress measures were significantly correlated with adiposity for females, but no relationship existed between stress variables and adiposity for males. Similarly, RSA during stress and RSA 40 minutes post-stress were only significantly correlated with adiposity for Black adolescents, not for white adolescents. These results suggested that females and/or Black adolescents may have experienced this relationship between stress and obesity more significantly than male and/or white adolescents.

Theoretical Implications

These results added to the current literature in many meaningful ways. First, our findings corroborated those in the literature that showed that various forms of stress correlated with adolescent adiposity (Tomiyama, 2019, Jääskeläinen et al., 2014, Tiwaloluwa and colleagues, 2021). Significant correlations with adiposity were found between perceived stress and RSA during and after stress. Interestingly we found that this relationship was more prominent for female adolescents and Black adolescents. Therefore, these results support research that proposes that being female and/or Black makes one more susceptible to weight gain due to stressors (Heraclides et. al, 2012), whether that is due to behaviors, disparities, etc. (Davis et. al, 2012). Our study also found evidence that physical activity acted as a moderator in the relationships between perceived stress and adiposity, and RSA during stress and adiposity among this sample of adolescents. As previously mentioned, research has found that physical activity influences both stress and obesity independently (Hills, 2011, Moljord, 2011), but the literature is unclear about the buffering effect of physical activity. Our results corroborated those found in a similar study conducted by Yin and colleagues (2005) which established physical activity as buffer in the relationship between subjective stress and adiposity. In contrast to their study, our results included RSA as an indicator of objective stress dysregulation, and found that physical activity was a significant moderator for the relationship between RSA during stress and adiposity.

Clinical Implications

The results of this study have implications for obesity prevention amongst adolescents experiencing poverty. Specifically, they may be important for observing that stressors, measured both subjectively and objectively, may have a differential impact on obesity in females and Black people. These results also provided evidence that regular physical activity may alter the relationship between stress and obesity, and is necessary for the long-term health of these adolescents. Although the Physical Activity Guidelines for Americans recommends 60 minutes of MVPA per day (US Dept. of Health, 2018), this study indicates that just 27 min/day of MVPA may have a significant impact upon adolescent health. Furthermore, additional analyses revealed that the moderating effects of physical activity remained significant in adolescents in this sample with just an average of 20 minutes of MVPA/day (data not shown). Some public schools across the nation are beginning to address the rapid rise in obesity among children and adolescents. In order to counteract the rising rates of childhood and adolescent obesity, policymakers and educators should re-orient intervention activities to reach their target demographic at or before the time in which problems begin. Obesity behaviors tend to develop between the ages of 5 and 6, or during adolescence. According to the American Academy of Child and Adolescent Psychiatry, 80% of obese adolescents will be obese adults as well ("Obesity in Children and Teens", 2017). This age is therefore a critical intervention point to fend off future health concerns. The CDC released "the Comprehensive School Physical Activity Programs: A Guide for Schools" in 2013 that explores the importance of instituting healthy physical habits and relationships as early as possible. The guide encourages a multi-tier, school intervention strategy that requires quality physical education classes, physical activity during the school day, physical activity before and after school, and staff, family and community involvement in every school district (Check, 2013).

Of the studies that have investigated the cost-benefit for obesity intervention, most if not all, arrived at the likely conclusion that early obesity prevention saved a substantial amount of future health care expenses and strains upon the system. A recent systematic review of 39 childhood and adolescent obesity interventions found that all but four were deemed cost-effective or even cost-beneficial when compared to the cost of adult obesity (Zanganeh, 2019). Physical activity is an important, low-cost, behavioral factor for preventing this unhealthy weight gain among adolescents, and unfortunately most Western adolescents do not meet physical activity guidelines (Hills, 2011). Research shows that exercise can counteract obesity through decreased body fat retention, improved self-image, and improved cardiovascular health (Hills, 2011). Ultimately, these significant findings uphold the need for regular physical activity in the lives of our adolescents in order to prevent obesity.

