

Child maltreatment and metabolic syndrome in midlife: a cohort study

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Abstract

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Background: Previous studies suggest associations between child maltreatment and individual adverse cardiovascular and metabolic diseases in adulthood. Less is known, however, about the relationship between child maltreatment and metabolic syndrome (MetS). This study examined the association between child maltreatment and MetS severity in midlife, and how age of child maltreatment initiation may influence this association.

Methods: This study used prospectively collected data from 725 individuals followed from age 10 to 47. Participants retrospectively reported experiences of child maltreatment at age 24 using the short-term Childhood Trauma Questionnaire. We examined child maltreatment exposure as a dichotomous variable (yes/no) and as a three-level categorical variable accounting for age at maltreatment initiation (no maltreatment, prior to age 10, between ages 10-17). Standardized z-scores were used to create a continuous MetS severity score based on individual components (HDL cholesterol, triglycerides, glycated hemoglobin, blood pressure, waist circumference) measured at age 47. In secondary analyses, we examined the association between forms of child maltreatment and MetS severity. We performed linear regression to obtain mean differences and 95% confidence intervals adjusted for sociodemographic characteristics.

Results: The prevalence of child maltreatment in the sample was 35.9%. There was little evidence for an association between child maltreatment and MetS score ($b = 0.044$; 95% CI: -0.27, 0.36). Although there was a different direction in associations depending on age of initiation, neither coefficient was statistically significant (b for initiation prior to age 10 = 0.10; 95% CI: -0.23, 0.44; b for initiation between ages 10-17 = -0.14; 95% CI: -0.81, 0.53). Emotional abuse was significantly associated with a higher MetS severity score ($b = 0.58$; 95% CI: 0.042, 1.11), and physical abuse was associated with a lower MetS severity score ($b = -0.52$; 95% CI: -1.02, -0.018).

Conclusion: While overall experience of child maltreatment was not associated with mid-adult MetS, specific forms of child maltreatment may have greater impacts on adult cardiometabolic health. Future longitudinal research into associations between forms of maltreatment and MetS, and potential mechanisms linking them, is warranted.

Introduction

Child maltreatment, encompassing experiences of physical, sexual, and emotional abuse and neglect that occurs before 18 years of age, has significant consequences for health and well-being across the life course.^{1,2} Experiences of abuse and neglect during sensitive periods of childhood and adolescence can disrupt normative developmental processes.¹ Studies consistently demonstrate an association between child maltreatment and elevated lifetime risk of chronic diseases, mental and behavioral health conditions, and early death.^{1,2}

A growing body of research has investigated the relationship between early life adversity and cardiovascular disease (CVD), the leading cause of morbidity and mortality among adults in the United States.^{2,3} A 2018 meta-analysis identified that cumulative childhood adversity, defined by the sum of different types of adverse experiences, is associated with nearly 1.5 fold higher odds of CVD in adulthood, including coronary heart disease, myocardial infarction, and stroke.³ Moreover, studies suggest that child maltreatment is associated with cardiometabolic risk factors strongly related to CVD, including obesity and hypertension.² However, these cardiometabolic risk factors are often examined independently, without considering co-occurrence that may more comprehensively capture cardiometabolic dysregulation.^{4,5}

Metabolic syndrome (MetS), characterized by a clustering of hypertension, hyperglycemia, elevated waist circumference, reduced high-density lipoprotein (HDL) cholesterol, and elevated triglycerides, is common precursor to cardiovascular morbidity and mortality.⁶ Emerging evidence suggests that the prevalence of MetS is rising, reflecting the enormous health risks among populations and burden on health care systems.^{5,6} Cross-sectional and longitudinal studies examining early life adversity and MetS in adulthood have yielded mixed results, with some suggesting an association between child maltreatment and composite cardiometabolic risk

indicators^{5,7,8} and others reporting null findings.^{4,9,10} strategies to reduce cardiovascular and metabolic disease progression and burden.

It is important to consider different characterizations of child maltreatment and their potential influences on cardiometabolic health. Past research has focused broadly on experiences of maltreatment at any age before 18. Childhood and adolescence are marked by distinct stages of neurobiological development,¹ and the timing of child maltreatment initiation may have differential impacts on cardiometabolic health.² For instance, previous studies have identified timing-specific effects of childhood adversity on cortisol levels,¹¹ cell-mediated immunity,¹² and mental health outcomes.^{13,14} Examining whether timing of child maltreatment initiation influences these associations may reveal sensitive periods where early life adversity confers greater susceptibility to poor cardiometabolic health in midlife. Further, previous studies suggest that some, but not all, forms of child abuse and neglect may be associated with MetS through potentially distinct biological and psychosocial mechanisms.^{8,15} The relationship between child maltreatment and cardiometabolic health may also differ by sex due to variations in physiological responses, coping mechanisms, and related behavioral impacts.^{2,8} Elucidating the relationship between different dimensions of child maltreatment and MetS could inform targeted prevention and early intervention strategies.

Using prospective data from a cohort of individuals followed from age 11 to 47, this study expands upon existing literature by examining the association between child maltreatment and MetS severity in midlife, and whether this association is dependent on the age of initiation of child maltreatment. As a secondary analysis, we examined associations between specific forms of child abuse and neglect and MetS severity in midlife. We reproduced analyses within cohort subsets stratified by sex to examine sex-specific associations.

Methods

Study design, setting, and participants

This study used data from the Seattle Social Development Project, a longitudinal study initiated in 1985 to assess health behaviors and outcomes across development. All students entering the 5th grade from 18 public schools in Seattle, Washington, were eligible for study enrollment. Of 1,053 eligible students, 808 (77%) students enrolled in the longitudinal study, with the consent of their parents or guardians. Participants consented to longitudinal follow-up upon turning 18. This study included study participants who were interviewed at the age 24 study wave and responded to the short-form Childhood Trauma Questionnaire. A total of 739 participants were interviewed at the age 24 study wave. After excluding participants who did not respond to at least one CTQ-SF subscale during the age 24 interview, our final analytic sample consisted of 725 participants. Informed consent was obtained for all study participants, and all study procedures were approved by the Human Subjects Review Committee at the University of Washington.

