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Adolescent sources of stress, stress levels, and associations between stress and changes in weight outcomes at the time of COVID-19 related school closure in March 2020

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ABSTRACT

Objective: Stress is associated with weight changes, yet how level and sources of stress relate to this association is poorly understood. This mixed methods study examined associations between adolescent stress at the COVID-19 pandemic onset and standardized BMI (BMIz) over a three-month period. Methods: Participants ($N = 197$, mean age 13.66 ± 1.43 years, 85% Hispanic, 56% female) were recruited from a charter school in Texas to participate in a healthy lifestyle intervention during physical education class. We calculated BMIz using height and weight measurements taken December 2019 and the week of COVID-19 school closures in March 2020. We measured stress in March 2020 with the 4-item Perceived Stress Scale. We ran a multiple linear regression model controlling for baseline BMIz (December 2019), age, sex, intervention condition, and assessed the interaction between baseline BMIz and PSS-4 score on BMIz change.

Results: Overall, our sample had an average PSS-4 score of seven and mean BMIz decrease of 0.04 over the three-month period. We observed a significant interaction between PSS-4 score and baseline BMIz. At lower baseline BMIz scores, higher PSS-4 scores were associated with decreases in BMIz over time. There was no significant association at higher baseline BMIz scores. COVID-19 pandemic-related concerns and school performance were the two primary stressors reported.

Conclusions: The relation between stress and weight changes differed based on starting weight status. Future interventions should consider the influence of external stressors on intervention adherence and outcomes.

1. Introduction

Stress is a common phenomenon associated with increased risk of obesity (Cohen et al., 1995). Frequent or prolonged activation of the body's stress-response system promotes adiposity directly and through behavioral mechanisms (Hewagalamulage et al., 2016). However, individual responses to stress can vary such that changes in health behaviors can favor weight gain or weight loss (Tajik et al., 2014; Pervanidou and Chrousos, 2011; Stults-Kolehmainen and Sinha, 2014; Torres and Nowson, 2007). For example, stress is associated with increased portion sizes and intake of calorie dense foods (Hewagalamulage et al., 2016; Torres and Nowson, 2007), and with reduced caloric intake and loss of appetite (Torres and Nowson, 2007; Emond et al., 2016). These changes in caloric intake may vary by whether the source of stress is acute or chronic (Torres and Nowson, 2007). Additionally, some individuals manage stress with physical activity, while for others stress can be a barrier to physical activity or a form of stress in itself (Stults-Kolehmainen and Sinha, 2014). Individual differences in health behaviors in response to varying forms of stress make it difficult to identify what circumstances and sources of stress have the greatest impact on the behavioral mechanisms linking stress and obesity risk.

Adolescence involves physical maturation, identity formation, increased independence, and shifting social dynamics, making it an important developmental stage to understand the relation between obesity risk and stress (Chulani and Gordon, 2014). Adolescents struggle to engage in positive behaviors for healthy growth and development. In

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the U.S., only 20% adolescents meet physical activity guidelines (Piercy et al., 2018) and 2–7% of adolescents meet recommendations for fruit and vegetable intake (Lange et al., 2021). These health behaviors can affect growth, an important consideration for adolescents facing systemic health inequities (Ogden et al., 2018). Adolescent stressors can be acute (e.g., exams) or chronic (e.g., economic insecurity and family conflict) (Ford et al., 2021; Suldo et al., 2009), and adolescents with low socioeconomic status (SES) experience greater chronic and psychosocial stress than their higher SES peers (Gundersen et al., 2011). Stress in adolescence affects dietary patterns through increased snacking, increased intake of highly palatable foods, and decreased intake of fruits and vegetables (Jääskeläinen et al., 2014; Cartwright et al., 2003). Persistent exposure to stress during adolescence is associated with development of chronic conditions such as cardiovascular disease, type 2 diabetes, poor mental health outcomes, and obesity (Pervanidou and Chrousos, 2011).

