

Examining the Relationship Between Stress and Cardiovascular Risk in Pediatric Populations

Karan S Nayak ^{1*}, Austin M Pollack ², Landon D Hamilton ³, Paige C Lueders ⁴, Gary J Luckasen ⁵

¹Anschutz School of Medicine, University of Colorado, USA.

²Research Northern Colorado, UC Health, USA.

***Corresponding Author:** Karan S Nayak, Anschutz School of Medicine, University of Colorado, USA.

Received Date: September 04, 2026 | **Accepted Date:** September 28, 2026 | **Published Date:** October 02, 2026

Citation: Karan S. Nayak, Austin M. Pollack, Landon D. Hamilton, Paige C. Lueders, Gary J. Luckasen, (2026), Examining the Relationship Between Stress and Cardiovascular Risk in Pediatric Populations, *J Clinical Cardiology and Cardiovascular Interventions*, 9(11); DOI:10.31579/2641-0419/594

Copyright: © 2026, Karan S Nayak. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract:

Background/Aim: Stress is a well-established risk factor for cardiovascular disease (CVD) in adults, but its role in childhood remains unclear. This study aimed to evaluate the relationship between stress and cardiovascular disease (CVD) risk in pediatric populations as an independent risk factor and with related factors such as body mass index (BMI), diet, and physical activity. By investigating these associations, we sought to highlight the influence of stress on children's biometric values and health behaviors.

Materials and Methods: The UCHealth Healthy Hearts and Minds (HHM) Program in Colorado conducted biometric screenings and health risk assessments on 59,492 elementary, middle, and high school students between 2014 and 2024. Student and parental stress were self-reported on a five-point Likert scale ranging from "No Stress" to "Very High." Relationships between stress, CVD risk factors, and health behaviors were analyzed using ANOVA and ordinal logistic regression models.

Results: Increased student stress was associated with shorter sleep duration, lower fruit and vegetable intake, greater sugary drink consumption, reduced physical activity, and increased BMI. Similar trends emerged between sexes, but these associations were more pronounced in females. Ordinal regression models identified elevated parental stress as an associated risk factor for student stress across subgroups (odds ratios (ORs) 1.50–4.37). Shorter sleep duration also emerged as a predictor of higher stress (OR 0.68).

Conclusion: Stress plays an important role in the early development of cardiovascular risk as seen by its impact on certain biometric markers and health behaviors. Environmental factors, including parental stress levels, can also directly influence student stress. Recognizing stress as a potential pediatric CVD risk factor highlights the importance of early intervention and supports the need for further research to clarify its long-term impact on cardiovascular health.

Key words: pediatric stress; cardiovascular disease risk; parental stress; health behaviors

Introduction

Cardiovascular disease (CVD) remains the leading cause of death in the United States, affecting individuals of all ages and presenting a significant public health concern for adolescents. Although clinical manifestations of CVD typically occur in adulthood, the development of cardiovascular risk begins much earlier in life.[1–4] Cardiovascular risk factors identified during childhood and adolescence, including obesity, hypertension, dyslipidemia, poor dietary patterns, and physical inactivity, have been associated with increased cardiovascular morbidity later in life.[5–9] Childhood and adolescence therefore represent critical periods for identifying modifiable risk factors and implementing preventive strategies before the development of established cardiovascular disease.[10]

Traditional approaches to pediatric cardiovascular prevention have focused primarily on physiologic and behavioral risk factors. However, growing evidence suggests that psychosocial factors may also contribute to cardiovascular health through both biological and behavioral pathways. Psychological stress, defined as an individual's perceived difficulty managing environmental or emotional demands, has been increasingly recognized as an important determinant of health across the lifespan.[11–13] Chronic activation of these stress pathways may contribute to elevated blood pressure and other physiologic changes associated with increased cardiovascular risk.[14]

In addition to direct physiological mechanisms, stress may influence cardiovascular health through changes in health-related behaviors. Increased stress has been associated with reduced physical activity, poorer dietary patterns, inadequate sleep, and other behaviors that contribute to unfavorable cardiovascular profiles. Diet quality, including

fruit and vegetable consumption and intake of sugar-sweetened beverages, plays an important role in childhood cardiovascular health. Similarly, insufficient sleep during childhood and adolescence has been associated with obesity, impaired metabolic regulation, and increased cardiovascular risk.[15] Stress may also contribute to unhealthy coping behaviors, including nicotine exposure, particularly among adolescents. Together, these findings suggest that stress may represent an important factor connecting psychosocial experiences with modifiable cardiovascular risk behaviors.

Family-level psychosocial factors may further influence childhood cardiovascular health. Parental stress has been associated with changes in child stress responses, emotional well-being, and health behaviors through both environmental and intergenerational pathways.[16,17] Understanding the relationship between parental and child stress may therefore provide additional insight into opportunities for early cardiovascular prevention.

