

Measuring the impact of obesity on cardiovascular risk for northern Colorado school children: Healthy hearts and minds program 2013–2023

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ABSTRACT

Obesity is associated with cardiovascular disease (CVD) risk factors in both children and adults and is predictive of poor cardiovascular outcomes. Prevalence of CVD risk factors among children has become more frequent and is often influenced by the family. The purpose of this study was to both cross-sectionally and longitudinally determine the prevalence and changes in CVD risk factors among northern Colorado students.

Data was collected from August 2013 to May 2023 as part of the UCHealth Healthy Hearts and Minds (HHM) program (51,882 students, 52.4 % female, 71.5 % White). Objective measures of total cholesterol (TChol), high-density lipoprotein cholesterol (HDL), blood pressure, height, and weight were collected. Self-reported familial CVD risk factors from parents/guardians including overweight/obesity were collected.

CVD risk consistently rises with increasing BMI across grade levels. TChol was higher and HDL was lower as BMI increased, regardless of age or sex.

Students who maintained a healthy weight in elementary and high school (66.2 % males, 67.6 % females) or moved to a healthy weight after elementary school (7.4 % males, 5.0 % females) had lower CVD risk compared to students who were overweight/obese (17.4 % males, 14.7 % females) at both timepoints. Students with a healthy weight in elementary and high school were less likely to have a family member reporting overweight/obesity (26.5 % and 28.0 %) than students who were overweight in both grade levels (50.5 % and 56.7 %).

Given the increase in childhood obesity, there is a need for aggressive screening and treatment of obesity and CVD risk in children and their families.

1. Background

Cardiovascular disease (CVD) is the leading cause of mortality in the United States, accounting for over 50 % of all deaths [1]. CVD remains one of the most preventable diseases as many risk factors (obesity, hypertension, diet, smoking and lack of exercise) are modifiable [2], identifiable in childhood, and typically carry over to adulthood [2–6]. National data from 2011 to 2014 has suggested 21 % of children and adolescents ages 8–17 have at least one abnormal cholesterol measure, 20 % are within the obese classification, and 11 % have elevated blood pressure/hypertension [7]. Previous findings (1992–2013) among 9694 northern Colorado school children corroborated these findings [8].

Obesity is associated with the other cardiovascular risk factors in children and adults, and predictive of poor cardiovascular outcomes in young adults [5,9]. Turchin et al. found that young men and women experiencing obesity over a 10-year period had a 25–60 % increase in the risk of heart attack and stroke [10]. In 2013, Healthy Hearts found that parents with overweight/obesity were more likely to have children with overweight/obesity. These parents and children with overweight/obesity also shared multiple CVD risk factors [8]. Given the recent findings of Aggarwal et al. showing increases in hypertension, diabetes, and obesity among those aged 20–44 years (age range similar to parents of students in over the last decade), an increase in rates of CVD risk factors among their children may be expected [11].

Despite expected changes in CVD risk factors during puberty, it is important to determine if weight status is related to these changes. In

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particularly, males tend to see decreases in TChol and potential decreases in HDL compared with female counterparts [12]. Few studies have established at what age CVD risk consistently and longitudinally increases and what association such longitudinal risk may have with childhood and family levels of overweight/obesity. Such information is imperative for CVD risk reduction and prevention as CVD events continue to be reported at younger ages, likely due to earlier onset of lifestyle factors associated with cumulative exposure to obesity [5,10].

This study seeks to determine the cross-sectional prevalence and longitudinal implications of CVD risk factors among youth at three important time points (elementary school age, middle school age and high school age). Similar to our previous work [8], we were interested in factors that may be associated with CVD risk factors including overweight/obesity, family history of overweight/obesity and other CVD risk factors. We also considered if weight status among the students tracked with self-reported weight status among the family.

2. Methods

The UHealth Healthy Hearts and Minds (HHM) program is a school-based education and screening program founded in 1992 that focuses on healthy lifestyles and cardiovascular risk factors for elementary, middle, and high school students; typically delivered in 5th grade, 7th grade, and 10th grade. HHM’s initial publication [8] included data from August 1992 to May 2013; subsequent education and screening has included 85,000 and 52,000 children (71.5 % White, 19.8 % Hispanic, 8.7 % other, 52.4 % female), respectively, from August 2013 to May 2023. Programming also expanded to middle schools in 2015 and now includes two additional school districts. Given the increasing trends of obesity and diabetes among young adults [11], family risk factors were collected to compare to student CVD risk factors both cross-sectionally and longitudinally.