Data collection

Data were collected annually from modal ages 11 to 15, and nine additional assessments were conducted between ages 18 to 47. The current study integrated data derived from childhood (ages 11, 12, and 13) and adulthood (ages 24, 39, and 47) assessments. Participant surveys were conducted in classrooms at the childhood study waves. At the age 24 study wave, trained study staff conducted in-person interviews at participants' homes. All other adulthood assessments combined in-person interviews and either password-protected web-based surveys or telephone or paper surveys by request. A brief in-person health assessment occurred at the age 47 study wave to evaluate physical and cognitive health in midlife, including the collection of cardiometabolic biomarkers. HDL cholesterol, triglycerides, and glycated hemoglobin were assessed using point-of-care testing. Interviewers collected small non-fasting blood samples

using a sterile finger prick. HDL cholesterol and triglyceride levels were measured using Cardiochek® PA devices, while glycated hemoglobin was measured using A1CNow®+ devices. Systolic and diastolic blood pressure were measured twice using an upper arm cuff, with at least 45 seconds between measures. Waist circumference was measured with a measuring tape at the height of the navel, over light clothing.

Variable definition

Child maltreatment. Child maltreatment was assessed at the age 24 study wave using the short-form Childhood Trauma Questionnaire (CTQ-SF). The CTQ-SF is a validated 25-item questionnaire developed to retrospectively assess a range of maltreatment experiences before age 18.¹⁶ The CTQ-SF consists of five subscales for emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect, with five items each. Seven items on the neglect subscales are positively worded and reverse coded, such as “I felt that I was loved.” Items of the CTQ-SF are rated on a 5-point Likert scale based on frequency of exposure [1: Never true, 2: Rarely true, 3: Sometimes true, 4: Often true, 5: Always true]. For each experience endorsed, participants were asked whether the experience occurred before age 10. Scores above the recommended cut-points for “moderate to severe” on CTQ-SF subscales [emotional abuse ≥ 13 ; physical abuse ≥ 10 ; sexual abuse ≥ 8 ; emotional neglect ≥ 15 ; physical neglect ≥ 10] are considered cases of abuse or neglect.¹⁶

Consistent with the WHO definition of child maltreatment,¹⁷ for our primary aim, we created a dichotomous variable to assess exposure to child maltreatment before age 18, as indicated by a score above recommended CTQ-SF cut-points on any subscale [0: no, 1: yes]. For our second aim to better understand the role of timing of initiation of maltreatment, we created a variable with three categories: no maltreatment (reference group), child maltreatment initiation prior to age 10,

and child maltreatment initiation between ages 10-17. Participants who experienced multiple forms of abuse or neglect were categorized based on their earliest reported experience of child maltreatment. We excluded follow-up questions to positively worded indicators for child maltreatment when assessing timing, resulting in the removal of two items for physical neglect and all five items for emotional neglect.

We also defined exposure to individual and cumulative forms of child maltreatment for secondary analyses. For the individual exposure to specific types of child abuse and neglect, we used the cut-points for each subscale described above. For each type of child maltreatment, participants who did not score above the recommended cut-points on the respective subscale were the reference group. To capture cumulative exposure to maltreatment before age 18, we created a three-level categorical variable based on the number of maltreatment forms experienced [0: no maltreatment, 1: one form of maltreatment, 2: two or more forms of maltreatment].

Metabolic syndrome. According to the National Cholesterol Education Program Adult Treatment Panel III clinical criteria, MetS is diagnosed in the presence of at least three of the following cardiometabolic risk indicators: reduced HDL cholesterol, elevated triglycerides, elevated fasting glucose, elevated blood pressure, and elevated waist circumference.¹⁸ Increasing evidence supports the use of a continuous score to represent the clustering of MetS components, providing greater sensitivity and statistical power compared to the dichotomous clinical MetS diagnosis.¹⁹ Prior to calculating the continuous MetS severity score, we removed biomarker values that were three standard deviations from the mean for each MetS component [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (in)]. For the severity score, similar to other approaches,¹⁹ we standardized as z-scores individual MetS components by sex, race, and ethnicity due to differences in biomedical

characteristics observed at the population-level.²⁰ Due to small sample sizes, we collapsed Multiracial, Native American, and Hispanic participants into a single racial and ethnic category. We multiplied z-scores for HDL cholesterol by -1 to account for its inverse relationship with metabolic risk. We summed the standardized individual MetS components to create the continuous MetS score, with higher values indicating greater degrees of cardiometabolic dysregulation.

Covariates. We selected the following potential confounders *a priori* based on previous studies relating them to both child maltreatment and MetS severity: sex assigned at birth [0: female, 1: male], race and ethnicity [Asian non-Hispanic [NH] (reference), Black NH, Multiracial NH, Native American NH, white NH, Hispanic], highest level of education completed by a parent or guardian [high school or less, some college or other trade or vocational program, 4-year college or higher], and eligibility for free or reduced-price school lunch in 5th grade [0: no, 1: yes] as a proxy for childhood household socioeconomic status. We included race as a proxy for racism, which may be associated with child maltreatment disclosure and MetS severity through perceived stigma,²¹ chronic stress,²² and interpersonal and institutional discrimination.^{21,22} We used parent reports and school records from the age 11, 12, and 13 study waves to ascertain highest parental educational attainment and eligibility for free or reduced-priced school lunch. We used multiple self-reports over six survey waves to determine sex assigned at birth, race, and ethnicity.

Data analysis

We conducted descriptive statistics to examine the distribution of child maltreatment, MetS severity and MetS components, and the covariates. We reported means and standard deviations for continuous variables and counts and proportions for categorical variables.

We used multiple linear regression to examine the relationship between child maltreatment and MetS severity in midlife for our primary aims. We calculated unadjusted and adjusted mean difference estimates with 95% confidence intervals for the continuous MetS severity score, using the dichotomous child maltreatment exposure variable for the first aim and three-level categorical child maltreatment exposure variable (accounting for timing of child maltreatment exposure) for the second aim. Adjusted models controlled for sex, race and ethnicity, highest parental educational attainment, and eligibility for free or reduced lunch.

For our secondary analyses, we examined associations between individual and cumulative forms of maltreatment and MetS severity. We fit multiple linear regression models to obtain unadjusted and adjusted mean difference estimates with 95% confidence intervals for the continuous MetS severity score, using the dichotomous variables for individual maltreatment types (emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect) and the three-level cumulative maltreatment exposure variable. Furthermore, we examined the associations between any child maltreatment and each of the standardized individual MetS components [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (in)]. Finally, we reproduced analyses separately for male and female participants to qualitatively assess variation in results by sex.