Despite increasing recognition of psychosocial influences on cardiovascular health, the relationship between perceived stress and cardiovascular risk-related behaviors and biomarkers in children remains incompletely understood. Previous studies have linked childhood stress with poorer health outcomes later in life, but much of the existing literature has focused on adverse childhood experiences, high-risk populations, or long-term outcomes rather than self-perceived stress in large, community-based pediatric populations. Additionally, few studies have simultaneously evaluated the associations between self-perceived stress and multiple modifiable cardiovascular risk factors, including sleep, diet, physical activity, BMI, blood pressure, and lipid profiles, while also examining the relationship between parental and child stress. Addressing these gaps may help identify opportunities for earlier, more comprehensive approaches to pediatric cardiovascular disease prevention.

The aim of this study was to examine the relationship between self-reported stress and cardiovascular risk-related behaviors and biomarkers among school-aged children participating in Healthy Hearts and Minds (HHM). Specifically, we evaluated associations between stress levels and modifiable cardiovascular risk factors, including sleep, dietary behaviors, physical activity, BMI, blood pressure, and lipid profiles, while also examining the relationship between parental stress and student-reported stress. We hypothesize that increased student and parental stress will be associated with greater cardiovascular disease risk and less healthy behaviors among children and adolescents. Understanding these relationships may inform future school-based interventions aimed at improving cardiovascular health and addressing stress-related contributors to pediatric CVD risk.

Materials and Methods

Healthy Hearts and Minds (HHM) is a school-based cardiovascular health program that provides age-specific cardiovascular education and screening to elementary (4th–5th grade), middle (6th–7th grade), and high school (9th–10th grade) students throughout Colorado. The program spans 2–3 days and incorporates education regarding nutrition, physical activity, nicotine use, sleep hygiene, and stress management while performing school-based screening for cardiovascular risk factors, including lipid profiles, blood pressure, and body mass index (BMI). Since 1992, HHM has educated more than 150,000 students and screened more than 85,000 students for cardiovascular risk factors, providing a unique opportunity to evaluate relationships between psychosocial factors and pediatric cardiovascular health in a large community-based population.[18,19]

This retrospective observational study analyzed data collected between 2014 and 2024 through the HHM school-based cardiovascular health program.[20] Written parental or guardian consent and student assent were obtained prior to participation in biometric screening. All procedures and research activities were approved by the Colorado Multiple Institutional Review Board (25-0340).

Students in elementary (4th–5th grade), middle (6th–7th grade), and high school (9th–10th grade) participating in HHM between 2014 and 2024 were included in this analysis. This was a retrospective study using data collected through the HHM program, and no predefined sample size was established. Inclusion required participation in the HHM program and completion of the questionnaire. No additional inclusion or exclusion criteria were applied. Demographic information, including age, sex, race/ethnicity, and school level, was collected at the time of participation. Parent-completed questionnaires provided additional family-level demographic information when available, including parental education, marital status, and family cardiovascular risk factors. Student stress was assessed using a self-administered questionnaire prior to HHM education sessions. Students were asked, "On most days, how stressed or worried are you?" and selected one of five response options: No stress, Low stress, Average stress, High stress, or Very high stress. Parent or guardian stress was assessed during program enrollment using the question, "How would you describe your stress/anxiety level over the past few weeks?" Response options included: No stress, Low stress, Average stress, High stress, Very high stress, or Prefer not to say. Student stress was analyzed as an ordered categorical variable using ordinal statistical methods where appropriate. Cardiovascular risk factors included both biometric measurements and self-reported health behaviors. Biometric measurements included body mass index (BMI), systolic blood pressure, diastolic blood pressure, total cholesterol, and high-density lipoprotein (HDL) cholesterol, which were collected during HHM screening according to standardized program protocols. Lifestyle behaviors were obtained through student questionnaires and included average sleep duration (hours/night), fruit and vegetable intake (days/week eating 5 servings combined), sugar-sweetened beverage consumption (days/week), and physical activity (days/week).