Data was collected from August 2013 to May 2023 and included objective measures of total cholesterol (TChol), high-density lipoprotein cholesterol (HDL), blood pressure, height, weight, body mass index (BMI), and age-sex specific BMI percentiles. Cross-sectional data was reported for all participants whereas longitudinal data was assessed using only participants with measures from at least two time points. Parents/legal guardians completed a voluntary survey with questions including parent lifestyle and health habits, family history, student health history, and demographic questions. Parental/guardian consent was obtained for all screening participants when the parent/guardian completed the health history questionnaire.

This study was exempt from IRB review due to utilization of de-identified data. Partial support for this study was funded through UHealth Northern Colorado Foundation and UHealth Research Administration.

2.1. Total cholesterol and HDL

Cholesterol was determined non-fasting using the Cholestech LDX Finger Stick Test from August 2013 to May 2017 and the PTS Diagnostic Cardiochek Finger Stick Test from August 2017 to May 2023. Normal total cholesterol was defined as <170 mg/dL, borderline total cholesterol was 170–199 mg/dL, and high total cholesterol ≥200 mg/dL [2, 13].

2.2. Body mass index

Height was measured using a Seca 217 stadiometer and weight was measured using a DETECTO or Seca 877 electronic scale. BMI percentile was calculated based on height, weight, age, and sex used in the most recent Centers for Disease Control and Prevention (CDC) BMI percentile calculator. The overweight category was defined as BMI percentile ≥85th and <95th and the obesity category defined as BMI percentile ≥95th [14,15].

2.3. Blood pressure

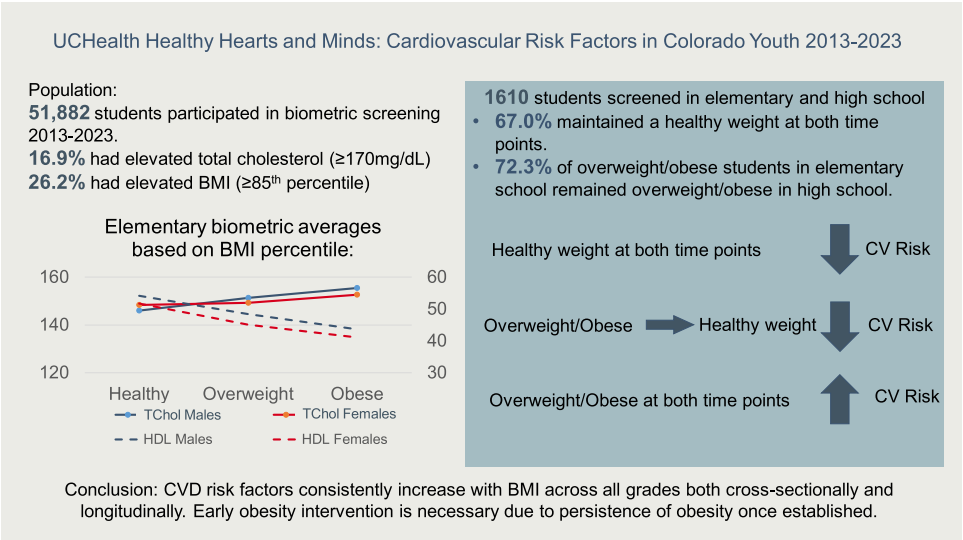
Blood pressure was measured with a Welch-Allen sphygmomanometer fitted with appropriately sized cuffs. Blood pressure was taken one time, sitting, typically on the left arm. Elevated blood pressure is defined as either systolic blood pressure ≥120 mmHg and/or diastolic blood pressure ≥80 mmHg [16].

2.4. Health history questionnaire

Parents/legal guardians completed a voluntary survey with questions including parent lifestyle and health habits such as exercise, smoking status, sleep, etc., family reported CVD risk factors such as obesity, high blood pressure, high cholesterol, diabetes, and smoking, student health history of diabetes, and demographic information.

3. Statistical methods

Mean levels of CVD risk factors were calculated for the entire sample



Central Illustration

by sex. Differences between mean levels of cardiovascular risk markers and weight status were determined for healthy weight, overweight, and obese categories in elementary, middle, and high school. ANOVA models were used to compare means (Tables 1, 3). Tukey's Honest Significant Difference methods were used for post-hoc analysis of ANOVA models. To identify the potential association of family-reported weight status with their child's weight status, self-reported levels of overweight/obesity among family members were considered relative to objectively measured BMI status of the student. Furthermore, CVD risk factors among students who maintained a healthy weight, maintained an overweight/obese weight status, or changed from healthy weight to overweight/obese, or overweight/obese to healthy weight status were reported. Percentages were calculated for various tables (Tables 2, 4–7) and chi-squared models were used to compare proportions. Holm-Bonferroni methods were used for post-hoc analysis of chi-squared models. Significance was defined at $\alpha=0.05$. All statistical analysis was calculated using R Studio Version 4.2.1.