Laboratory-induced stress protocols are one method to examine how changes in eating behaviors and physiological stress response (e.g., cortisol levels) relate to weight status following stress simulations. Findings indicate eating behaviors favoring weight gain (e.g., eating in the absence of hunger) and cortisol response may be greater among participants with higher weights relative to participants with lower weights following simulated academic and social stressors (Miller et al., 2019; Slochower et al., 1981; Verdejo-Garcia et al., 2015; Kidwell et al., 2022). However, stress simulations are unlikely to reproduce the combination of acute and chronic stressors characteristic of real-life situations, and there is limited research examining how this combination of stressors relate to weight status among adolescent populations (Kidwell et al., 2022). Additionally, laboratory stress simulations are unlikely to capture weight changes, which often require weeks to observe. Outside of laboratory-induced protocols, cross-sectional research among adolescents suggests higher levels of perceived stress are positively associated with BMI (Roy et al., 2021; Hernandez and Pressler, 2015) and with reduced physical activity enjoyment among adolescents with higher weights (Ajibewa et al., 2021). Longitudinal analyses following adolescent stress levels into adulthood indicate persistently high perceived stress levels are associated with higher body mass index (BMI) and waist circumference relative to lower stress levels (van Jaarsveld et al., 2009). These studies did not assess sources of adolescent stress (Ajibewa et al., 2021; van Jaarsveld et al., 2009), examined specific sources of stress (Hernandez and Pressler, 2015), or participants selected from pre-determined sources of stress (Roy et al., 2021). Allowing adolescents to identify the relevant stressors in their lives can overcome this limitation (Emond et al., 2016).

The World Health Organization declared a global pandemic on March 11, 2020 following rising international concern regarding the spread of SARS-CoV-2 virus starting January 2020 (Organization, 2020). The rapid onset of the COVID-19 pandemic interrupted our school-based healthy lifestyles intervention and created a natural opportunity to examine the relation between adolescent stress and weight change over time outside of a laboratory stress simulation. We assessed levels and sources of student stress as schools prepared to close in response to the COVID-19 pandemic among our adolescent participants, who were predominantly low SES and identified as Hispanic and non-Hispanic Black. Using a mixed-methods approach, this secondary data analysis addressed the following questions: How much stress were adolescents experiencing during this period in 2020?; how did stress relate to changes in standardized BMI (BMIz)?; and, what were adolescents stressed about during this time period? We hypothesized that increases in stress would be associated with increases in BMIz for adolescents with higher weights and factors related to abrupt school closures might emerge as sources of stress. This analysis adds to the literature examining how stress relates to weight management in real-world settings among a historically underserved adolescent population.

2. Methods

2.1. Sample

Adolescents attending a public charter school in Houston, Texas were recruited during the 2018–2019 (cohort one) and 2019–2020 (cohort two) academic years to participate in a healthy lifestyles intervention during their physical education class (Arlinghaus et al., 2021). The charter school district meets eligibility requirements for the Community Eligibility Provision (e.g., at least 40% of students are directly certified for free school meals as recipients of programs such as the Supplemental Nutrition Assistance Program or through categorical eligibility, such as Migrant children) such that all students receive free school meals. The present study is a secondary data analysis of participants in cohort two of the healthy lifestyles intervention, as only this cohort completed measures to examine the relation between stress and weight change. The University of Houston Institutional Review Board approved the original trial.

Full details of the intervention are described elsewhere (Arlinghaus et al., 2021). Briefly, during the first phase of the intervention (Fall 2019), all participants received the same healthy lifestyles intervention integrated into their physical education class. After completing the first phase of the healthy lifestyle intervention in Fall 2019, all participants were randomized to a maintenance condition or an escalated intervention condition that comprised the second phase of the intervention (Spring 2020). Participants in the maintenance condition designed their own physical education plans. The escalated intervention condition received increased self-monitoring instruction, additional behavioral modification techniques, and support from a registered dietitian.