Descriptive statistics summarized demographics, biometric measures, and lifestyle behaviors; means and standard deviations were reported for continuous variables, while proportions were used for categorical variables. Given the large sample size, only complete cases were used for regression analyses ($n=12,139$), meaning that 47,359 were excluded from these analyses only. This approach may introduce selection bias if missingness is related to stress, health behaviors, socioeconomic status, health status, or other study variables, potentially resulting in biased comparisons. However, missingness did not differ by demographic characteristics, stress level, school level, or outcome status, and all available survey responses were included in the descriptive analyses. Results were stratified by sex and grade level to capture developmental and sex-based differences. Sex-based differences within each school level were tested using independent samples t-tests for continuous variables and chi-square tests for categorical variables. Differences between stress and continuous outcomes were assessed using analysis of variance (ANOVA) models across the five stress categories. Significant findings ($p\text{-value} < 0.05$) were further evaluated with Tukey's Honest Significant Difference (HSD) test. Ordinal logistic regression was applied to identify predictors of self-reported Likert Scale stress level. Backward elimination was used for variable selection to indicate the best model fit. The model with the lowest Akaike Information Criteria was selected with the residuals plotted and visually inspected to determine appropriate fit. Sex and age specific ordinal logistic regression models were conducted, with similar findings across all groups. Ordinal logistic regression models were first assessed using a proportional odds framework with results verified using a relaxed framework.

The participants of this study did not give written consent for their data to be shared publicly. Due to the sensitive nature of the research, supporting data are therefore not available. All statistical analyses were conducted in R-Studio 4.2.1 with significance set at $\alpha < 0.05$.

Results

A total of 59,492 students (31,133 females and 28,359 males) participated in the HHM screening program between 2014 and 2024. Student

demographic characteristics and cardiovascular risk measures were stratified by sex and school level (Table 1).

School Level	Variable	Females (Mean $\pm$ SD (n) or % (n/N))	Males (Mean $\pm$ SD (n) or % (n/N))	p-value
All Students	Age	13.01 $\pm$ 2.52 (n=31,133)	13.01 $\pm$ 2.39 (n=28,359)	0.850
	Sex	52.3% (31,133/59,492)	47.7% (28,359/59,492)	<0.001
	BMI	20.59 $\pm$ 4.56 (n=28,704)	20.41 $\pm$ 4.65 (n=26,361)	<0.001
	Sys BP	102.96 $\pm$ 10.54 (n=29,223)	104.29 $\pm$ 11.36 (n=26,545)	<0.001
	Dia BP	65.46 $\pm$ 8.12 (n=29,223)	64.91 $\pm$ 8.46 (n=26,544)	<0.001
	Chol	146.17 $\pm$ 28.31 (n=27,485)	138.35 $\pm$ 28.61 (n=24,776)	<0.001
	HDL	49.53 $\pm$ 12.78 (n=27,482)	46.97 $\pm$ 13.35 (n=24,773)	<0.001
	Overweight %	14.9% (4,280/28,693)	13.8% (3,641/26,350)	<0.001
Elementary	Obese %	10.1% (2,885/28,693)	13.8% (3,637/26,350)	<0.001
	Age	10.61 $\pm$ 0.61 (n=11,493)	10.66 $\pm$ 0.62 (n=10,818)	<0.001
	Sex	51.5% (11,493/22,311)	48.5% (10,818/22,311)	<0.001
	BMI	18.52 $\pm$ 3.75 (n=10,895)	18.73 $\pm$ 3.94 (n=10,253)	<0.001
	Sys BP	99.80 $\pm$ 10.40 (n=11,033)	99.87 $\pm$ 10.28 (n=10,340)	0.610
	Dia BP	64.42 $\pm$ 8.04 (n=11,033)	64.10 $\pm$ 8.02 (n=10,339)	0.003
	Chol	148.42 $\pm$ 27.97 (n=10,174)	147.99 $\pm$ 27.88 (n=9,470)	0.272
	HDL	49.77 $\pm$ 12.97 (n=10,173)	51.87 $\pm$ 13.64 (n=9,469)	<0.001
Middle School	Overweight %	13.5% (1,466/10,894)	14.0% (1,437/10,253)	0.246
	Obese %	9.8% (1,066/10,894)	14.3% (1,462/10,253)	<0.001
	Age	12.91 $\pm$ 0.54 (n=8,296)	12.99 $\pm$ 0.55 (n=7,673)	<0.001
	Sex	52.0% (8,296/15,969)	48.0% (7,673/15,969)	<0.001
	BMI	20.67 $\pm$ 4.25 (n=7,530)	20.23 $\pm$ 4.36 (n=7,037)	<0.001
	Sys BP	103.87 $\pm$ 10.15 (n=7,720)	104.05 $\pm$ 10.39 (n=7,100)	0.281
	Dia BP	65.31 $\pm$ 7.97 (n=7,720)	64.17 $\pm$ 8.34 (n=7,100)	<0.001
	Chol	143.67 $\pm$ 27.18 (n=7,214)	137.61 $\pm$ 27.88 (n=6,504)	<0.001
High School	HDL	48.97 $\pm$ 12.59 (n=7,212)	47.34 $\pm$ 12.88 (n=6,504)	<0.001
	Overweight %	14.7% (1,109/7,528)	13.4% (942/7,036)	0.021
	Obese %	10.3% (778/7,528)	13.0% (913/7,036)	<0.001
	Age	15.52 $\pm$ 2.15 (n=11,344)	15.60 $\pm$ 1.75 (n=9,868)	0.008
	Sex	53.5% (11,344/21,212)	46.5% (9,868/21,212)	<0.001
	BMI	22.71 $\pm$ 4.58 (n=10,279)	22.46 $\pm$ 4.81 (n=9,071)	<0.001
	Sys BP	105.62 $\pm$ 10.09 (n=10,470)	109.49 $\pm$ 11.08 (n=9,105)	<0.001
	Dia BP	66.65 $\pm$ 8.14 (n=10,470)	66.41 $\pm$ 8.82 (n=9,105)	0.052
	Chol	145.69 $\pm$ 29.26 (n=10,097)	128.52 $\pm$ 26.40 (n=8,802)	<0.001
	HDL	49.68 $\pm$ 12.70 (n=10,097)	41.42 $\pm$ 11.06 (n=8,800)	<0.001
	Overweight %	16.6% (1,705/10,271)	13.9% (1,262/9,061)	<0.001
	Obese %	10.1% (1,041/10,271)	13.9% (1,262/9,061)	<0.001