Table 1

Cardiovascular risk markers for all school aged students August 2013 – May 2023 (mean $\pm$ standard deviation).

	Elementary School <i>n</i> = 20,117	Middle School <i>n</i> = 12,997	High School <i>n</i> = 18,768
Age (years)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	10.65 (0.63)* ^{†,§}	13.02 (0.53)* ^{†,‡}	15.58 (0.99) * ^{†,§}
Female	10.59 (0.62)* ^{†,§}	12.95 (0.52)* ^{†,‡}	15.50 (0.98) * ^{†,§}
Body Mass Index (kg/m²)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	18.71 (3.94)* ^{†,§}	20.27 (4.40)* ^{†,‡}	22.48 (4.82) * ^{†,§}
Female	18.52 (3.75)* ^{†,§}	20.70 (4.27)* ^{†,‡}	22.71 (4.58) * ^{†,§}
BMI Percentile (%)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	55.98 (30.82) ^{†,§}	57.87 (29.91) ^{†,‡}	61.97 (28.00) ^{†,§}
Female	56.09 (30.76) ^{†,§}	58.72 (29.87) ^{†,‡}	61.18 (28.33) ^{†,§}
Total Cholesterol (mg/dL)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	148.08 (27.82) ^{†,§}	137.70 (27.98) * ^{†,‡}	129.42 (26.91) * ^{†,§}
Female	148.81 (28.03) ^{†,§}	143.88 (27.17) * ^{†,‡}	146.26 (29.31) * ^{†,§}
HDL Cholesterol (mg/dL)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	51.88 (13.73)* ^{†,§}	47.10 (13.12) * ^{†,‡}	41.40 (11.26) * ^{†,§}
Female	49.83 (13.14)* [†]	48.85 (12.85) * ^{†,‡}	49.92 (12.92) * [†]
Systolic Blood Pressure (mm Hg)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	99.79 (10.29) ^{†,§}	104.10 (10.45) ^{†,‡}	109.49 (11.11) * ^{†,§}
Female	99.69 (10.40) ^{†,§}	103.81 (10.18) ^{†,‡}	105.62 (10.20) * ^{†,§}
Diastolic Blood Pressure (mm Hg)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	64.22 (7.97) ^{†,§}	64.25 (8.27)* [†]	66.43 (8.80) * ^{†,§}
Female	64.59 (8.00)* ^{†,§}	65.25 (7.89)* ^{†,‡}	66.73 (8.18) * ^{†,§}

* significantly different between males/females in the same grade at $\alpha=0.05$.

[†] significantly different between elementary and middle school students of the same sex at $\alpha=0.05$.

[‡] significantly different between middle and high school students of the same sex at $\alpha=0.05$.

[§] significantly different between elementary and high school students of the same sex at $\alpha=0.05$.

Table 2

Proportion of students falling in cardiovascular risk categories for all school aged students by sex August 2013 – May 2023 (percentage).

	Elementary School <i>n</i> = 20,117	Middle School <i>n</i> = 12,997	High School <i>n</i> = 18,768
BMI Percentile	<i>Percentage</i>	<i>Percentage</i>	<i>Percentage</i>
85th–<95th			
Male	14.1 % (1305/9280)	13.4 %* (769/5734)	13.8 %* (1122/8145)
Female	13.5 % ^{†,§} (1337/9897)	14.8 %* ^{†,‡} (920/6231)	16.4 %* ^{†,§} (1501/9171)
BMI Percentile			
≥95th			
Male	14.2 %* (1314/9280)	13.1 %* (752/5734)	14.0 %* (1141/8145)
Female	9.8 %* (974/9897)	10.3 %* (641/6231)	10.2 %* (931/9171)
Total Cholesterol			
170–199			
Male	16.1 % ^{†,§} (1396/8675)	10.4 %* ^{†,‡} (558/5361)	6.5 %* ^{†,§} (512/7936)
Female	16.6 % ^{†,§} (1549/9322)	13.4 %* [†] (804/5981)	14.5 %* ^{†,§} (1310/9031)
Total Cholesterol			
≥200			
Male	4.3 % ^{†,§} (376/8675)	2.6 %* ^{†,‡} (139/5361)	1.7 %* ^{†,§} (132/7936)
Female	4.5 % [†] (415/9322)	3.3 %* ^{†,‡} (197/5981)	4.9 %* ^{†,‡} (443/9031)
HDL Cholesterol			
<40			
Male	18.2 %* ^{†,§} (1583/8674)	30.1 %* ^{†,‡} (1616/5361)	47.9 %* ^{†,§} (3800/7934)
Female	21.8 %* [†] (2032/9321)	24.7 %* ^{†,‡} (1475/5980)	21.7 %* ^{†,‡} (1964/9031)
Systolic Blood Pressure			
≥120			
Male	3.1 % ^{†,§} (291/9342)	7.1 %* ^{†,‡} (409/5778)	17.8 %* ^{†,§} (1456/8161)
Female	3.0 % ^{†,§} (299/9999)	5.8 %* ^{†,‡} (369/6343)	8.3 %* ^{†,§} (769/9302)
Diastolic Blood Pressure			
≥80			
Male	3.2 % [§] (301/9341)	3.8 % [†] (217/5778)	7.7 %* ^{†,§} (628/8161)
Female	3.7 % [§] (370/9999)	4.1 % [†] (260/6343)	6.8 %* ^{†,§} (629/9302)