In March 2020, abrupt COVID-19 pandemic-related school closures interrupted the second phase of the intervention. In response, we measured participants' stress to determine whether participants experienced the COVID-19 pandemic differently by intervention condition. As expected, there were no significant differences in stress level by intervention condition. We collapsed the two intervention conditions for the present analysis of the association between stress and BMIz change. Fig. 1 outlines the flow of participants included in this analysis. Of the 231 adolescents who participated in the second phase, we excluded participants with incomplete anthropometric data ($n = 6$), incomplete stress data ($n = 24$), and participants classified as underweight due to

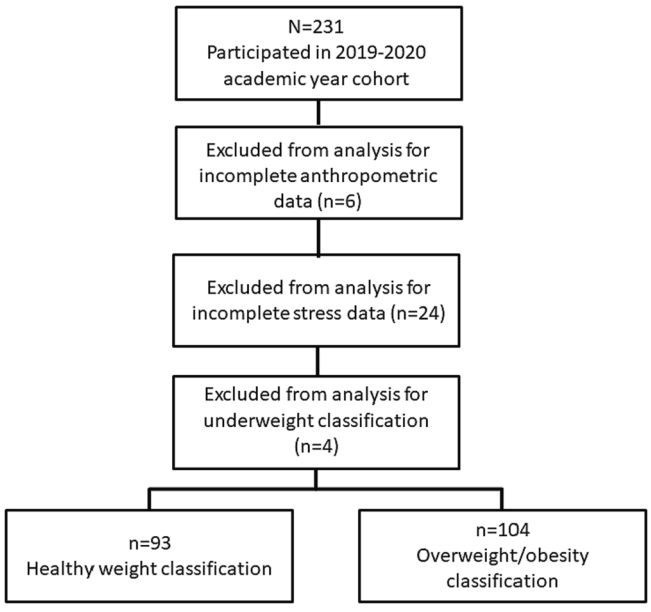

Fig. 1. Flow of adolescent sample from a charter school in Houston, Texas for secondary data analysis.

insufficient sample size for analysis ($n = 4$). The final analytical sample included 197 adolescents. Table 1 provides additional characteristics.

2.2. Measures

2.2.1 Anthropometrics. Trained research staff measured participant height to the nearest 0.1 cm and weight to the nearest 0.1 kg in December 2019 and the week schools closed in March 2020. At each measurement, participants wore minimal clothing and no shoes. We used these measurements to calculate BMI (*weight in kilograms/height in meters*^{2}), an indicator of adiposity (Kuczmarski et al., 2000). As youth are still growing, it is important to contextualize their BMI relative to their peers by translating age and sex specific BMI values into a percentile and z-score relative to a specified distribution of age and sex specific BMI (Flegal and Ogden, 2011). We calculated BMI percentiles and BMIz scores based on age and sex specific growth charts from the Centers for Disease Control and Prevention, which classify youth with BMI percentile $\geq$ 85thile as having overweight and youth with BMI percentile $\geq$ 95thile as having obesity (Kuczmarski et al., 2000). We determined change in BMIz by taking the difference between each participant's BMIz score post-program and pre-program. A negative result indicates a decrease in BMIz.

2.2.2 *Stress Level & Sources of Stress.* We quantitatively assessed stress with the 4-item Perceived Stress Scale the week schools closed (March 2020). The 4-item Perceived Stress Scale (PSS-4) demonstrates good internal reliability and is useful when longer assessments may not be suitable (Cohen, 1988; Mitchell et al., 2008). The PSS-4 is scored on a 5-point Likert scale with response options ranging from "Never" to "Very Often" (Cohen et al., 1983). Items ask about stress in the last month. Two items are reverse coded, for example, "In the last month, how often have you felt confident about your ability to handle your personal problems?" The maximum score is 16; higher scores indicate higher stress levels.

Table 1
Descriptive characteristics of an adolescent sample ($N = 197$) from Houston, Texas in December 2019 prior to receiving the second phase of the healthy lifestyles intervention, Count [Percent] or Mean (*SD*).

Characteristic	Overall ($N = 197$)
Age	13.66 (±1.43)
Female	110 [56%]
Male	87 [44%]
Hispanic	168 [85%]
Non-Hispanic Black	28 [14%]
Asian	1 [1%]
Born in the U.S.	173 [91%]
6th grade	50 [25%]
7th grade	50 [25%]
8th grade	74 [38%]
10th grade	17 [9%]
11th grade	4 [2%]
12th grade	2 [1%]
Weight Classification*	
Healthy Weight	93 [47%]
Overweight	48 [24%]
Obesity	56 [28%]
BMI %ile	76.55 (±24.33)
BMIz	0.99 (±0.94)
BMIz change[a]	−0.04 (±0.17)
PSS-4 score	7 (3.10)

BMI = body mass index; BMIz = standardized body mass index; PSS-4 = 4-item Perceived Stress Scale.
*Weight classifications follow guidelines from the Centers for Disease Control and Prevention. Healthy Weight = 5th to < 85th%ile, Overweight = 85th to < 95th%ile, and Obesity = ≥ 95th%ile. [27].
[a] BMIz change reflects the difference in participant BMIz score between December 2019 (pre-program) and March 2020 (post-program).