We performed multiple imputation by chained equations (MICE) to reduce potential bias from missing outcome and covariate data under a missing-at-random assumption. The proportion of missing covariate values ranged from 1.7% to 4.0%, and the proportion of missing age 47 outcome values ranged from 41.4% to 54.5%. We included all analytic variables, as well as relevant family history and physical health measures as auxiliary variables, in the imputation

model. We imputed 30 datasets over 50 iterations for the full analytic sample and subsets of female and male participants. We ran regression models within each of the imputed datasets and pooled model results using Rubin's rules to account for within- and between-imputation uncertainty.²³

We defined statistical significance at an alpha level of 0.05. We performed all analyses in R version 4.2.2, using the "mice" package for multiple imputation.

Results

The study population was balanced by sex (50.2% female), and 39.4% of participants were eligible for free or reduced lunch. A relatively high proportion of participants had minoritized racial and ethnic identities (20.6% Asian, 19.9% Black, 8.7% Multiracial, 2.9% Native American, 4.8% Hispanic). The prevalence of child maltreatment in the study population was 35.9% (n = 260) (**Table 1**). Among participants who experienced child maltreatment, 81.2% first experienced abuse or neglect before the age of 10 (**Supplementary Table 2**). Sexual abuse was the most frequently reported form of child maltreatment (n = 47; 18.1%), followed by physical abuse (n = 27; 10.4%) and emotional abuse (n = 23; 8.8%). Nearly half (47.7%) of participants who experienced child maltreatment reported multiple forms of maltreatment (**Supplementary Figure 1**). The most common patterns were experiencing emotional abuse, physical abuse, emotional neglect, and physical neglect (n = 13) and experiencing all previously listed forms, including sexual abuse (n = 13).

Overall, participants who experienced child maltreatment were more likely to be female, Multiracial, and eligible for free or reduced lunch, as compared to participants who did not experience child maltreatment (**Table 1**). Participants who first experienced child maltreatment between ages 10 and 17 were more likely to be male, Asian, and have a parent or guardian with 4-years of college or higher, relative to participants who first experienced maltreatment before age 10 and participants who did not experience child maltreatment (**Supplementary Table 2**). Furthermore, participants who first experienced child maltreatment between ages 10 and 17 were less likely to be eligible for free or reduced lunch than participants who first experienced child maltreatment before age 10.

The mean MetS severity score was -0.05 (SD = 2.88) among participants who did not experience child maltreatment and 0.09 (SD = 3.02) among participants who experienced child maltreatment (p-value = 0.530). Before or after adjusting for covariates, there was no evidence for an association between any child maltreatment and MetS severity score in this cohort (**Table 2**; adjusted mean difference [AMD] = 0.044; 95% CI: -0.27, 0.36).

The mean MetS severity score among participants who first experienced maltreatment before age 10 was 0.17 (SD = 3.02), while it was -0.37 (SD = 2.95) among participants who first experienced maltreatment between ages 10 and 17. The estimate for MetS severity score comparing the group with no experience of child maltreatment to the group first experiencing maltreatment before the age of 10 was positive (**Table 3**; AMD = 0.10; 95% CI: -0.23, 0.44) while a similar comparison with the group first experiencing maltreatment between ages 10 and 17 was negative (**Table 3**; AMD = -0.14; 95% CI: -0.81, 0.53). Associations accounting for age of child maltreatment initiation were not statistically significant.

Consistent with our primary analyses, secondary analyses examining associations by individual standardized MetS components and by cumulative experiences of child maltreatment yielded small and non-statistically significant effect sizes (**Tables 4 and 5**). However, certain forms of maltreatment were significantly associated with MetS severity (**Table 6**). Compared to participants who did not experience emotional abuse, participants who experienced emotional abuse had a 0.58 higher MetS severity score after adjusting for confounders and other forms of maltreatment (AMD = 0.58; 95% CI: 0.04, 1.11). Experiencing physical abuse was associated with a 0.52 lower MetS severity score after adjusting for confounders and other forms of maltreatment (AMD = -0.52; 95% CI: -1.02, -0.02). Experiencing sexual abuse was associated with a 0.46 higher MetS severity score after adjusting for other forms of maltreatment (AMD = 0.46; 95% CI: 0.02, 0.90),

but this association was no longer statistically significant after further adjusting for confounders (AMD = 0.44; 95% CI: -0.02, 0.89).

When examining cohort subsets stratified by sex, there was no evidence of a significant association between any maltreatment and MetS severity score among female and male participants (AMD in females = 0.10; 95% CI: -0.37, 0.58; AMD in males = 0.20; 95% CI: -0.52, 0.92) (**Supplementary Tables 3 and 4**). The association between emotional abuse and MetS severity was statistically significant among female participants, but not male participants (AMD in females = 0.80; 95% CI: 0.001, 1.60; AMD in males = -0.07; 95% CI: -0.47, 0.32) (**Supplementary Tables 5 and 6**). Conversely, there was a stronger and statistically significant association between sexual abuse and MetS severity among male participants, but not female participants (AMD in females = 0.22; 95% CI: -0.39, 0.83; AMD in males = 0.78; 95% CI: 0.02, 1.55).

Discussion

This study found limited evidence supporting an association of child maltreatment, as well as timing of initiation of child maltreatment, with MetS severity in midlife. However, secondary analyses suggested that between specific forms of maltreatment may have complex relationships with MetS severity, and these relationships may differ by sex. Emotional abuse was associated with a 0.58 higher MetS severity score, while physical abuse was associated with a 0.52 lower MetS severity score in this cohort. In sex-stratified analyses, emotional abuse was significantly associated with a higher MetS severity score among female participants, while sexual abuse was significantly associated with a higher MetS severity score among male participants.