* significantly different between males/females in the same grade at $\alpha=0.05$.

[†] significantly different between elementary and middle school students of the same sex at $\alpha=0.05$.

[‡] significantly different between middle and high school students of the same sex at $\alpha=0.05$.

[§] significantly different between elementary and high school students of the same sex at $\alpha=0.05$.

4. Results

The study sample included 51,882 students, 52.4 % female, primarily white (71.5 %). There were 20,117 students screened at the elementary age (grades 4th–5th; age 8–12), 12,997 students at middle school age (grades 6th–8th; age 11–14), and 18,768 students screened at the high school age (grades 9th–12th; age 14–18) (Table 1).

Table 1 shows cross-sectional data on cardiovascular risk markers by sex among elementary, middle, and high school students. Although BMI significantly increased from elementary school to high school among males and females, mean levels BMI stayed within a healthy range based on age-sex specific percentiles. Total cholesterol and HDL were also within normal values and significantly decreased from elementary to middle to high school among males while they stayed relatively stable among females (Non-HDL level reported in Supplemental Table 2).

Longitudinal measures for participants who had data at all three time points (elementary, middle, and high school students; *N* = 765) corroborated the trends identified in Table 1 (Supplemental Table 1).

Standard cardiovascular risk categories were used to determine the prevalence of cardiovascular disease risk factors among students at each grade level (Table 2). CVD risk factors were present at all grades in males and females with overweight/obesity levels mostly consistent at each age group for males and females. However, significant differences by sex at each group were observed with females having lower levels of obesity than males (BMI Percentile ≥ 95 %) at each grade level. The prevalence of borderline high (170–190 mg/dL) to high cholesterol (≥ 200 mg/dL) levels decreased for males from elementary to high school, but levels remained relatively stable among females. Importantly, ~ 20 % and ~ 7 % of high-school students had borderline high (170–199 md/dL) and high cholesterol (≥ 200 mg/dL), respectively.

Cross-sectionally, significant increases in all cardiovascular risk values were associated with increases in BMI, regardless of grade for males and females (Table 3). Repeated, longitudinal measures between CVD risk markers and BMI status corroborated cross-sectional associations (Supplemental Table 3).

Children in the overweight or obese categories were more likely to have a family member with overweight or obesity (Table 4); 42.6 % of students within the overweight category reported a familial risk of overweight/obesity while 57.9 % of students with obesity reported a familial risk of overweight/obesity. Alternatively, 27.4 % of students in the healthy weight category reported a familial risk of overweight or obesity. Further, children within the overweight/obese category were more likely to have families with cardiovascular risk factors including, diabetes, high cholesterol, high blood pressure, and smoking.

Among males, 66.2 % (475/717) maintained a healthy weight from elementary to high school while 17.4 % were classified within the overweight/obese categories at both time points. 8.9 % shifted from healthy weight in elementary school to the overweight/obese category in high school and 7.4 % shifted from overweight/obese status in elementary school to healthy weight status in high school (Tables 5 and 6; males and females combined in Supplemental Table 4). Weight status at these two time points was associated with CVD risk factor changes; those who were at a healthy weight at both time points, or moved to a healthy weight from the overweight group, had more favorable CVD risk factor levels. Among females, 67.6 % maintained a healthy weight from elementary to high school while 14.7 % were classified within the overweight/obese categories at both time points. 12.7 % shifted from healthy weight status in elementary school to overweight/obese status in high school and 5.0 % shifted from overweight/obese status in elementary school to healthy weight status in high school. Comparable to males, female weight status at these two time points was associated with changes in CVD risk factors. Prevalence of high cholesterol (≥ 200 mg/dL) significantly decreased for those who maintained a healthy weight, but less so in those who were overweight/obese at both time points.

Self-reported levels of overweight and obesity among family members were considered in relation to students measured BMI at both elementary and high school age (Table 7). Students with a healthy weight status in elementary and high school were 26.5 % and 28.0 %, respectively, less likely to have family members with overweight/obesity than students within overweight categories in both elementary school and high school (family history 50.5 % and 56.7 %, respectively). Further, students who went from healthy to overweight status had families who developed an ~ 11 % increase in family reported overweight/obesity.