While there is no consistent threshold for characterizing high stress using the PSS-4, previous studies consider scores ≥ 6 as indicative of higher levels of stress (Kotwal et al., 2012; McClellan et al., 2010; Malik et al., 2020; Arnold et al., 2012). Following the PSS-4, students provided written answers to the free-response question, "Explain what concerns, worries, or stresses you have right now" to determine student-reported sources of stress.

2.3. Data analysis

Data analyses were performed in Stata 17 Software (StataCorp, 2021). To address our first research question regarding levels of student stress, we found the distribution of PSS scores and computed descriptive statistics to describe the sample. To address our second research question regarding how stress levels related to BMIz change over the three-month period, we ran a multiple linear regression model controlling for BMIz collected in December 2019 (baseline), age, sex, and intervention condition. We included an interaction term to determine if baseline BMIz moderated the effect of PSS-4 score on BMIz change, based on prior literature indicating weight-related responses to stress could differ by weight status (Torres and Nowson, 2007; Miller et al., 2019; Kanellopoulou et al., 2022; Pelletier et al., 2016; Block et al., 2009). We computed the interaction term with baseline BMIz and PSS-4 scores centered at their respective sample means. We used the Stata margins command to facilitate interpretation of this interaction of interest and graph how the effect of stress on BMIz change differed by representative baseline BMIz values.

To address our third research question of identifying sources of student stress, qualitative data were analyzed using inductive content analysis (Elo and Kyngäs, 2008). In an open coding process, the lead qualitative researcher read each student response to gain a full understanding of reported sources of stress. Then, the lead qualitative researcher identified initial sub-codes and key phrases within the content to develop overarching categories. Categories and sub-codes were determined based on words used by the participants and documented in an Excel coding sheet. The lead qualitative researcher made initial decisions regarding categories and codes, then the research team provided critical review and audit trails of coding decisions in multiple iterative rounds until achieving 100% agreement on coding and categories (Krefting, 1991). Qualitative responses were used to complement and provide context to the quantitative analysis (Johnson and Onwuegbuzie, 2004).

3. Results

3.1. How much stress were students experiencing during the onset of the COVID-19 pandemic?

Table 1 shows descriptive characteristics of the adolescent population at baseline. On average, participants were 13.66 ($SD = 1.43$) years old, predominately identified as Hispanic (85%), and female (56%). Overall, the average PSS-4 score among our sample was seven ($SD = 3.10$). The distribution of PSS-4 scores was five in the 25th percentile, seven in the 50th percentile, and nine in the 75th percentile. Among our sample, 67% of students scored six or higher.

3.2. How did stress levels relate to changes in BMIz?

Our adolescent sample demonstrated an overall mean decrease in BMIz of 0.04 over the three-month period (Table 1). Table 2 reports the results of the regression model. The interaction between PSS-4 score and baseline BMIz was statistically significant ($R^2 = 0.07$, $F(6, 190) = 2.48$, $\beta = 0.009$, $t(2.13)$, $p = .035$, 95% CI [0.001, 0.017]), indicating that baseline BMIz moderated the effect of stress on BMIz change. Higher PSS-4 scores were associated with decreased BMIz overtime only at lower baseline BMIz levels. Fig. 2 illustrates this moderation effect by

Table 2
Results from the linear regression model examining the effect of PSS-4 score on BMIz change from December 2019 to March 2020 among a sample of middle and high school students from a public charter school in Houston, Texas ($N = 197$).