We did not observe an association between a broad categorization of child maltreatment and MetS severity in midlife, a finding that aligns with much of the extant literature.^{9,10,15} For example, Li et al. did not observe a relationship between the number of maltreatment forms experienced and MetS at mid-adulthood in a British birth cohort.⁹ Null results were also reported in a study of child maltreatment and MetS diagnosis in a large multiethnic cohort in Western Europe.¹⁰ In contrast, Lee et al. found that a measure of cumulative abuse was associated with a marginally higher number of MetS symptoms when controlling for sociodemographic characteristics in U.S. men and women (b in females = 0.06, p-value < 0.05; b in males = 0.10; p-value < 0.01).⁸ Unlike studies that operationalized child maltreatment as a dichotomous or count variable, Lee et al. accounted for both co-occurrence and severity of emotional, physical, and sexual abuse in their cumulative abuse measure, which may contribute to their statistically significant findings. The current study extends this literature by using prospectively collected data to control for multiple measures of childhood socioeconomic status, a key confounder in the relationship between child maltreatment and MetS. This study operationalized MetS using a continuous severity score, improving statistical precision and better capturing the influence of individual MetS components on cardiometabolic health when compared to a dichotomous MetS diagnosis.¹⁹

To the best of our knowledge, this is the first study to examine the influence of age of child maltreatment initiation on the association between child maltreatment and MetS. Although there was a different direction in associations depending on age of child maltreatment initiation, neither coefficient was large nor statistically significant. Notably, a limited number of participants first experienced maltreatment between ages 10 and 17, suggesting that study power may play a role in the different direction in associations. Our finding that age of child maltreatment did not substantively impact MetS severity in midlife is in line with findings from emerging studies of the timing of child adversities and cardiometabolic health in adulthood.^{24,25} Several methodological

considerations may explain our limited evidence for timing-specific effects of abuse on MetS. We measured timing of maltreatment initiation at broad periods of childhood and adolescence, which may not adequately capture sensitive periods for cardiometabolic health.^{24,26} Moreover, we did not account for the chronicity of child maltreatment, which may play an important role in shaping cardiometabolic outcomes in adulthood.^{2,24} Future research investigating the roles of initial and repeated exposure to maltreatment across narrower life course stages on MetS is warranted.

Our secondary analyses indicated that emotional abuse was significantly associated with a higher MetS severity score, while physical abuse was significantly associated with a lower MetS severity score in this cohort. Previous studies have observed associations between specific forms of maltreatment and MetS. Notably, Midei et al. did not find evidence of a relationship between any experience of abuse and MetS at baseline in a cohort of midlife women; however, in contrast with our findings, physical abuse was associated with an increased risk for MetS incidence over seven years of follow-up.¹⁵ Lee et al. also identified that emotional and physical abuse were significantly associated with an elevated number of MetS symptoms and higher odds of MetS diagnosis in U.S. men and women, with greater effect sizes compared to their measure of cumulative abuse.⁸

The observed association between emotional abuse and higher MetS severity may be explained through mechanisms related to mental health. Previous studies suggest that emotional abuse specifically is associated with greater incidence and severity of adult psychopathology,^{27,28} an established risk factor for poor cardiometabolic health.² Emotional abuse may impair social and cognitive development and emotional regulation, inducing or exacerbating mental health conditions.^{2,27} Mental health may contribute to the development of MetS by directly impacting biological regulatory systems and influencing lifestyle factors associated with cardiometabolic health.² Unexpectedly, we also found that physical abuse was associated with lower MetS

severity, contradicting prior evidence that physical abuse ^{8,15,24} and harsh physical punishment ²⁹ increase risk for poor cardiometabolic outcomes. These findings highlight the need for future longitudinal research with greater statistical power to explore associations and mediators between forms of maltreatment and MetS. Taken together, our findings suggest that specific forms of maltreatment may have particularly salient impacts on cardiometabolic health in midlife.

Furthermore, although there was no evidence of significant associations between any maltreatment and MetS severity within subsets of female or male participants, the association between certain forms of maltreatment and MetS severity appeared to differ by sex. The adverse effects of emotional abuse on cardiometabolic health were more pronounced among female participants, while the adverse effects of sexual abuse on cardiometabolic health were more pronounced among male participants. These findings are suggestive of unique health impacts of emotional and sexual abuse on girls and boys, which may support child maltreatment prevention and intervention strategies mindful of potential sex differences.

A key limitation of this study is potential misclassification of the exposure and outcome. Participants retrospectively reported child maltreatment at age 24, and these self-reports may be affected by memory, current emotional states, and reporting bias.³⁰ Furthermore, we were unable to adjust for antihypertensive use, resulting in potentially biased systolic blood pressure measures that may not fully capture underlying cardiometabolic risk. Some cardiometabolic indicators were assessed from non-fasting blood samples. Non-fasting blood samples may not be appropriate for clinical assessment of MetS due to differences in biomarker values, such as lower triglyceride levels.⁹ However, research suggests that non-fasting and fasting lipid profiles are comparable in CVD prediction.³¹ For our imputation model, we assumed that systematic differences in missing outcome were fully accounted for by measured covariates, and we are unable to empirically

determine missing-at-random from missing-not-at-random. This study also had a relatively small sample size and may not be adequately powered to detect modest associations, particularly when examining less prevalent maltreatment exposures, associations among participants who first experienced maltreatment between ages 10 and 17, and sex-stratified associations. The generalizability of our findings may be limited by study eligibility criteria and the use of z-score standardization for MetS variables. The study sample originated from lower-income neighborhoods in Seattle, Washington, and sample-standardized MetS outcomes may not reflect the distribution of cardiometabolic health indicators in the general adult population.

In conclusion, this study did not find evidence of an association between a broad categorization of child maltreatment and MetS severity in midlife, independently and when accounting for age of maltreatment initiation. Findings from secondary analyses suggest that emotional and physical abuse, in particular, may influence cardiometabolic health in mid-adulthood. This study highlights the importance of screening for specific forms of abuse and neglect as an opportunity for public health professionals, social workers, and clinicians to intervene on the adverse cardiovascular and metabolic health impacts of child maltreatment. Findings lend support for future longitudinal studies that explore potential mediating pathways between specific forms of maltreatment and MetS to uncover mechanisms and inform prevention and intervention strategies.

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Tables and Figures

Table 1. Selected characteristics of study sample by experience of child maltreatment.