Table 1: Student Characteristics by Sex and School Level Mean $\pm$ standard deviation; proportion (count/total); significance determined by ANOVA for continuous variables and Chi-square for count variables; $\alpha < 0.05$.

Sex-specific differences were observed across several cardiovascular risk factors (Table 1). Overall, males had higher mean systolic blood pressure than females (104.29 $\pm$ 11.36 vs. 102.96 $\pm$ 10.54 mmHg, $p < 0.001$) and a greater prevalence of obesity (13.8% vs. 10.1%, $p < 0.001$). In contrast, females had higher mean total cholesterol (146.17 $\pm$ 28.31 vs. 138.35 $\pm$ 28.61 mg/dL, $p < 0.001$) and HDL cholesterol (49.53 $\pm$ 12.78 vs. 46.97 $\pm$ 13.35 mg/dL, $p < 0.001$). Mean BMI was slightly higher among females

overall (20.59 $\pm$ 4.56 vs. 20.41 $\pm$ 4.65 kg/m², $p < 0.001$) and varied by school level, with males demonstrating higher BMI in elementary school and females demonstrating higher BMI in middle and high school. Mean systolic blood pressure increased from elementary to high school in both sexes, rising from 99.80 to 105.62 mmHg in females and from 99.87 to 109.49 mmHg in males.

Females:

Stress Level	Elementary % (n)	Middle School % (n)	High School % (n)	p-value
No Stress	12.6% (1232)	3.9% (218)	1.9% (131)	<0.001
Low	37.8% (3692)	26.6% (1490)	14.2% (996)	<0.001
Average	29.2% (2851)	37.2% (2082)	41.4% (2900)	<0.001
High	15.0% (1466)	25.2% (1414)	32.9% (2302)	<0.001
Very High	5.4% (527)	7.1% (400)	9.7% (678)	<0.001
Total	100% (9768)	100% (5604)	100% (7007)	

Males:

Stress Level	Elementary % (n)	Middle School % (n)	High School % (n)	p-value
No Stress	18.1% (1647)	11.1% (576)	8.3% (485)	<0.001
Low	40.5% (3673)	40.0% (2085)	33.9% (1984)	<0.001
Average	25.9% (2353)	31.1% (1620)	34.3% (2008)	<0.001
High	11.3% (1023)	14.2% (737)	19.2% (1122)	<0.001
Very High	4.2% (384)	3.6% (190)	4.3% (254)	0.140
Total	100% (9080)	100% (5208)	100% (5853)	

Proportion (count); significance determined by Chi-square; $\alpha < 0.05$.

Table 2: Stress Levels by Sex and School Level

Stress levels differed significantly by sex and school level (Table 2). Among females, the proportion reporting high or very high stress increased from 20.4% in elementary school to 42.6% in high school. Among males, the corresponding proportion increased from 15.5% to 23.5%. Conversely, the proportion reporting no stress declined from

12.6% to 1.9% among females and from 18.1% to 8.3% among males. Females consistently reported higher levels of stress compared with males, with greater proportions of females categorized within the high and very high stress categories across elementary, middle, and high school levels (all $p < 0.001$).