Effect	Estimate	Standard Error	Standardized Estimate	95% CI	*p*
PSS-4 score (March 2020)	−0.008	0.004	−0.142	(-0.015, −0.00)	0.047
Baseline BMIz (December 2019)	−0.009	0.013	−0.049	(-0.034, 0.016)	0.494
PSS-4*Baseline BMIz[a]	0.009	0.004	0.149	(0.001, 0.017)	0.035
Age (December 2019)	0.016	0.008	0.139	(-0.00, 0.033)	0.052
Sex (Male = 0, Female = 1)	0.044	0.024	0.131	(-0.003, 0.092)	0.069
Study Arm (Maintenance condition = 0, Escalated condition = 1)	0.013	0.024	0.039	(-0.034, 0.059)	0.585

BMIz = standardized body mass index; PSS-4 = 4-item Perceived Stress Scale.
[a] Variables are centered at their respective sample means.

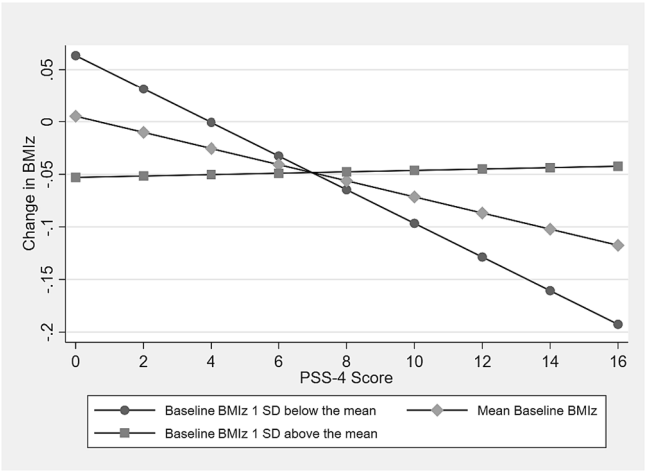

Fig. 2. Moderation by baseline BMIz of the association between self-reported stress and BMIz change over a three month period among a sample of middle and high school students ($N = 197$) from Houston, Texas.

Fig. 2 descriptively shows the interaction between baseline standardized body mass index (BMIz) and perceived stress (PSS-4 score) using simple slopes and baseline BMIz scores at the sample mean, 1 *SD* below the mean, and 1 *SD* above the mean. There was a significant negative association between stress and BMIz change among an exemplar BMIz score 1 *SD* below the mean (b_{simple} = -0.016, p =.005, *95% CI*: −0.027, −0.005) and at our sample mean (b_{simple} = -0.008, p =.047, *95% CI*: −0.015, −0.000), which was not observed at 1 *SD* above the mean (b_{simple} = 0.001, p =.902, *95% CI*: −0.010, −0.011).

plotting PSS-4 scores against BMIz change overtime at exemplar baseline BMIz levels (i.e., at the sample mean, one standard deviation above the mean, and one standard deviation below the mean). Higher perceived stress predicted decreases in BMIz at baseline BMIz levels one standard deviation below and at the sample mean. The association lost statistical significance as baseline BMIz increased.

3.3. What were sources of adolescent stress during this period?

Table 3 shows the summary abstraction process for determining the eight categories and 293 sub-codes identified as sources of stress. COVID-19 pandemic-related concerns ($n = 112$) and school performance concerns ($n = 66$) were the two most prevalent sources of stress in our sample. Less frequently reported sources of stress included nothing ($n = 38$), future unknown ($n = 24$), family relationships ($n = 18$), social relationships ($n = 14$), and health-related concerns ($n = 13$). A miscellaneous category captured stressors inconsistent with other categories ($n = 8$). Table 4 shows example quotations reflecting these categories. Given the free response nature of data collection, one response could contain information coded into multiple categories.

3.3.1. COVID-19 pandemic-related concerns

COVID-19 pandemic-related concerns comprised 38% of the 293 sub-codes identified. It was common for students to express multiple overlapping concerns about the COVID-19 pandemic. The most frequently reported concern about the COVID-19 pandemic was the rapid spread of the virus, followed by worry about family, friends, or themselves getting sick or dying from the virus.

Table 3
Abstraction Coding Schema for "Explain what concerns, worries, or stresses you have right now" among a sample of middle and high school students at a public charter school in Houston, Texas ($N = 197$).