Biobehavioral Health Implications

Because I am pursuing honors in Biobehavioral Health, this study incorporated aspects of biology, behavior and health. One biological independent measure was stress dysregulation and recovery (RSA) in response to a manipulated psychosocial stressor. Dependent measures for obesity were also biological, including BMI and waist circumference, as well as race and sex. Physical activity was also a nuanced behavioral variable influenced by personal choices, resources, income and education. These behavioral aspects informed the incorporation of physical activity as a potential moderator for the relationship between adolescent stress and adiposity (Zanganeh, 2019). And finally, the ultimate goal of my thesis was to contribute to our understanding of factors that are important for obesity prevention amongst adolescents experiencing poverty (Cardel, 2020).

Limitations

There are several limitations to this study. Due to the sociodemographic characteristics of this sample being predominantly rural and experiencing poverty, it is difficult to generalize these results to non-rural youth who are not experiencing poverty in the U.S. Similarly, demographic sample sizes were uneven for sex and race. Although we were able to examine within-group variation in the effects of stress, we did not have the statistical power to examine interactions in physical activity moderation models by race and sex. These data are also cross-sectional and although we hypothesize that stress influences adiposity and that physical activity moderates it (for certain groups), we cannot confirm the directionality of this relationship. Additionally, other factors outside of those considered in this study may have played an important role in the relationship between stress and obesity, including food intake or issues with access to physical activity opportunities, or other resources conducive to health (Jääskeläinen, 2014). There also may have been technological errors with the Actigraph device or program adherence issues when the adolescents were responsible for wearing the device. However, this concern is reduced based on the finding that adolescents wore the device for an average of 6 out of the 7 required days. Despite these limitations, this study adds new information on the important role that physical activity may play in reducing the effects of stress on obesity development in a diverse sample of rural adolescents experiencing poverty. Additional strengths include the use of objective measures of stress, physical activity, and central adiposity.

Conclusions

The findings from this study contribute uniquely to our understanding of the potential buffering effects of physical activity on the association between stress and adiposity among adolescents experiencing poverty. Additionally, this study utilized both subjective and objective measures of stress to increase the validity of these results. This study also provided evidence for sex and racial differences in the association between various stressors and adiposity. Future longitudinal research needs to be conducted in order to investigate potential mechanisms that may explain this association further.

REFERENCES

Ajibewa, T. A., Adams, T. A., Gill, A. K., Mazin, L. E., Gerras, J. E., & Hasson, R. E. (2021). Stress coping strategies and stress reactivity in adolescents with overweight/obesity. *Stress and Health*, *37*(2), 243-254.

Bagøien, T. E., Halvari, H., & Nesheim, H. (2010). Self-determined motivation in physical education and its links to motivation for leisure-time physical activity, physical activity, and well-being in general. *Perceptual and Motor Skills*, 111(2), 407-432.

Basu, S., McKee, M., Galea, G., & Stuckler, D. (2013). Relationship of soft drink consumption to global overweight, obesity, and diabetes: a cross-national analysis of 75 countries. *American journal of public health*, *103*(11), 2071–2077. https://doi.org/10.2105/AJPH.2012.300974

Barlow, S. E., & Expert Committee (2007). Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. *Pediatrics*, *120 Suppl 4*, S164–S192. https://doi.org/10.1542/peds.2007-2329C.

Cardel, M. I., Atkinson, M. A., Taveras, E. M., Holm, J. C., & Kelly, A. S. (2020). Obesity Treatment Among Adolescents: A Review of Current Evidence and Future Directions. *JAMA pediatrics*, *174*(6), 609–617. https://doi.org/10.1001/jamapediatrics.2020.0085.

Caspi, C. E., Sorensen, G., Subramanian, S. V., & Kawachi, I. (2012). The local food environment and diet: a systematic review. *Health & place*, 18(5), 1172-1187.