Characteristic	Experience of child maltreatment*		Overall N = 725 n (%)
	No n = 465 n (%)	Yes n = 260 n (%)	
Sex			
Female	224 (48.2)	140 (53.8)	364 (50.2)
Male	241 (51.8)	120 (46.2)	361 (49.8)
Race and ethnicity			
Asian, Non-Hispanic	97 (20.9)	52 (20.0)	149 (20.6)
Black, Non-Hispanic	90 (19.4)	54 (20.8)	144 (19.9)
Multiracial, Non-Hispanic	31 (6.7)	32 (12.3)	63 (8.7)
Native American, Non-Hispanic	9 (1.9)	12 (4.6)	21 (2.9)
White, Non-Hispanic	216 (46.5)	97 (37.3)	313 (43.2)
Hispanic	22 (4.7)	13 (5.0)	35 (4.8)
Eligibility for free or reduced lunch			
Eligible	149 (33.1)	125 (50.8)	274 (39.4)
Not eligible	301 (66.9)	121 (49.2)	422 (60.6)
Missing	15	14	29
Highest parental educational attainment			
High school or less	143 (31.3)	90 (35.2)	233 (32.7)
Some college or vocational school	142 (31.1)	87 (34.0)	229 (32.1)
4-year college or higher	172 (37.6)	79 (30.9)	251 (35.2)
Missing	8	4	12

*Experience of child maltreatment defined by scoring above the recommended cut-points for “moderate to severe” for at least one subscale on the short-form Childhood Trauma Questionnaire [emotional abuse ≥ 13 ; physical abuse ≥ 10 ; sexual abuse ≥ 8 ; emotional neglect ≥ 15 ; physical neglect ≥ 10]

Table 2. Unadjusted and adjusted mean differences in continuous metabolic syndrome severity score* by exposure to child maltreatment.

Experience of child maltreatment†	No.	Unadjusted mean difference	95% CI	p-value	Adjusted mean difference‡	95% CI	p-value
No maltreatment	465	Reference			Reference		
Any maltreatment	260	0.098	-0.21, 0.40	0.530	0.044	-0.27, 0.36	0.779

*Continuous metabolic syndrome score calculated using individual metabolic syndrome components [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (in)] standardized by sex and race and ethnicity. Higher values indicate greater degrees of cardiometabolic dysregulation.

†Experience of child maltreatment defined by scoring above the recommended cut-points for “moderate to severe” for at least one subscale on the short-form Childhood Trauma Questionnaire [emotional abuse ≥ 13 ; physical abuse ≥ 10 ; sexual abuse ≥ 8 ; emotional neglect ≥ 15 ; physical neglect ≥ 10]

‡Model adjusted for sex, race and ethnicity, eligibility for free or reduced lunch program, and highest level of education completed by a parent or guardian.

Table 3. Unadjusted and adjusted mean differences in continuous metabolic syndrome severity score* by timing of child maltreatment initiation.

Timing of child maltreatment†	No.	Unadjusted mean difference	95% CI	p-value	Adjusted mean difference‡	95% CI	p-value
No maltreatment	465	Reference			Reference		
Maltreatment initiation prior to age 10	211	0.18	-0.15, 0.51	0.283	0.10	-0.23, 0.44	0.541
Maltreatment initiation between ages 10-17	38	-0.23	-0.89, 0.44	0.496	-0.14	-0.81, 0.53	0.691

*Continuous metabolic syndrome score calculated using individual metabolic syndrome components [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (in)] standardized by sex and race and ethnicity. Higher values indicate greater degrees of cardiometabolic dysregulation.

†Timing of child maltreatment defined based on responses to the follow-up question “Did this happen before you were 10 years old?” for participants who endorsed experiences of emotional abuse, physical abuse, sexual abuse, and physical neglect. Participants were categorized based on their earliest experience of child maltreatment.

‡Model adjusted for sex, race and ethnicity, eligibility for free or reduced lunch program, and highest level of education completed by a parent or guardian.

Table 4. Unadjusted and adjusted mean differences in standardized metabolic syndrome components* by exposure to child maltreatment.†

Standardized metabolic syndrome component	Unadjusted mean difference	95% CI	p-value	Adjusted mean difference‡	95% CI	p-value
Systolic blood pressure (mmHg)	-0.067	-0.26, 0.13	0.497	-0.11	-0.30, 0.086	0.271
Waist circumference (in)	0.18	-0.0051, 0.36	0.057	0.15	-0.042, 0.33	0.128
HDL cholesterol (mmol/L)	-0.064	-0.29, 0.16	0.573	-0.025	-0.26, 0.21	0.833
Triglycerides (mmol/L)	-0.094	-0.33, 0.14	0.423	-0.072	-0.31, 0.17	0.549
Glycated hemoglobin (mmol/L)	0.068	-0.14, 0.27	0.509	0.079	-0.14, 0.29	0.470

*Individual metabolic syndrome components are standardized by sex and race and ethnicity.

†Estimates compare participants who met criteria for experiencing child maltreatment to those who did not meet criteria for experiencing child maltreatment based on the short-form Childhood Trauma Questionnaire.

‡Model adjusted for sex, race and ethnicity, eligibility for free or reduced lunch program, and highest level of education completed by a parent or guardian.

Table 5. Unadjusted and adjusted mean differences in continuous metabolic syndrome severity score* by cumulative maltreatment forms experienced.

Cumulative maltreatment forms†	No.	Unadjusted mean difference	95% CI	p-value	Adjusted mean difference‡	95% CI	p-value
No maltreatment	465	Reference			Reference		
One form of maltreatment	136	0.047	-0.34, 0.43	0.811	0.028	-0.36, 0.41	0.886
Multiple forms of maltreatment	124	0.15	-0.25, 0.55	0.449	0.063	-0.35, 0.47	0.761

*Continuous metabolic syndrome score calculated using individual metabolic syndrome components [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (in)] standardized by sex and race and ethnicity. Higher values indicate greater degrees of cardiometabolic dysregulation.

†Experience of child maltreatment defined by scoring above the recommended cut-points for “moderate to severe” on subscales on the short-form Childhood Trauma Questionnaire [emotional abuse ≥ 13 ; physical abuse ≥ 10 ; sexual abuse ≥ 8 ; emotional neglect ≥ 15 ; physical neglect ≥ 10]. Participants who scored above the recommended cut-points for “moderate to severe” on at least two subscales were categorized as having experienced multiple forms of maltreatment.

‡Model adjusted for sex, race and ethnicity, eligibility for free or reduced lunch program, and highest level of education completed by a parent or guardian.

Table 6. Unadjusted and adjusted mean differences in continuous metabolic syndrome severity score* by forms of child abuse and neglect.