Main Category	Subcode
SARS-CoV-2	Spreading/getting worse
	Significant others dying (family/friends dying)
	Me dying/sick
	Lockdown in house
	People dying
	No cure
	General
	No supplies, food, water, or resources
	School shutdown
	Not passing
School performance	Grades
	STAAR – not passing
	Passing to the next grade
	Doing bad in gym
	Geometry
Nothing	Nothing
Future Unknown	Future-general, so close
	Dying too early
	In the future
	Death-what happens afterwards/afterlife
	Following path to success in life
	Not doing things I planned
	Global warming
Family relationships	Family problems
	Disappointing family
	Talking to dad
	Aunt's finances
	General
Social relationships	Friendships
	Friendships broken
	Losing friends
	Girl relationship
	Talking to new people
	Being alone
	Perceived weakness
Overall Health	Weight
	Physical health, appearance
	Other sickness
	General
Miscellaneous	Non-open-ended
	External stressors
	Personal

3.3.2. School performance

The second most prevalent reported stressor for students was school performance (23% of codes). Specifically, students were concerned they could not improve their current grades. Students discussed concerns about upcoming standardized testing (State of Texas Assessments of

Table 4
Example quotation responses to "Explain what concerns, worries, or stresses you have right now" from a sample of middle and high school students from Houston, Texas ($N = 197$) with overarching codes and subcodes.

Overarching Code and Subcode	Example Quotation
COVID-19 Pandemic-Related Concerns	
COVID-19 could spread and get worse.	*"One thing that has been making me nervous and scared is the coronavirus because what if this virus spreads even more throughout the world? What would happen to us?" –13 years, female, high stress, overweight/obesity*
Significant others, including family and friends, could die.	*"I'm worried about the coronavirus because there are more and more cases every day. I'm worried that someone in my family could be infected and possibly die. I don't want my friends or family to get infected because they are all important to me." –15 years, female, low stress, overweight/obesity*
	"Coronavirus because supposedly it kills old people and my mom is almost in her 50 s." – 14 years, male, low stress, overweight/obesity
	"I'm mostly scared about the virus infecting me or my loved ones because it could be deadly to their health or mine." – 13 years, male, high stress, overweight/obesity
I could get sick or die.	*"Something that makes me nervous is the coronavirus because I am scared [about] what [if] it may get to me and I don't want to be infected with the coronavirus. Apart from what we are doing to not get the coronavirus what else can we do?" – 14 years, female, low stress, healthy weight*
School Performance	
Worry about grades.	*"Something I'm scared and nervous about are my grades, I'm worried that I won't get good grades and I'll let myself down." – 13 years, female, high stress, healthy weight*
Worry about passing STAAR exams.	*"I'm worried my STAAR exams coming up because if I don't pass all 4 of them I'm going to stay in the 8 grade. I've been stressing about it trying to make sure I remember everything." – 14 years, female, high stress, healthy weight*
Concern about not passing on to the next grade level.	*"I'm scared of not passing my classes or the next grade because my mom gets mad when I bring 79 and lower." – 11 years, female, low stress, overweight/obesity*
The Future Unknown	
The future is so close.	*"I am worried about my senior year. The reason for that is because it is so close and I have very little time left here and I am just worried for the future." – 18 years, male, high stress, healthy weight*
Concern about dying too early.	*"What worries me in life is dying too early and not being able to see my mom and maybe even my grandchildren." – 15 years, male, high stress, overweight/obesity*
Concern of what could happen in the future.	*"I'm usually worried about the uncertainty of life. That makes me very uncomfortable. Making very anxious about growing up." – 11 years, male, high stress, overweight/obesity*
Family Relationships	
Worry of disappointing family.	*"As the year ends and I prepare to go to college I am scared that I'm going to waste my mom's hard-earned money when I go to college and that I will fail and never be able to repay her." – 17 years, male, low stress, healthy weight*
Social Relationships	
Worry about friendships.	*"I'm usually worried that my friends will get bored of me and leave me. And that I'm irrelevant to everyone." – 13 years, female, high stress, healthy weight*
Overall Health	
Worry about managing weight.	*"Something that worries me is my weight. This worries me because I procrastinate in exercising. I also need to start working out. My weight worries me because I want to lose weight, every time I go to the doctor my weight gets higher. What I have planned is to exercise 1 hr a day and go for a run or walk at the park and stop eating junk food." – 16 years, female, high stress, overweight/obesity.*
Miscellaneous	
	"I'm worried about my dog's health because she is kind of old." – 13 years, female, low stress, healthy weight