Centers for Disease Control and Prevention. (2022, May 17). Prevalence of Childhood Obesity in the United States. *Centers for Disease Control and Prevention*. Retrieved December 14, 2022, from https://www.cdc.gov/obesity/data/childhood.html.

Check, K. (2013). Comprehensive School Physical Activity Programs a Guide for Schools.

Chen, E., Langer, D. A., Raphaelson, Y. E., & Matthews, K. A. (2004). Socioeconomic status and health in adolescents: The role of stress interpretations. *Child development*, *75*(4), 1039-1052.

Cohen, S., Kamarck, T., & Mermelstein, R. (1994). Perceived stress scale. Measuring stress: A guide for health and social scientists, 10(2), 1-2.

Davis, E. M., Stange, K. C., & Horwitz, R. I. (2012). Childbearing, stress and obesity disparities in women: a public health perspective. *Maternal and child health journal*, *16*, 109-118.

Davison, K. K., & Birch, L. L. (2001). Childhood overweight: a contextual model and recommendations for future research. *Obesity reviews : an official journal of the International Association for the Study of Obesity*, *2*(3), 159–171. https://doi.org/10.1046/j.1467-789x.2001.00036.x

Dyson, M. W., Olino, T. M., Durbin, C. E., Goldsmith, H. H., Bufferd, S. J., Miller, A. R., & Klein, D. N. (2015). The structural and rank-order stability of temperament in young children based on a laboratory-observational measure. *Psychological Assessment*, 27(4), 1388–1401. https://doi.org/10.1037/pas0000104

Eckberg, D. L. (2000). Physiological basis for human autonomic rhythms. *Annals of Medicine*. 32, 341–349. doi: 10.3109/07853890008995937.

Friedman BH. (2007). An autonomic flexibility-neurovisceral integration model of anxiety and cardiac vagal tone. Biol Psychol 74(2):185–99.

Freedson, P., Pober, D., & Janz, K. F. (2005). Calibration of accelerometer output for children. *Medicine and Science in Sports and Exercise, 37*(11), S523-S530. doi:10.1249/01.mss.0000185658.28284.ba

Gerber, M., & Pühse, U. (2008). "Don't crack under pressure!"—Do leisure time physical activity and self-esteem moderate the relationship between school-based stress and psychosomatic complaints?. *Journal of Psychosomatic Research*, *65*(4), 363-369. https://doi.org/10.1016/j.jpsychores.2008.06.012.

Graham, J. W., Taylor, B. J., Olchowski, A. E., & Cumsille, P. E. (2006). Planned missing data designs in psychological research. *Psychological Methods*, 11(4), 323-343. doi:10.1037/1082-989X.11.4.323.

Gouin, J. P., Deschênes, S. S., & Dugas, M. J. (2014). Respiratory sinus arrhythmia during worry forecasts stress-related increases in psychological distress. *Stress (Amsterdam, Netherlands)*, *17*(5), 416–422. https://doi.org/10.3109/10253890.2014.949666.

Gulliksen, H. (2013). *Theory of mental tests*. Routledge.

Heraclides, A. M., Chandola, T., Witte, D. R., & Brunner, E. J. (2012). Work stress, obesity and the risk of type 2 diabetes: sex-specific bidirectional effect in the Whitehall II study. *Obesity, 20*(2), 428-433.

Hills, A. P., Andersen, L. B., & Byrne, N. M. (2011). Physical activity and obesity in children.

British Journal of Sports Medicine, 45(11), 866-870.

Hong, I., Coker-Bolt, P., Anderson, K. R., Lee, D., & Velozo, C. A. (2016). Relationship Between Physical Activity and Overweight and Obesity in Children: Findings From the 2012 National Health and Nutrition Examination Survey National Youth Fitness Survey. *Am J Occup Ther*, *70*(5), 7005180060p7005180061-7005180068. https://doi.org/10.5014/ajot.2016.021212.

Jääskeläinen, A., Nevanperä, N., Remes, J., Rahkonen, F., Järvelin, M. R., & Laitinen, J. (2014). Stress-related eating, obesity and associated behavioral traits in adolescents: a prospective population-based cohort study. *BMC public health*, *14*(1), 1-14.