5. Discussion

Cardiovascular disease risk factors were found to consistently increase with greater BMI percentiles among elementary, middle, and high school age children. These findings were consistent using cross-sectional data as well as repeated measures longitudinal data. Specifically, cross-sectional data showed increased CVD risk for all markers (TChol, HDL, Systolic, and Diastolic Blood Pressure) to be significantly associated with

Table 3

Cardiovascular disease risk values for students August 2013 – May 2023 by BMI (mean $\pm$ standard deviation).

	Elementary School		
	Healthy Weight <i>n</i> = 13,410	Overweight <i>n</i> = 2642	Obese <i>n</i> = 2288
Total Cholesterol (mg/dL)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	146.01 (26.47) ^{*,†}	151.29 (29.37) ^{*,†}	155.35 (30.81) ^{†,‡}
Female	148.32 (27.39) [†]	149.19 (30.00) [‡]	152.62 (29.72) ^{†,‡}
HDL Cholesterol (mg/dL)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	54.18 (13.57) ^{*,†}	48.42 (12.24) ^{*,†}	43.58 (11.51) ^{†,‡}
Female	51.74 (13.03) ^{*,†}	45.09 (11.29) ^{*,†}	41.12 (10.83) ^{†,‡}
Systolic Blood Pressure (mm Hg)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	97.97 (9.61) ^{*,†}	102.48 (9.56) ^{*,†}	107.16 (10.04) ^{†,‡}
Female	98.34 (9.98) ^{*,†}	103.07 (9.58) ^{*,†}	106.61 (9.92) ^{†,‡}
Diastolic Blood Pressure (mm Hg)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	63.05 (7.54) ^{*,†}	66.00 (7.76) ^{*,†}	68.78 (8.13) ^{†,‡}
Female	63.85 (7.78) ^{*,†}	66.27 (7.75) ^{*,†}	68.87 (7.99) ^{†,‡}
Middle School			
	Healthy Weight <i>n</i> = 8403	Overweight <i>n</i> = 1689	Obese <i>n</i> = 1393
Total Cholesterol (mg/dL)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	135.59 (26.98) [†]	137.90 (29.22) [‡]	146.80 (30.07) ^{†,‡}
Female	142.99 (26.69) [†]	144.84 (27.57) ^{*,†}	147.35 (28.86) [†]
HDL Cholesterol (mg/dL)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	48.93 (13.12) ^{*,†}	43.18 (11.49) ^{*,†}	39.56 (10.13) ^{†,‡}
Female	50.31 (12.91) ^{*,†}	45.97 (11.63) ^{*,†}	41.91 (10.43) ^{†,‡}
Systolic Blood Pressure (mm Hg)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	102.75 (10.02) ^{*,†}	106.55 (9.78) ^{*,†}	110.38 (10.21) ^{†,‡}
Female	102.76 (9.92) ^{*,†}	105.86 (9.71) ^{*,†}	109.41 (9.93) ^{†,‡}
Diastolic Blood Pressure (mm Hg)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	63.47 (8.06) ^{*,†}	65.46 (8.02) ^{*,†}	67.86 (8.50) ^{†,‡}
Female	64.65 (7.77) ^{*,†}	66.26 (7.61) ^{*,†}	68.60 (7.81) ^{†,‡}
High School			
	Healthy Weight <i>n</i> = 12,169	Overweight <i>n</i> = 2623	Obese <i>n</i> = 2072
Total Cholesterol (mg/dL)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	126.53 (25.12) ^{*,†}	132.75 (28.44) ^{*,†}	141.41 (30.55) ^{†,‡}
Female	145.09 (29.03) ^{*,†}	148.62 (29.92) ^{*,†}	150.87 (29.35) [†]
HDL Cholesterol (mg/dL)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	42.89 (11.38) ^{*,†}	38.61 (9.87) ^{*,†}	35.64 (9.15) ^{†,‡}
Female	51.53 (12.88) ^{*,†}	47.36 (11.91) ^{*,†}	42.39 (10.94) ^{†,‡}
Systolic Blood Pressure (mm Hg)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>
Male	107.91 (10.56) ^{*,†}	111.82 (10.42) ^{*,†}	116.31 (10.98) ^{†,‡}
Female	104.41 (9.78) ^{*,†}	107.68 (9.99) ^{*,†}	111.50 (10.15) ^{†,‡}
Diastolic Blood Pressure (mm Hg)	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>Mean (SD)</i>

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Table 3 (continued)

	Elementary School		
	Healthy Weight <i>n</i> = 13,410	Overweight <i>n</i> = 2642	Obese <i>n</i> = 2288
Male	65.64 (8.59) ^{*,†}	66.97 (8.45) ^{*,‡}	70.16 (8.97) ^{‡,§}
Female	66.04 (7.92) ^{*,†}	67.59 (8.18) ^{*,‡}	70.39 (8.51) ^{‡,§}

Healthy is defined as BMI Percentile ≥ 5 and < 85 th, Overweight is defined as ≥ 85 th and < 95 th, Obese is defined as ≥ 95 th.