Academic Readiness, referred to as STAAR), often in relation to passing on to the next grade level. Students expressed worries that they would not be able to advance with their peers and would disappoint their family. Additionally, many students reported they were not worried or stressed about anything at the time of this assessment (13%).

3.3.3. The future unknown

A category reflecting concerns about the future unknown (8%) emerged. Students expressed uncertainty regarding what could happen in both the immediate and distant future. Within this category, students expressed concerns about dying early and not being able to accomplish their plans.

3.3.4. Concerns about family and social relationships

Two distinct categories regarding relationship concerns with family (6%) and other social relationships (5%) emerged. Students with family relationship concerns shared stressors such as divorce and financial hardship. Additionally, students questioned if their friends genuinely accepted them and if trust was present in their relationships.

3.3.5. Overall health

Several students reported concerns about their health outside of the COVID-19 pandemic (4%). Students were concerned about weight management, their physical appearance, and self-confidence.

3.3.6. Miscellaneous

Some students reported sources of stress that were unique to their personal circumstances and could not be categorized among their peers (3%). For example, one participant expressed concern for the health of their pet.

3.4. Discussion

The onset of the COVID-19 pandemic during a healthy lifestyles intervention provided the opportunity to examine the level and sources of stress experienced by a sample of historically marginalized adolescents as schools closed to mitigate viral spread. Among our sample, 67% scored ≥ 6 on the PSS-4, similar to a sample of German adolescents ($N = 824$, mean age 13 years, mean PSS-4 score 6.93 in April 2020) who experienced a significant increase in stress in during COVID-19 lockdown (Paschke et al., 2021). A sample of undergraduate medical students surveyed between June 2020 – August 2020 ($N = 852$, mean PSS-4 score 7.25) (Guo et al., 2021) and a sample of health care workers surveyed April 2020 ($N = 61$, median PSS-4 score 7) (Choudhury et al., 2020) also experienced similar stress levels. Thus, although there is no established threshold for "high" stress levels using the PSS-4, the comparable average stress levels experienced by other populations during

this period provides further context for considering scores ≥ 6 as elevated stress. The COVID-19 pandemic and school performance were the most prevalent sources of stress reported. These findings demonstrate that psychosocial context and external stressors are important considerations for adolescent behavioral interventions.

While the changes in BMIz observed in this study are unlikely to substantively impact growth (Homan, 2016), our findings suggest that the impact of perceived stress on BMIz change depends on the adolescent's starting BMIz. Specifically, for students with lower baseline BMIz, increased perceived stress was associated with a decrease in BMIz. The association between perceived stress and BMIz change was not statistically significant at higher baseline BMIz levels. Individual differences in eating patterns in response to stress, such as lack of appetite versus increased caloric intake (Tajik et al., 2014; Torres and Nowson, 2007) could explain the differences in BMIz change observed between youth with lower versus higher baseline BMIz. Dietary restraint, which can differ by weight status, could also influence weight outcomes, as previous research indicates that adolescents of lower weight statuses tend to demonstrate less dietary restraint and thus decreased caloric intake in response to stress (Roemmich et al., 2011; Roemmich et al., 2002). Additionally, further research is needed to understand how the combined effects of acute and chronic stress on adolescent physiology (e.g., cortisol levels) relate to and reinforce weight-related stress management behaviors, such as maladaptive eating patterns and sedentary behavior (Kidwell et al., 2022). Additional height and weight measurements would provide greater context to identify patterns in the relation between stress and growth, as the overall prevalence of obesity among adolescents increased as the COVID-19 pandemic progressed (Chang et al., 2021; Jenssen et al., 2021).