Experience of child maltreatment†	No.	Unadjusted model			Adjusted model‡			Fully adjusted model§		
		Mean difference	95% CI	p-value	Mean difference	95% CI	p-value	Mean difference	95% CI	p-value
Emotional abuse	105	0.46	0.047, 0.88	0.029	0.61	0.074, 1.14	0.026	0.58	0.042, 1.11	0.035
Physical abuse	107	-0.22	-0.63, 0.20	0.309	-0.52	-1.01, -0.025	0.039	-0.52	-1.02, -0.018	0.043
Sexual abuse	116	0.45	0.044, 0.85	0.030	0.46	0.023, 0.90	0.039	0.44	-0.016, 0.89	0.059
Emotional neglect	100	0.28	-0.14, 0.71	0.193	0.26	-0.27, 0.80	0.331	0.28	-0.25, 0.81	0.305
Physical neglect	92	-0.41	-0.48, 0.40	0.855	-0.42	-0.96, 0.14	0.143	-0.51	-1.07, 0.048	0.073

*Continuous metabolic syndrome score calculated using individual metabolic syndrome components [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (in)] standardized by sex and race and ethnicity. Higher values indicate greater degrees of cardiometabolic dysregulation.

†Experience of child maltreatment defined by scoring above the recommended cut-points for “moderate to severe” on subscales on the short-form Childhood Trauma Questionnaire [emotional abuse ≥ 13 ; physical abuse ≥ 10 ; sexual abuse ≥ 8 ; emotional neglect ≥ 15 ; physical neglect ≥ 10]. For each form of child maltreatment, participants that did not score above the recommended cut-points on the respective subscale are the reference group. Categories are not mutually exclusive.

‡Model adjusted for all other forms of child maltreatment.

§Model adjusted for all other forms of child maltreatment, sex, race and ethnicity, eligibility for free or reduced lunch program, and highest level of education completed by a parent or guardian.

Supplemental Materials

Supplementary Table 1. Prevalence of child maltreatment indicators across short-form Childhood Trauma Questionnaire subscales.

Child maltreatment indicator	n (%)
Emotional abuse	
People in my family called me things like "stupid" or "lazy" or "ugly".	
Never true	362 (50.3)
Rarely true	158 (21.9)
Sometimes true	144 (20.0)
Often true	44 (6.1)
Always true	12 (1.7)
I thought that my parents wished I had never been born.	
Never true	609 (85.4)
Rarely true	46 (6.5)
Sometimes true	41 (5.8)
Often true	12 (1.7)
Always true	5 (0.7)
People in my family said hurtful or insulting things to me.	
Never true	372 (52.0)
Rarely true	158 (22.1)
Sometimes true	131 (18.3)
Often true	43 (6.0)
Always true	11 (1.5)
I felt that someone in my family hated me.	
Never true	529 (73.9)
Rarely true	72 (10.1)
Sometimes true	66 (9.2)
Often true	28 (3.9)
Always true	21 (2.9)
I believe that I was emotionally abused.	
Never true	498 (69.7)
Rarely true	69 (9.7)
Sometimes true	82 (11.5)
Often true	41 (5.7)
Always true	25 (3.5)
Physical abuse	
I got hit so hard by someone in my family that I had to see a doctor or go to the hospital.	
Never true	655 (92.3)
Rarely true	28 (3.9)
Sometimes true	15 (2.1)
Often true	8 (1.1)

Always true	4 (0.6)
People in my family hit me so hard that it left me with bruises or marks.	
Never true	547 (76.8)
Rarely true	80 (11.2)
Sometimes true	58 (8.1)
Often true	21 (2.9)
Always true	6 (0.8)
I was punished with a belt, a board, a cord, or some other hard object.	
Never true	330 (46.2)
Rarely true	126 (17.6)
Sometimes true	164 (22.9)
Often true	63 (8.8)
Always true	32 (4.5)
I got hit or beaten so badly that it was noticed by someone like a teacher, neighbor, or doctor.	
Never true	662 (92.7)
Rarely true	24 (3.4)
Sometimes true	17 (2.4)
Often true	4 (0.6)
Always true	7 (1.0)
I believe that I was physically abused.	
Never true	599 (84.0)
Rarely true	36 (5.0)
Sometimes true	41 (5.8)
Often true	17 (2.4)
Always true	20 (2.8)
Sexual abuse	
Someone tried to touch me in a sexual way, or tried to make me touch them.	
Never true	578 (81.8)
Rarely true	54 (7.6)
Sometimes true	43 (6.1)
Often true	22 (3.1)
Always true	10 (1.4)
Someone threatened to hurt me or tell lies about me unless I did something sexual with them.	
Never true	661 (93.2)
Rarely true	18 (2.5)
Sometimes true	17 (2.4)
Often true	12 (1.7)
Always true	1 (0.1)
Someone tried to make me do sexual things or watch sexual things.	
Never true	604 (85.7)
Rarely true	41 (5.8)

Sometimes true	40 (5.7)
Often true	17 (2.4)
Always true	3 (0.4)
Someone molested me.	
Never true	589 (83.8)
Rarely true	46 (6.5)
Sometimes true	27 (3.8)
Often true	10 (1.4)
Always true	31 (4.4)
I believe that I was sexually abused.	
Never true	600 (85.1)
Rarely true	34 (4.8)
Sometimes true	22 (3.1)
Often true	11 (1.6)
Always true	38 (5.4)
Emotional neglect	
There was someone in my family who helped me feel that I was important or special.	
Never true	28 (3.9)
Rarely true	23 (3.2)
Sometimes true	112 (15.6)
Often true	212 (29.6)
Always true	342 (47.7)
I felt that I was loved.	
Never true	7 (1.0)
Rarely true	20 (2.8)
Sometimes true	80 (11.2)
Often true	147 (20.5)
Always true	463 (64.6)
People in my family looked out for one another.	
Never true	25 (3.5)
Rarely true	36 (5.0)
Sometimes true	98 (13.7)
Often true	225 (31.4)
Always true	333 (46.4)
People in my family felt close to each other.	
Never true	29 (4.0)
Rarely true	55 (7.6)
Sometimes true	154 (21.4)
Often true	262 (36.4)
Always true	220 (30.6)
My family was a source of strength and support.	