^{*} significantly different between Healthy Weight and Overweight at $\alpha = 0.05$.

[†] significantly different between Healthy Weight and Obese at $\alpha = 0.05$.

[‡] significantly different between Overweight and Obese at $\alpha = 0.05$.

Table 4

Percentage of families reporting (FR) cardiovascular disease risk factors by categories of students BMI (August 2013–May 2023) (percentage).

Student Weight	FR Overweight Obesity	FR Diabetes	FR High Cholesterol	FR High Blood Pressure	FR Smoking
Healthy	27.4 % ^{*,†} (7797/ 28,433)	11.5 % ^{*,†} (3269/ 28,451)	21.3 % ^{*,†} (6053/ 28,423)	21.6 % ^{*,†} (6153/ 28,492)	13.5 % ^{*,†} (3655/ 27,163)
Overweight	42.6 % ^{*,‡} (2440/ 5733)	17.4 % ^{*,‡} (998/ 5735)	23.3 % [*] (1336/ 5728)	26.4 % ^{*,†} (1516/ 5750)	18.9 % ^{*,‡} (1043/ 5513)
Obese	57.9 % ^{‡,§} (2721/ 4700)	23.4 % ^{‡,§} (1098/ 4697)	23.8 % [†] (1112/ 4682)	31.0 % ^{‡,§} (1455/ 4692)	25.2 % ^{‡,§} (1135/ 4504)

Healthy is defined as BMI Percentile ≥ 5 and < 85 th, Overweight is defined as ≥ 85 th and < 95 th, Obese is defined as ≥ 95 th.

^{*} significantly different between Healthy and Overweight at $\alpha = 0.05$.

[†] significantly different between Healthy and Obese at $\alpha = 0.05$.

[‡] significantly different between Overweight and Obese at $\alpha = 0.05$.

increasing weight status at all grade levels. These findings are consistent with findings from the Bogalusa Heart Study where children and adolescents at or above the 85th percentile of body weight yielded poorer cardiovascular risk markers [17]. Other studies have found similar

results [18,19] including our previous work using the HHM study data collected from (1992–2013) among elementary aged children [8].

The repeated measures longitudinal data, collected among the same children in elementary and in high school, showed that students who maintained a healthy weight at both time points (66.2 % males, 67.6 % females) or moved to a healthy weight status after being in the overweight category in elementary school (7.4 % males, 5.0 % females) had more favorable CVD risk factors in high school than students who maintained overweight/obese status from elementary to high school (17.4 % male; 14.7 % female). There are few studies that have assessed repeated measures CVD risk factors from elementary school age to high school age. Lawlor et al. assessed changes in BMI, and other measures of adiposity, from age 9–12 to age 15–16 and the association with CVD risk factors [18]. They found females who maintained a healthy weight or moved from overweight to healthy weight status had cardiovascular risk factors similar to females who maintained a healthy weight at both time points. Among males however, they found those who moved from overweight to healthy weight status had intermediate risk between those who maintained a healthy or overweight/obesity status. Our study found similar results for HDL < 40 mg/dL and blood pressure; however, all borderline and high TChol males at elementary school age moved to a healthy cholesterol by high school. This longitudinal repeated measures data emphasizes the early influence overweight/obesity has on cardiovascular risk markers starting as early as 10 years old.

It is important to note, TChol dropped as well as HDL for males between elementary school and high school in our repeated sample. One mechanistic explanation might be that the body's increased need for cholesterol during puberty as well as increased testosterone levels in males and estradiol in females can result in lower cholesterol in both sexes [20]. Decreases in TChol were primarily among males in our study, similar to other studies [21,22]; females TChol remained fairly steady. Importantly, the decreases in TChol were not nearly as pronounced for children/adolescent within the overweight category as the children/adolescents of a healthy weight status. Male students with TChol ≥ 200 saw an 0.8 % drop in TChol compared with a 2.3 % TChol drop for males with TChol < 200 ; female students with TChol ≥ 200 had a 0.7 % drop in TChol relative to a 3.0 % TChol drop among females with TChol < 200 . HDL significantly decreased, which is also expected to occur with puberty in males more so than females, and blood pressure levels significantly increased from elementary to high school for both males and females, but this was tempered among those who maintained a

Table 5

Longitudinal within student association of CVD risk with weight status from elementary (ES) to high school (HS) among males (*N* = 717) (percentage).