Females

Elementary	No Stress Mean (SD)	Low Mean (SD)	Average Mean (SD)	High Mean (SD)	Very High Mean (SD)	P-value
Sleep (hrs/night)	9.27 (1.32)	9.01 (1.24)	8.84 (1.34)	8.57 (1.43)	8.21 (1.80)	<0.001
Fruits and Veggies (days/wk)	4.90 (2.0)	4.65 (2.02)	4.58 (1.98)	4.49 (2.08)	4.69 (2.24)	<0.001
Sugary Drinks (days/wk)	1.89 (1.74)	2.20 (1.79)	2.51 (1.90)	2.71 (2.03)	2.81 (2.17)	<0.001
Physical Activity (days/wk)	4.76 (2.19)	4.60 (2.15)	4.38 (2.15)	4.35 (2.19)	4.44 (2.36)	<0.001
BMI (kg/m ²)	18.26 (3.51)	18.27 (3.51)	18.50 (3.65)	18.83 (3.98)	19.52 (4.51)	<0.001
Middle School	No Stress	Low	Average	High	Very High	P-value
Sleep (hrs/night)	8.83 (1.23)	8.73 (1.02)	8.48 (1.10)	8.07 (1.37)	7.61 (1.69)	<0.001
Fruits and Veggies (days/wk)	4.55 (2.02)	4.46 (1.92)	4.26 (1.96)	4.12 (2.02)	4.10 (2.14)	<0.001
Sugary Drinks (days/wk)	2.08 (1.81)	2.18 (1.74)	2.42 (1.79)	2.69 (2.02)	2.79 (2.12)	<0.001
Physical Activity (days/wk)	4.63 (2.25)	4.69 (2.07)	4.35 (2.16)	4.24 (2.18)	4.28 (2.30)	<0.001
BMI (kg/m ²)	20.40 (4.29)	19.96 (3.78)	20.49 (4.06)	20.92 (4.22)	21.36 (4.67)	<0.001
High School	No Stress	Low	Average	High	Very High	P-value
Sleep (hrs/night)	8.17 (1.24)	8.08 (1.06)	7.77 (1.10)	7.44 (1.27)	6.95 (1.43)	<0.001
Fruits and Veggies (days/wk)	3.82 (2.19)	3.93 (1.96)	3.73 (1.97)	3.69 (1.95)	3.58 (2.09)	<0.001
Sugary Drinks ((days/wk)	1.90 (1.75)	2.29 (1.76)	2.62 (1.87)	2.86 (2.01)	3.17 (2.20)	<0.001
Physical Activity (days/wk)	4.05 (2.21)	4.04 (2.22)	3.87 (2.21)	3.83 (2.27)	3.48 (2.35)	<0.001
BMI (kg/m ²)	22.78 (4.41)	22.23 (4.26)	22.27 (4.12)	22.99 (5.03)	23.85 (5.46)	<0.001

Males

Elementary	No Stress Mean (SD)	Low Mean (SD)	Average Mean (SD)	High Mean (SD)	Very High Mean (SD)	P-value Mean (SD)
Sleep (hrs/night)	9.05 (1.50)	8.91 (1.29)	8.78 (1.32)	8.49 (1.51)	8.26 (1.85)	<0.001
Fruits and Veggies (days/wk)	4.60 (2.12)	4.38 (2.07)	4.30 (2.08)	4.32 (2.11)	4.20 (2.40)	<0.001
Sugary Drinks (days/wk)	2.16 (1.88)	2.39 (1.90)	2.61 (1.98)	2.82 (2.15)	2.99 (2.27)	<0.001
Physical Activity (days/wk)	5.16 (2.20)	4.95 (2.17)	4.71 (2.22)	4.68 (2.28)	4.42 (2.47)	<0.001
BMI (kg/m ²)	18.46 (3.71)	18.51 (3.69)	18.89 (4.06)	18.85 (4.03)	19.52 (4.60)	<0.001
Middle School	No Stress	Low	Average	High	Very High	P-value
Sleep (hrs/night)	8.67 (1.53)	8.83 (1.05)	8.63 (1.16)	8.30 (1.38)	7.48 (1.78)	<0.001
Fruits and Veggies (days/wk)	4.36 (2.12)	4.23 (1.99)	4.05 (1.97)	4.03 (2.01)	3.90 (2.38)	0.001
Sugary Drinks (days/wk)	2.24 (1.89)	2.45 (1.88)	2.62 (1.89)	2.83 (2.00)	3.14 (2.29)	<0.001
Physical Activity (days/wk)	5.13 (2.23)	5.17 (2.10)	4.86 (2.16)	4.75 (2.17)	4.70 (2.49)	<0.001
BMI (kg/m ²)	20.02 (4.13)	19.71 (3.99)	20.16 (4.21)	20.82 (4.66)	20.61 (4.82)	<0.001
High School	No Stress	Low	Average	High	Very High	P-value
Sleep (hrs/night)	8.07 (1.33)	8.07 (1.14)	7.83 (1.17)	7.42 (1.33)	6.92 (1.63)	<0.001
Fruits and Veggies (days/wk)	3.60 (2.11)	3.75 (2.01)	3.57 (1.94)	3.53 (2.01)	3.53 (2.21)	0.011
Sugary Drinks (days/wk)	2.80 (2.16)	2.72 (1.90)	2.97 (2.00)	3.18 (2.12)	3.51 (2.32)	<0.001
Physical Activity (days/wk)	4.80 (2.34)	4.88 (2.14)	4.50 (2.22)	4.42 (2.23)	4.36 (2.40)	<0.001
BMI (kg/m ²)	21.96 (4.70)	22.10 (4.58)	22.47 (4.89)	22.84 (5.09)	22.91 (5.62)	<0.001

Mean (standard deviation); significance determined by ANOVA; $\alpha < 0.05$.