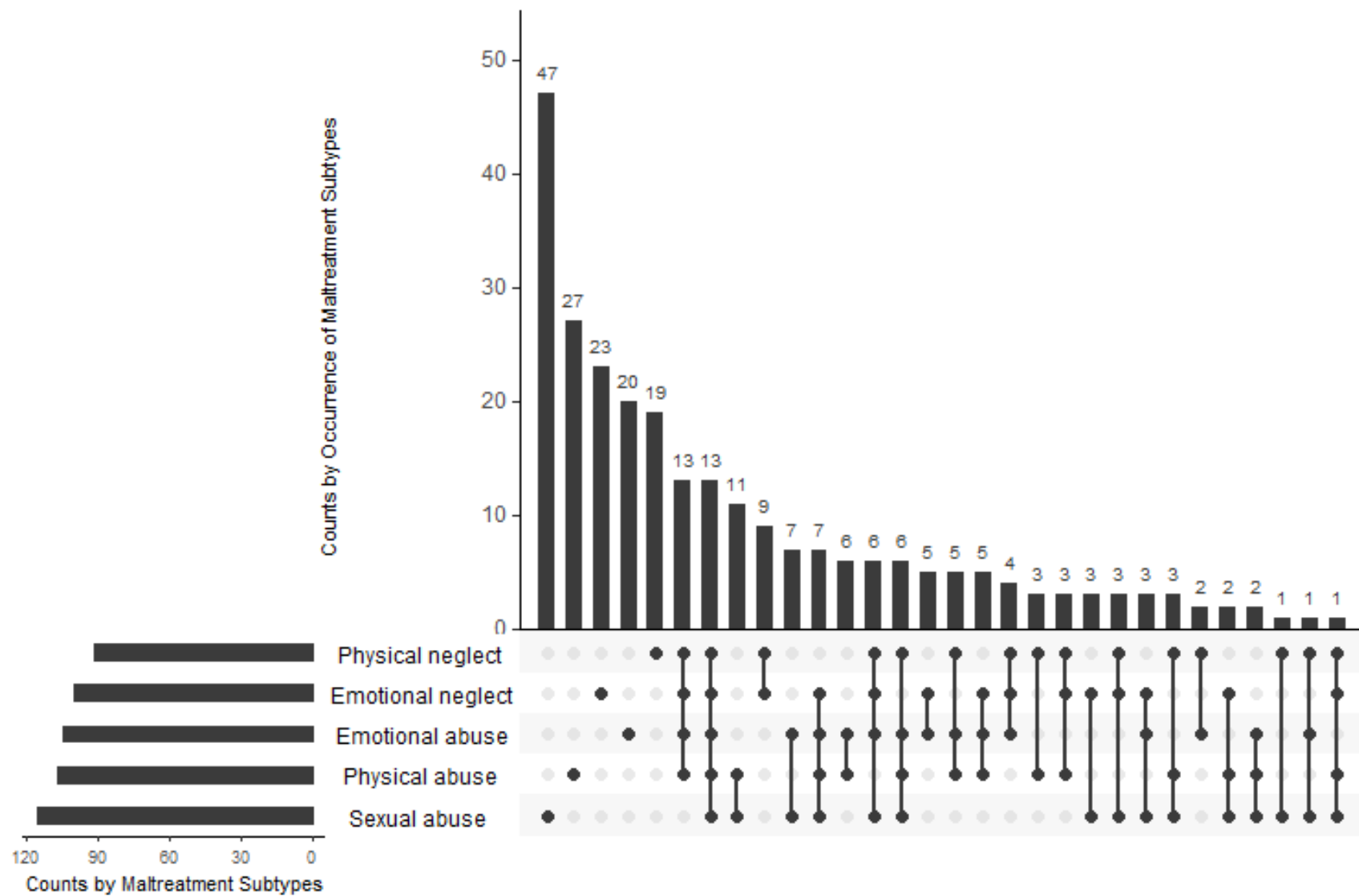
Never true	42 (5.8)
Rarely true	67 (9.3)
Sometimes true	137 (19.0)
Often true	200 (27.7)
Always true	275 (38.1)
Physical neglect	
I didn't have enough to eat.	
Never true	617 (86.7)
Rarely true	42 (5.9)
Sometimes true	39 (5.5)
Often true	9 (1.3)
Always true	5 (0.7)
I knew that there was someone to take care of me and protect me.	
Never true	14 (1.9)
Rarely true	29 (4.0)
Sometimes true	47 (6.5)
Often true	118 (16.4)
Always true	511 (71.1)
My parents were too drunk or high to take care of the family.	
Never true	616 (86.5)
Rarely true	41 (5.8)
Sometimes true	30 (4.2)
Often true	13 (1.8)
Always true	12 (1.7)
I had to wear dirty clothes.	
Never true	619 (86.7)
Rarely true	47 (6.6)
Sometimes true	36 (5.0)
Often true	5 (0.7)
Always true	7 (1.0)
There was someone to take me to the doctor if I needed it.	
Never true	8 (1.1)
Rarely true	12 (1.7)
Sometimes true	29 (4.0)
Often true	99 (13.8)
Always true	570 (79.4)

Supplementary Table 2. Selected characteristics of study sample by age of child maltreatment initiation.

Characteristic	Age of child maltreatment initiation*			Overall N = 714 n (%)
	No n = 465 n (%)	Before age 10 n = 211 n (%)	Between ages 10-17 n = 31 n (%)	
Sex				
Female	224 (48.2)	121 (57.3)	17 (44.7)	362 (50.7)
Male	241 (51.8)	90 (42.7)	21 (55.3)	352 (49.3)
Race and ethnicity				
Asian, Non-Hispanic	97 (20.9)	37 (17.5)	11 (28.9)	145 (20.3)
Black, Non-Hispanic	90 (19.4)	43 (20.4)	7 (18.4)	140 (19.6)
Multiracial, Non-Hispanic	31 (6.7)	31 (14.7)	1 (2.6)	63 (8.8)
Native American, Non-Hispanic	9 (1.9)	9 (4.3)	2 (5.3)	20 (2.8)
White, Non-Hispanic	216 (46.5)	83 (39.3)	14 (36.8)	313 (43.8)
Hispanic	22 (4.7)	8 (3.8)	3 (7.9)	33 (4.6)
Eligibility for free or reduced lunch				
Eligible	149 (33.1)	103 (52.0)	14 (37.8)	266 (38.8)
Not eligible	301 (66.9)	95 (48.0)	23 (62.2)	419 (61.2)
Missing	15	13	1	29
Highest parental educational attainment				
High school or less	143 (31.3)	74 (35.6)	9 (24.3)	226 (32.2)
Some college or vocational school	142 (31.1)	75 (36.1)	10 (27.0)	227 (32.3)
4-year college or higher	172 (37.6)	59 (28.4)	18 (48.6)	249 (35.5)
Missing	8	3	1	12

*Timing of child maltreatment defined based on responses to the follow-up question "Did this happen before you were 10 years old?" for participants who endorsed experiences of emotional abuse, physical abuse, sexual abuse, and physical neglect. Participants were categorized based on their earliest experience of child maltreatment.

Supplementary Figure 1. Patterns of maltreatment occurrence.