	Healthy Weight both ES and HS (<i>N</i> = 475)	Overweight or Obese both ES and HS (<i>N</i> = 125)	Healthy W ES Overweight or Obese HS (<i>N</i> = 64)	Overweight or Obese ES Healthy Weight HS (<i>N</i> = 53)
TChol				
170–199				
ES	17.3 % ^{*,§} (82/475)	22.4 % [*] (28/125)	21.9 % [*] (14/64)	34.0 % ^{*,§} (18/53)
HS	3.2 % [*] (15/475)	8.8 % [*] (11/125)	4.7 % [*] (3/64)	0.0 % [*] (0/53)
TChol ≥ 200				
ES	2.5 % [*] (12/475)	4.8 % (6/125)	0.0 % (0/64)	1.8 % (1/53)
HS	0.2 % ^{*,†} (1/475)	4.0 % [†] (5/125)	0.0 % (0/64)	0.0 % (0/53)
HDL < 40				
ES	11.2 % ^{*,†} (53/475)	42.4 % ^{*,†,§} (53/125)	15.6 % ^{*,§} (10/64)	22.6 % [*] (12/53)
HS	51.2 % ^{*,†} (243/475)	69.6 % ^{*,†} (87/125)	67.2 % [*] (43/64)	52.8 % [*] (28/53)
Sys BP ≥ 120				
ES	1.9 % [*] (9/475)	4.8 % [*] (6/125)	0.0 % [*] (0/64)	5.7 % [*] (3/53)
HS	12.2 % ^{*,†,§} (58/475)	29.6 % ^{*,†} (37/125)	25.0 % ^{*,†} (16/64)	20.8 % [*] (11/53)
Dia BP ≥ 80				
ES	1.7 % [§] (8/475)	4.8 % (6/125)	3.1 % (2/64)	11.3 % [§] (6/53)
HS	4.0 % [†] (19/475)	11.2 % [†] (14/125)	4.7 % (3/64)	5.7 % (3/53)

Healthy is defined as BMI Percentile ≥ 5 and < 85 th, Overweight is defined as ≥ 85 th and < 95 th, Obese is defined as ≥ 95 th.

^{*} significantly different between ES and HS.

[†] significantly different between Healthy weight both and Overweight/Obese both.

[‡] significantly different between Healthy weight both and Healthy ES to Overweight/Obese HS.

[§] significantly different between Healthy weight both and Overweight/Obese ES to H HS.

[¶] significantly different between Overweight/Obese both and Healthy ES to Overweight/Obese HS.

Table 6
Longitudinal within student association of CVD risk with weight status from elementary (ES) to high school (HS) among females (N = 893) (percentage).

	Healthy Weight both ES and HS (N = 604)	Overweight/Obese both ES and HS (N = 131)	Healthy Weight ES HS (N = 113)	Overweight or Obese HS (N = 45)
TChol				
170–199				
ES	18.5 %* (112/604)	18.3 % (24/131)	25.7 % (29/113)	22.2 % (10/45)
HS	12.1 %* (73/604)	12.2 % (16/131)	18.6 % (21/113)	11.1 % (5/45)
TChol ≥200				
ES	7.0 %* (42/604)	7.6 % (10/131)	4.4 % (5/113)	6.7 % (3/45)
HS	4.0 %* (24/604)	6.9 % (9/131)	3.5 % (4/113)	2.2 % (1/45)
HDL < 40				
ES	15.6 % [†] (94/604)	35.1 % [‡] (46/131)	21.2 % (24/113)	28.9 % (13/45)
HS	18.2 % ^{†,‡} (110/604)	6	33.6 % [‡] (38/113)	20.0 % (9/45)
Sys BP ≥120				
ES	2.2 % (13/604)	4.6 %* (6/131)	1.8 %* (2/113)	2.2 % (1/45)
HS	4.1 % [‡] (25/604)	18.3 %* [‡] (24/131)	8.8 %* (10/113)	4.4 % (2/45)
Dia BP ≥80	4			
ES	3.1 % (19/604)	4.6 % (6/131)	3.5 % (4/113)	4.4 % (2/45)
HS	3.5 % (21/604)	8.4 % (11/131)	5.3 % (6/113)	0.0 % (0/45)

Healthy is defined as BMI Percentile ≥5 and <85th, Overweight is defined as ≥85th and <95th, Obese is defined as ≥95th.

* significantly different between ES and HS.
† significantly different between Healthy weight both and Overweight/Obese both.
‡ significantly different between Healthy weight both and Healthy ES to Overweight/Obese HS.

Table 7
Family reported overweight/obesity by categories of students BMI measured in elementary (ES) and high school (HS) (percentage).