COVID-19 pandemic-related concerns were the most prevalent source of stress in our sample irrespective of stress level or weight status. Adolescents expressed uncertainty regarding the COVID-19 pandemic, which has since negatively affected adolescent mental health, weight status, and health behaviors (Chang et al., 2021; Hawes et al., 2021; McGuine et al., 2021; Browne et al., 2021; Jones et al., 2021; Woolford et al., 2021; Neshteruk et al., 2021). Since March 2020, several additional external stressors have become increasingly relevant concerns for adolescents, including increased gun violence on school campuses (Reeping et al., 2022; Riehm et al., 2021; Ssentongo et al., 2021), racism (Mpofu et al., 2021; Trent et al., 2019), and legislation changes affecting sexual and gender minority youth (Barbee et al., 2022). Further, the adolescents in this study are demographically similar to youth disproportionately affected by obesity before and during the COVID-19 pandemic (Jenssen et al., 2021; Fryar et al., 2018) and disproportionately affected by COVID-19 related deaths within families (Feldman and Bassett, 2021). Underserved adolescents must navigate multiple, chronic external stressors that influence health behaviors and have long-term impacts on disease risk, an important consideration for interventions aiming to improve the health of this population.

School performance was the second most prevalent source of stress identified by students in our sample. Previous research indicates that academic stress is highly prevalent among youth reporting elevated stress levels (Roy et al., 2021; Kanellopoulou et al., 2022; Feld and Shusterman, 2015). Generally, academic stress is associated with eating behaviors favoring increased caloric intake (Emond et al., 2016; Slochower et al., 1981; Feld and Shusterman, 2015; Pollard et al., 1995). Although school exams are typically acute in nature, academics could represent a consistent stressor for students, particularly for our participants attending a charter school focused on college preparedness. Additionally, we collected data nearing the end of the academic semester when students might have heightened concerns for standardized testing, advancing to the next grade level, and college preparedness. Schools are common settings to access and develop interventions for adolescents. However, few school-based interventions consider the potential role of academic-related stress on targeted health outcomes. Adolescents worried about school performance might prioritize academics over positive diet and physical activity behaviors promoted in healthy lifestyle interventions. Our findings suggest considerations of how societal context and psychosocial factors relate to the intervention setting could benefit participants. While mindfulness-based strategies and stress management techniques have some potential to improve adiposity biomarkers in obesity interventions (Paltoglou et al., 2021), students of all weight statuses may benefit from support from healthy coping strategies.

3.5. Strengths and limitations

Strengths of this study include the opportunity to explore sources of adolescent stress in a naturalistic setting among our student cohort participating in a healthy lifestyles intervention when schools closed for the COVID-19 pandemic. We assessed stress among a sample of historically marginalized adolescents often underrepresented in the literature. While trained research staff objectively measured height and weight, we do not have data on additional factors that could be relevant to the observed BMIz changes, such as health behaviors, pubertal status, and the socioeconomic status of individual participants. An additional strength of this study is the inclusion of qualitative and quantitative stress data; however, we assessed stress at one time point and focused on a descriptive qualitative level. An in-depth qualitative design, like phenomenology, may capture a richer understanding of adolescents' lived experiences regarding stress and lifestyle behaviors, promoting more nuanced components to interventions. Weight changes occurred before we measured stress and stress fluctuates over time. Thus, drawing conclusions around stress and weight change is tenuous. Finally, the 4-item Perceived Stress Scale is a brief screening tool that does not capture physiological changes in the stress response system (e.g., cortisol levels) which could contribute to weight changes.

3.6. Conclusions

Adolescents are commonly the focus of health behavior interventions; however, few behavioral interventions consider internal and external stressors relevant to adolescents. External stressors have the potential to affect weight for youth of all weight statuses. Future qualitative research is needed to understand how societal context affects adolescent stress levels, followed by quantitative research on the implications of these sources of stress on adolescent health behavior within and outside of behavioral interventions. Public health practitioners could aid in providing resources for addressing chronic and acute external stressors among adolescents, ranging from education on behavioral stress management techniques to broadening social safety nets. Further, individuals working with adolescents in schools may consider how providing additional support for academic related stress could promote overall holistic wellbeing among their students, including positive dietary and physical activity behaviors.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

the work reported in this paper.

Data availability

The authors do not have permission to share data.

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