Table 3: Association Between Self-Reported Stress and Cardiovascular Risk Factors in Male and Female Youth

Across both sexes and all school levels, increasing stress severity across Likert categories was associated with shorter sleep duration, lower fruit and vegetable intake, lower physical activity, higher sugary drink

consumption, and higher BMI (all $p < 0.001$, except fruit and vegetable intake among middle school males [$p = 0.001$] and high school males [$p = 0.011$]) (Table 3).

Value	Value	Std. Error	t value	p value
Sleep	-0.384	0.015	-26.322	0.000
Stress parent2 low	0.406	0.097	4.202	0.000
Stress_parent3 average	0.740	0.091	8.102	0.000
Stress parent4 high	1.133	0.096	11.777	0.000
Stress_parent5 very high	1.475	0.135	10.940	0.000
BMI	0.043	0.004	10.825	0.000
Stress_none Stress_low	-4.118	0.185	-22.297	0.000
Stress_low Stress_average	-1.993	0.182	-10.950	0.000
Stress_average Stress_high	-0.189	0.181	-1.044	0.297
Stress_high Stress_veryhigh	1.932	0.185	10.467	0.000

Log odds; standard error; significance determined by proportional odds ordinal logistic regression; $\alpha < 0.05$

Ordinal logistic regression analyses were performed to identify factors associated with student-reported stress (Table 4).

Table 4: Ordinal Logistic Regression Model

Variable	Odda Ratio
Sleep	0.68 [0.66, 0.70]
Stress parent2 low	1.50 [1.24, 1.82]
Stress parent3 average	2.10 [1.75, 2.51]
Stress parent4 high	3.10 [2.57, 3.75]
Stress parent5 very high	4.37 [3.35, 5.70]
BMI	1.04 [1.04, 1.05]

Odds ratio [95% confidence interval]

Table 5: Odds Ratios

Higher parental stress was the strongest predictor of increased student stress. Compared with students reporting no parental stress, students exposed to increasing levels of parental stress demonstrated progressively higher odds of reporting greater stress levels (OR 1.50, 2.10, 3.10, and 4.37 for increasing parental stress categories; $p < 0.001$) (Table 5). Greater sleep duration was associated with reduced odds of higher student stress (OR 0.68, $p < 0.001$). BMI demonstrated a modest positive association with student stress (OR 1.04, $p < 0.001$). Overall, parental stress demonstrated the strongest association with student-reported stress, while behavioral and biometric factors showed additional but smaller associations.

Discussion

These findings highlight the importance of addressing stress and its contributing factors early in life to potentially mitigate cardiovascular risk. Interventions targeting sleep, physical activity, nutrition, and family-level stress management may have meaningful impacts on pediatric cardiovascular health risks. For example, the Child and Adolescent Trial

for Cardiovascular Health (CATCH) demonstrated that school- and family-based interventions can significantly improve children's health behaviors.[21]

Female students demonstrated consistent associations between increasing stress levels and less favorable cardiovascular risk-related behaviors, including higher BMI and sugary drink consumption, along with lower fruit and vegetable intake, physical activity, and sleep duration (all $p < 0.001$; Table 3). These findings suggest that higher stress levels are associated with poorer health behaviors and a less favorable cardiovascular risk profile among female students.

Similar patterns were observed among male students. Increasing stress was associated with higher BMI and sugary drink consumption, while fruit and vegetable intake, physical activity, and sleep duration decreased (all $p < 0.001$). Higher stress was likewise associated with adverse biometric profiles and less healthy behavioral patterns in male students.

Several notable trends emerged across age and sex. BMI increased with higher stress across all groups, although the relationship was not always

linear within every subgroup. While some of this increase likely reflects normal growth and development, it also underscores the importance of early preventive interventions given the rising prevalence of pediatric obesity in the United States.[22] Stress levels increased with age and were consistently higher among females across grade levels, supporting the need for age- and sex-specific interventions that address health behaviors and stress during adolescence.[23–25]

Higher stress levels were associated with reduced physical activity across school levels, consistent with previous literature demonstrating relationships between physical activity and psychological well-being in youth.[26] These findings suggest that physical activity may represent an important behavioral target within broader strategies addressing stress and cardiovascular risk, although the directionality of this relationship cannot be determined from this cross-sectional analysis.