	Healthy Weight both ES and HS (N = 856)	Overweight or Obese both ES and HS (N = 208)	Healthy Weight ES to Overweight Obese HS (N = 134)	Overweight Obese ES to Healthy Weight HS (N = 78)
Family Reported Overweight Obesity ES	26.5 % ^{‡,§} (227/856)	50.5 % ^{‡,¶} (105/208)	35.8 %* (48/134)	47.4 % [§] (37/78)
Family Reported Overweight Obesity HS	28.0 % ^{‡,§} (240/856)	56.7 % [‡] (118/208)	47.0 % [‡] (63/134)	48.7 % [§] (38/78)

Healthy (H) = BMI Percentile 5th-<85th, Overweight (Ov) = BMI Percentile 85th-<95th, Obese (Ob) = BMI Percentile ≥95th.
† significantly different between Healthy weight status at both and Overweight/Obese status at both.
‡ significantly different between Healthy weight status at both and Healthy ES status to Overweight/Obese HS status.
§ significantly different between Healthy weight status at both and Overweight ES to Healthy HS status.
¶ significantly different between Overweight status at both and Healthy ES to Overweight HS status.

healthy weight between elementary and high school (Tables 5 and 6). Given the ever-increasing levels of overweight/obesity among children and adolescents in the U.S. (~41.5 %) and the association between childhood CVD risk factors and adult CVD events, particularly BMI, [5, 23], there is a compelling need for aggressive screening for CVD risk and treatment of children with obesity. These corroborating studies further show duration of obesity status is associated with an increased percentage of CVD events at earlier ages, especially if obesity is present for over 10 years. [5,24,25] The family unit is an important influence in addressing overweight/obesity status among children/adolescents [26]. Self-reported levels of overweight and obesity among family members trended with student BMI at both elementary school and high school ages. Students within the healthy weight category in elementary and high school were less likely to have a family history of overweight/obesity (26.5 % and 28.0 %, respectively) than students within overweight categories in both elementary school and high school (family history 50.5 % and 56.7 %

respectively). Further, students who went from healthy to overweight categories had families who also saw ~11 % increase in family reported overweight/obesity status (Table 7). Children with overweight/obesity were also more likely to have families with cardiovascular risk factors including, diabetes, high cholesterol, high blood pressure, and smoking. Given the increases in these risk factors in recent years among young adults, the same age as many of these students' parents [11], it is expected these trends in CVD risk factors among youth will continue. The role that obesity plays in the development of CVD is unparalleled and will not be corrected without early intervention that includes peers, families [27–30], caregivers and communities. Family education, especially where the parents are committed to change, can be an effective catalyst in improving family health habits and reducing CVD risk factors. Early health education, lifestyle modification and risk factor reduction will help decrease CV risk [31].

6. Limitations/Strengths

The strength of this paper includes objective measures of CVD risk obtained over the last 10 years (2013–2023). The data is representative of the northern Colorado region due to high levels of student participation. The family risk factors were self-reported. Due to the study being conducted in a primarily white population (71.5 %), caution is advised in generalizing these results to specific ethnic or racial populations. Individual socioeconomic status was not provided by the families and should be considered in future studies. Male and female populations were fully represented. BMI calculations were utilized for determination of overweight/obesity status and did not account for those with elevated lean body weight. School-based screenings did not allow for the use of more accurate measures of body composition.

7. Conclusions

Increased cardiovascular risk factors were associated with elevated BMI starting as early as elementary school with similar trends seen in middle school and high school age youth. Additional longitudinal measures established that BMI status remains relatively steady overtime. Thus, early obesity intervention is necessary due to persistence of obesity once present. These findings corroborate several other studies as well as our previous work among elementary school-aged children. Given the continued increase in childhood overweight and obesity there is a need for aggressive screening of CVD risk and early treatment of obesity in

children. As suggested in our earlier work, these interventions need to be performed with consideration of the family as the family has much influence over the child. Further, using school-based programs allows access for all children and ensures preventive heart health education regardless of socioeconomic status.

CRedit authorship contribution statement

Austin M. Pollack: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Tracy L. Nelson:** Writing – review & editing, Methodology, Conceptualization. **NaNet A. Jenkins:** Resources, Project administration, Funding acquisition, Conceptualization. **Meghan W. Willis:** Writing – review & editing. **Paige C. Lueders:** Writing – review & editing, Visualization, Data curation. **Anna K. Kingman:** Writing – review & editing. **Landon D. Hamilton:** Writing – review & editing, Methodology, Formal analysis. **Gary J. Luckasen:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Gary J. Luckasen reports was provided by University of Colorado Health. Gary J. Luckasen reports a relationship with UCHHealth that includes: employment.

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Supplementary materials

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