Jimenez, V., Sanchez, N., Clark, E. L., Miller, R. L., Casamassima, M., Verros, M., ... & Shomaker, L. B. (2021). Associations of adverse childhood experiences with stress physiology and insulin resistance in adolescents at risk for adult obesity. *Developmental Psychobiology*, *63*(6), e22127.

Kohs, S. C. (1923). Intelligence measurement: A psychological and statistical study based upon the block-design tests. New York: MacMillan Co.

Kral, T. V. E., Moore, R. H., Chittams, J., Jones, E., O'Malley, L., Fisher, J. O. (2018). Identifying behavioral phenotypes for childhood obesity. *Appetite*, *127*, 87-96. https://doi.org/10.1016/j.appet.2018.04.021.

LeCroy, M. N., Kim, R. S., Stevens, J., Hanna, D. B., & Isasi, C. R. (2021). Identifying Key Determinants of Childhood Obesity: A Narrative Review of Machine Learning

Studies. *Childhood obesity (Print)*, *17*(3), 153–159.
https://doi.org/10.1089/chi.2020.0324

Migueles, J. H., Cadenas-Sanchez, C., Ekelund, U., Nystrom, C. D., Mora-Gonzalez, J., Lof, M., . . . Ortega, F. B. (2017). Accelerometer Data Collection and Processing Criteria to Assess Physical Activity and Other Outcomes: A Systematic Review and Practical Considerations. *Sports Medicine, 47*(9), 1821-1845. doi:10.1007/s40279-017-0716-0.

Meyer, S., Grob, A., & Gerber, M. (2021). No fun, no gain: The stress-buffering effect of physical activity on life satisfaction depends on adolescents' intrinsic motivation. *Psychology of Sport and Exercise*, *56*. https://doi.org/10.1016/j.psychsport.2021.102004.

Moljord, I. E. O., Eriksen, L., Moksnes, U. K., & Espnes, G. A. (2011). Stress and happiness among adolescents with varying frequency of physical activity. *Perceptual and Motor Skills*, 113(2), 631-646.

Must, A., & Strauss, R. S. (1999). Risks and consequences of childhood and adolescent obesity. *International journal of obesity*, *23*(2), S2-S11.

Nagata, J. M., Garber, A. K., Tabler, J. L., Murray, S. B., & Bibbins-Domingo, K. (2018). Prevalence and Correlates of Disordered Eating Behaviors Among Young Adults with Overweight or Obesity. *J Gen Intern Med*, *33*(8), 1337-1343. https://doi.org/10.1007/s11606-018-4465-z.

Obesity in Children and Teens. (April, 2017). *American Academy of Child and Adolescent*

Psychology, No. 79. Retrieved from https://www.aacap.org/AACAP/Families_and_Youth/Facts_for_Families/FFF-Guide/Obesity-In-Children-And-Teens-079.aspx.

Porges, S.W. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116–143.

Robinson, T. N., Banda, J. A., Hale, L., Lu, A. S., Fleming-Milici, F., Calvert, S. L., & Wartella, E. (2017). Screen Media Exposure and Obesity in Children and Adolescents. *Pediatrics*, *140*(Suppl 2), S97–S101. https://doi.org/10.1542/peds.2016-1758K

Rodgers, R. F., Watts, A. W., Austin, S. B., Haines, J., & Neumark-Sztainer, D. (2017). Disordered eating in ethnic minority adolescents with overweight. *Int J Eat Disord*, *50*(6), 665-671. https://doi.org/10.1002/eat.22652.

Stierman, B., Afful, J., Carroll, M. D., Chen, T., Davy, Orlando, Fink, S., Fryar, C. D., Gu, Q,. Hales, C. M., Hughes, J. P., Ostchega, Y, Storandt, R. J., Akinbami, L. J. (2021, June 14). National Health and Nutrition Examination Survey 2017–March 2020 Prepandemic Data Files Development of Files and Prevalence Estimates for Selected Health Outcomes. *National Health Statistics Reports, NHSR No. 158,* http://dx.doi.org/10.15620/cdc:106273.