A strong and consistent relationship was observed between parental stress and student-reported stress, with increasing parental stress associated with progressively higher levels of student stress. This finding aligns with previous literature suggesting both psychological and biological pathways for intergenerational stress transmission. [16,17] Sleep was the strongest protective factor across analyses, with longer sleep duration associated with lower stress levels, supporting existing evidence that inadequate sleep contributes to increased stress and anxiety.[27]

These findings may help inform future improvements to the HHM program by identifying more effective approaches to assessing and educating participants and families about stress. Recognizing stress-related cardiovascular risk factors early provides an opportunity to educate students about the potential physiological effects of stress, encourage healthy behaviors, and intervene during critical developmental periods. Ultimately, these efforts may improve long-term cardiovascular health in Colorado and beyond.

Limitations

Although these findings demonstrate consistent associations between stress and cardiovascular risk-related factors, several limitations should be considered. The use of self-reported stress measures introduces the potential for reporting bias because perceptions and reporting of stress vary among individuals. In addition, the cross-sectional study design prevents determination of whether stress contributes to cardiovascular risk factors or whether cardiovascular risk factors influence stress levels. Residual confounding by unmeasured factors remains possible, and detailed environmental and socioeconomic data that may influence both stress and cardiovascular outcomes were not available.[28] Participation in school-based screenings may have introduced selection bias, limiting the generalizability of findings beyond participating Colorado schools and students. Variation in screening procedures and school conditions across the 2014–2024 study period may also have affected the results. Finally, single measurements of BMI, lipid profiles, and other biometric values may not fully reflect students' usual cardiometabolic status. Future longitudinal studies examining changes in stress alongside changes in biometric measures, biomarkers, and genetic components would help clarify these relationships. Further investigation into the specific sources of stress experienced by students could also inform more targeted and effective interventions.

Conclusion

Our findings extend evidence from adults by demonstrating that increased student-reported stress is associated with multiple pediatric cardiovascular risk-related behaviors and biomarkers including shorter sleep, poorer diet, reduced physical activity, greater sugary drink consumption, higher BMI, and differences in lipid profiles. Parental stress was a strong predictor of student stress, while longer sleep was associated with lower stress.

These findings support early, family-centered interventions that address stress with modifiable risk factors, though further work is needed to establish causal associations. Because stress and weight status may influence one another, integrated approaches targeting both psychological stress and health behaviors may provide the greatest benefit. Longitudinal studies using repeated assessments are needed to establish temporality, determine whether stress independently contributes to future CVD risk, and guide evidence-based interventions.

References:

1. Mensah GA, Roth GA, Fuster V.(2019), The Global Burden of Cardiovascular Diseases and Risk Factors: 2020 and Beyond. *J Am Coll Cardiol.* Nov 19;74(20):2529–2532.
2. Mozaffarian D, Wilson PWF, Kannel WB. (2008), Beyond established and novel risk factors: lifestyle risk factors for cardiovascular disease. *Circulation.* Jun 10;117(23):3031–3038.
3. Daniels SR, Greer FR.(2008),Committee on Nutrition. Lipid screening and cardiovascular health in childhood. *Pediatrics.* Jul;122(1):198–208.
4. Chung ST, Krenek A, Magge SN. (2023),Childhood Obesity and Cardiovascular Disease Risk. *Curr Atheroscler Rep.* Jul;25(7):405–415.
5. Eriksson M, Räikkönen K, Eriksson JG. (2014),Early life stress and later health outcomes--findings from the Helsinki Birth Cohort Study. *Am J Hum Biol Off J Hum Biol Counc.*;26(2):111–116.
6. Shonkoff JP, Garner AS, (2012),Committee on Psychosocial Aspects of Child and Family Health, Committee on Early Childhood, Adoption, and Dependent Care, Section on Developmental and Behavioral Pediatrics. The lifelong effects of early childhood adversity and toxic stress. *Pediatrics.* Jan;129(1):e232–246.
7. McEwen BS. (2007),Physiology and neurobiology of stress and adaptation: central role of the brain. *Physiol Rev.* Jul;87(3):873–904.
8. Kartiosuo N, Raitakari OT, Juonala M, Viikari JSA, Sinaiko AR, Venn AJ, et al. (2024),Cardiovascular Risk Factors in Childhood and Adulthood and Cardiovascular Disease in Middle Age. *JAMA Netw Open.* Jun 3;7(6):e2418148..
9. Jacobs DR, Woo JG, Sinaiko AR, Daniels SR, Ikonen J, Juonala M, et al. (2022),Childhood Cardiovascular Risk Factors and Adult Cardiovascular Events. *N Engl J Med.* May 19;386(20):1877–1888.
10. Childhood and Adolescent Adversity and Cardiometabolic Outcomes: A Scientific Statement From the American Heart Association. *Circulation* [Internet]. [cited Jul 30].
11. Li H, Xia N. (2023),The Role of Oxidative Stress in Cardiovascular Disease Caused by Social Isolation and Loneliness. In: *Environmental Stressors and OxInflammatory Tissues Responses.* CRC Press;.
12. Steptoe A, Kivimäki M. (2013),Stress and cardiovascular disease: an update on current knowledge. *Annu Rev Public Health.*;34:337–354.
13. Dimsdale JE. (2008),Psychological stress and cardiovascular disease. *J Am Coll Cardiol.* Apr 1;51(13):1237–1246.
14. Vancheri F, Longo G, Vancheri E, Henein MY. (2022),Mental Stress and Cardiovascular Health—Part I. *J Clin Med.* Jun 10;11(12):3353.
15. Onyegbule CJ, Muoghalu CG, Ofoegbu CC, Ezeorah F. The Impact of Poor Sleep Quality on Cardiovascular Risk Factors and Quality of Life. *Cureus.* 17(1):e77397.
16. Bowers ME, Yehuda R. (2016),Intergenerational Transmission of Stress in Humans. *Neuropsychopharmacology.* Jan;41(1):232–244.