Supplementary Table 3. Unadjusted and adjusted mean differences in continuous metabolic syndrome severity score* by exposure to child maltreatment among female participants (n = 364).

Experience of child maltreatment†	No.	Unadjusted mean difference	95% CI	p-value	Adjusted mean difference‡	95% CI	p-value
No maltreatment	224	Reference			Reference		
Any maltreatment	140	0.23	-0.24, 0.70	0.345	0.10	-0.37, 0.58	0.667

*Continuous metabolic syndrome score calculated using individual metabolic syndrome components [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (in)] standardized by race and ethnicity. Higher values indicate greater degrees of cardiometabolic dysregulation.

†Experience of child maltreatment defined by scoring above the recommended cut-points for “moderate to severe” for at least one subscale on the short-form Childhood Trauma Questionnaire [emotional neglect ≥ 15 ; emotional abuse ≥ 13 ; physical neglect ≥ 10 ; physical abuse ≥ 10 ; sexual abuse ≥ 8]

‡Model adjusted for race and ethnicity, eligibility for free or reduced lunch program, and highest level of education completed by a parent or guardian.

Supplementary Table 4. Unadjusted and adjusted mean differences in continuous metabolic syndrome severity score* by exposure to child maltreatment among male participants (n = 361).

Experience of child maltreatment†	No.	Unadjusted mean difference	95% CI	p-value	Adjusted mean difference‡	95% CI	p-value
No maltreatment	241	Reference			Reference		
Any maltreatment	120	-0.079	-0.47, 0.31	0.688	-0.073	-0.47, 0.32	0.716

*Continuous metabolic syndrome score calculated using individual metabolic syndrome components [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (in)] standardized by race and ethnicity. Higher values indicate greater degrees of cardiometabolic dysregulation.

†Experience of child maltreatment defined by scoring above the recommended cut-points for “moderate to severe” for at least one subscale on the short-form Childhood Trauma Questionnaire [emotional neglect ≥ 15 ; emotional abuse ≥ 13 ; physical neglect ≥ 10 ; physical abuse ≥ 10 ; sexual abuse ≥ 8]

‡Model adjusted for race and ethnicity, eligibility for free or reduced lunch program, and highest level of education completed by a parent or guardian.

Supplementary Table 5. Unadjusted and adjusted mean differences in continuous metabolic syndrome* severity score by forms of child abuse and neglect among female participants (n = 364).

Form of child maltreatment†	No.	Unadjusted model			Adjusted model†			Fully adjusted model§		
		Mean difference	95% CI	p-value	Mean difference	95% CI	p-value	Mean difference	95% CI	p-value
Emotional abuse	64	0.63	0.026, 1.23	0.041	0.89	0.095, 1.68	0.028	0.80	0.0010, 1.60	0.050
Physical abuse	50	-0.54	-0.72, 0.61	0.875	-0.54	-1.40, 0.33	0.222	-0.42	-1.30, 0.45	0.341
Sexual abuse	89	0.40	-0.13, 0.94	0.140	0.39	-0.21, 0.99	0.198	0.22	-0.39, 0.83	0.475
Emotional neglect	52	0.24	-0.42, 0.90	0.471	0.093	-0.77, 0.95	0.832	0.14	-0.71, 1.00	0.744
Physical neglect	45	0.074	-0.63, 0.77	0.836	-0.35	-1.27, 0.57	0.454	-0.51	-1.44, 0.42	0.281

*Continuous metabolic syndrome score calculated using individual metabolic syndrome components [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (cm)] standardized by race and ethnicity. Higher values indicate greater degrees of cardiometabolic dysregulation.

†Experience of child maltreatment defined by scoring above the recommended cut-points for “moderate to severe” on subscales on the short-form Childhood Trauma Questionnaire [emotional abuse ≥ 13 ; physical abuse ≥ 10 ; sexual abuse ≥ 8 ; emotional neglect ≥ 15 ; physical neglect ≥ 10]. For each form of child maltreatment, participants that did not score above the recommended cut-points on the respective subscale are the reference group. Categories are not mutually exclusive.

‡Model adjusted for all other forms of child maltreatment.

§Model adjusted for all other forms of child maltreatment, race and ethnicity, eligibility for free or reduced lunch program, and highest level of education completed by a parent or guardian.

Supplementary Table 6. Unadjusted and adjusted mean differences in continuous metabolic syndrome* severity score by forms of child abuse and neglect among male participants (n = 361).

Form of child maltreatment†	No.	Unadjusted model			Adjusted model†			Fully adjusted model§		
		Mean difference	95% CI	p-value	Mean difference	95% CI	p-value	Mean difference	95% CI	p-value
Emotional abuse	41	0.22	-0.36, 0.80	0.455	0.28	-0.44, 1.00	0.443	0.20	-0.52, 0.92	0.583
Physical abuse	57	-0.37	-0.88, 0.14	0.152	-0.50	-1.08, 0.07	0.085	-0.48	-1.06, 0.099	0.104
Sexual abuse	27	0.47	-0.23, 1.17	0.191	0.58	-0.16, 1.32	0.125	0.78	0.02, 1.55	0.044
Emotional neglect	48	0.32	-0.21, 0.86	0.235	0.42	-0.23, 1.07	0.206	0.38	-0.27, 1.04	0.250
Physical neglect	50	-0.19	-0.74, 0.35	0.489	-0.51	-1.16, 0.14	0.125	-0.57	-1.24, 0.096	0.093

*Continuous metabolic syndrome score calculated using individual metabolic syndrome components [HDL cholesterol (mmol/L), triglycerides (mmol/L), glycated hemoglobin (mmol/L), blood pressure (mmHG), waist circumference (in)] standardized by race and ethnicity. Higher values indicate greater degrees of cardiometabolic dysregulation.

†Experience of child maltreatment defined by scoring above the recommended cut-points for “moderate to severe” on subscales on the short-form Childhood Trauma Questionnaire [emotional abuse ≥ 13 ; physical abuse ≥ 10 ; sexual abuse ≥ 8 ; emotional neglect ≥ 15 ; physical neglect ≥ 10]. For each form of child maltreatment, participants that did not score above the recommended cut-points on the respective subscale are the reference group. Categories are not mutually exclusive.

‡Model adjusted for all other forms of child maltreatment.

§Model adjusted for all other forms of child maltreatment, race and ethnicity, eligibility for free or reduced lunch program, and highest level of education completed by a parent or guardian.