Stults-Kolehmainen, M. A., & Sinha, R. (2014). The effects of stress on physical activity and exercise. *Sports medicine*, *44*, 81-121.

Tomiyama, A. J. (2019). Stress and obesity. *Annual review of psychology*, *70*, 703-718.

United States. Dept. of Health and Human Services. Physical Activity Guidelines Advisory Committee & United States. Dept. of Health and Human Services. (2018). *Physical Activity Guidelines Advisory Committee report, 2018: To the Secretary of Health and Human Services*. U.S. Dept. of Health and Human Services.

Vernon-Feagans, L., Cox, M., & Investigators, F. L. F. K. (2013). The Family Life Project: an epidemiological and developmental study of young children living in poor rural communities. *Monogr Soc Res Child Dev, 78*(5), 1-150, vii. doi:10.1111/mono.12046.

Wilson, S. M., & Sato, A. F. (2014). Stress and paediatric obesity: what we know and where to go. Stress and Health, 30(2), 91-102. https://onlinelibrary.wiley.com/doi/full/10.1002/smi.2501?casa_token=B_xSKLhfl8MAAAAA%3AiG8EYnDLs5bHpolH1pyPk0SHyZV-hd_dFpqCchtm0OFyG29R5v0AwYk_bLrTU32B6IIsJajTpyrV.

Yin, Z., Davis, C.L., Moore, J.B., & Treiber, F.A. (2005). Physical activity buffers the effects of chronic stress on adiposity in youth. *Annals of Behavioral Medicine, 29*, pp. 29–36. https://doi.org/10.1207/s15324796abm2901_5.

Zanganeh, M., Adab, P., Li, B., & Frew, E. (2019). A Systematic Review of Methods, Study Quality, and Results of Economic Evaluation for Childhood and Adolescent Obesity Intervention. *International journal of environmental research and public health*, 16(3), 485. https://doi.org/10.3390/ijerph16030485

Academic Vita - Camryn Buss

Aspiring Physical Therapist with extensive experience in the field as well as research, communication and leadership skills.

Committed to lifelong learning, positivity and delivering excellence.

- Major: Biobehavioral Health (Pre-PT)
- Minor: Psychology
- 3 years of Research Experience

EDUCATION

Pennsylvania State University: State College, PA
—*Biobehavioral Health,* August 2019 - PRESENT

Schreyer Honors College: State College, PA
—*First Year Admit,* August 2019 – PRESENT

University of Pittsburgh School of Health and Rehabilitation Sciences: Pittsburgh, PA
–*Doctorate of Physical Therapy*, August 2023-December 2025

INVOLVEMENT

Phi Sigma Pi National Honors Fraternity: Vice President
January 2021-PRESENT

- National Honors Fraternity that develops academic and professional skills
- As Vice President, assign and lead 28 chair positions in planning and executing events (service, scholarship, sustainability, etc.)
- Raised over $27,000 for pediatric cancer

Penn State Sign Language Organization
January 2021-PRESENT

- Penn State's only club that practices and promotes American Sign Language use
- Perform in sign language for THON and local conventions
- Promote ASL education and Deaf culture awareness at Penn State to improve inclusivity on campus

Schreyer Orientation Mentor
March 2020-August 2020

- Guide group of 18 new scholars through Schreyer Honors College Orientation
- Work on Communications Team to maintain Scholar relations over summer
- Assist Scholars preparing to arrive and facilitated scheduled activities

AWARDS

Penn State Dean's List: 2019, 2020, 2021, 2022, 2023
Pentz Academic Excellence Scholarship: 2019, 2020, 2021, 2022, 2023
Smith Scholarship in Health and Human Development: 2019, 2020, 2021, 2022, 2023
President's Freshman Award: 2020