17. Evans GW, Kim P. (2013), Childhood Poverty, Chronic Stress, Self-Regulation, and Coping. *Child Dev Perspect.*;7(1):43–48.
18. Pollack AM, Nelson TL, Jenkins NA, Willis MW, Lueders PC, Kingman AK, et al. (2025), Measuring the impact of obesity on cardiovascular risk for northern Colorado school children: Healthy hearts and minds program 2013-2023. *Am J Prev Cardiol.* Mar;21:100933.
19. Nelson TL, Puccetti N, Luckasen GJ. (2015), Healthy hearts: a cross-sectional study of clinical cardiovascular disease risk factors in Northern Colorado school children (1992-2013). *BMC Obes.*;2:48.
20. Healthy Hearts and Minds. UCHHealth [Internet]. [cited 2026 Jul 30].
21. Luepker RV, Perry CL, McKinlay SM, Nader PR, Parcel GS, Stone EJ, et al. (1996), Outcomes of a field trial to improve children's dietary patterns and physical activity. The Child and Adolescent Trial for Cardiovascular Health. CATCH collaborative group. *JAMA.* Mar 13;275(10):768–76.
22. Ogden CL, Carroll MD, Lawman HG, Fryar CD, Kruszon-Moran D, Kit BK, et al. (. 2016), Trends in Obesity Prevalence Among Children and Adolescents in the United States, 1988-1994 Through 2013-2014. *JAMA* Jun 7;315(21):2292–2299.
23. Kessler RC, Berglund P, Demler O, Jin R, Merikangas KR, Walters EE. (2005), Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Arch Gen Psychiatry.* Jun;62(6):593–602.
24. Hankin BL, Abramson LY, Moffitt TE, Silva PA, McGee R, Angell KE. (1998), Development of depression from preadolescence to young adulthood: emerging gender differences in a 10-year longitudinal study. *J Abnorm Psychol.* Feb;107(1):128–40.
25. Löfstedt P, García-Moya I, Corell M, Paniagua C, Samdal O, Välimaa R, et al. (2018) School Satisfaction and School Pressure in the WHO European Region and North America: An Analysis of Time Trends and Patterns of Co-occurrence in 32
26. Schmalz DL, Deane GD, Birch LL, Davison KK. (2007), A longitudinal assessment of the links between physical activity and self-esteem in early adolescent non-Hispanic females. *J Adolesc Health Off Publ Soc Adolesc Med.* Dec;41(6):559–565.
27. Your child's mental health: Why does sleep matter? | Texas Children's [Internet]. 2016 [cited 2026 Apr 25].
28. Fan CC, Marshall A, Smolker H, Gonzalez MR, Tapert SF, Barch DM, et al. (2021), Adolescent Brain Cognitive Development (ABCD) study Linked External Data (LED): Protocol and practices for geocoding and assignment of environmental data. *Dev Cogn Neurosci.* Dec 1;52:101030.



This work is licensed under Creative Commons Attribution 4.0 License

To Submit Your Article Click Here:

Submit Manuscript

DOI:10.31579/2641-0419/594

Ready to submit your research? Choose Auctores and benefit from:

- fast, convenient online submission
- rigorous peer review by experienced research in your field
- rapid publication on acceptance
- authors retain copyrights
- unique DOI for all articles
- immediate, unrestricted online access

At Auctores, research is always in progress.

Learn more <https://auctoresonline.org/journals/clinical-cardiology-and-cardiovascular-interventions>