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Sex-specific associations of childhood maltreatment with obesity-related traits - The Study of Health in Pomerania (SHIP)

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A R T I C L E I N F O

Keywords:
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A B S T R A C T

Background: Child maltreatment (CM) is linked to obesity in adulthood. However, sex-differences and direct measurements of body fat have previously been insufficiently considered in this context.
Objective: To assess sex-specific associations of CM with anthropometric markers of overweight/obesity and direct measures of body fat.
Participants and setting: Analyses were conducted in 4006 adults from a population-based cohort in Northeastern Germany (SHIP-TREND-0).
Methods: CM was assessed using the Childhood Trauma Questionnaire (CTQ). Obesity-related traits included anthropometric indicators (i.e., height, weight, body mass index [BMI], waist [WC] and hip circumference [HC], waist-to-hip ratio [WHR], waist-to-height ratio [WHtR]), fat mass (FM) and fat-free mass (FFM) derived from bioelectrical impedance analysis (BIA), and subcutaneous (SAT) and visceral adipose tissue (VAT) ascertained using magnetic resonance imaging (MRI). Sex-stratified linear regression models predicting obesity-related traits from total CTQ scores were adjusted for age and education. Exploratory analyses investigated effects of CTQ subscales on obesity-related traits.
Results: In men, CM was positively associated with WHtR ($\beta = 0.04$; $p = .030$) and VAT ($\beta = 0.02$; $p = .031$) and inversely with body height ($\beta = -0.05$; $p = .010$). In women, CM-exposure was positively associated with body weight ($\beta = 0.07$; $p = .018$), BMI ($\beta = 0.03$; $p = .013$), WC ($\beta = 0.07$; $p = .005$), HC ($\beta = 0.05$; $p = .046$), WHR ($\beta = 0.03$; $p = .015$), WHtR ($\beta = 0.04$; $p = .006$), FM ($\beta = 0.04$; $p = .006$), and SAT ($\beta = 0.06$; $p = .041$). In both sexes, effects were mainly driven by exposure to emotional and physical abuse.

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Conclusions: Results suggest that associations between CM-exposure and obesity-related traits in adulthood are primarily present in women. This may have implications for sex-specific obesity-related cardiometabolic risk after CM.

1. Introduction

Childhood maltreatment (CM), which refers to different forms of abuse (i.e., sexual, physical, emotional) and neglect (i.e. physical and emotional) occurring during early developmental periods, is a prevalent and pathogenic stressor with long-term effects on mental and physical health across the lifespan (Anda et al., 2006; Felitti et al., 1998; Hughes et al., 2017). For example, individuals with CM-exposure are at increased risk of major depressive disorder (MDD) (Nanni et al., 2012), anxiety disorders (Gardner et al., 2019), type-2-diabetes (T2D), cardiovascular disease (CVD) (Basu et al., 2017; Godoy et al., 2021), and overweight/obesity (Danese & Tan, 2014; Hemmingsson et al., 2014; Hughes et al., 2017). Overweight and obesity in turn are associated with various chronic diseases such as T2D, CVD, cancer, and chronic kidney disease which are major contributors to the worldwide health burden and responsible for up to four million annual deaths, of which two thirds are related to CVD (GBD, 2017). Overweight/obesity may thus represent an important pathway linking CM-exposure to chronic diseases in adulthood. Meta-analytic evidence suggests a consistent moderate positive relationship between CM and overweight/obesity (Danese & Tan, 2014; Felitti et al., 1998; Hemmingsson et al., 2014) with adjusted odds ratios ranging between 1.34 (Hemmingsson et al., 2014) and 1.39 (Hughes et al., 2017).

However, there are some important shortcomings in most studies investigating CM and overweight/obesity in adulthood. First, the majority of studies have focused on anthropometric markers of general obesity, i.e., body mass index (BMI) (Danese & Tan, 2014; Hemmingsson et al., 2014) or markers of visceral adiposity, such as waist-circumference (WC). Anthropometric markers of overweight/obesity might be considered controversial however (Prentice & Jebb, 2001) because they do not consider the body fat mass (FM) and the fat-free mass (FFM) of the total body weight (body weight composition). Moreover, anthropometric markers do not (i.e., BMI) or only indirectly (i.e., WC) capture body fat distribution, which among others includes visceral (VAT) and subcutaneous adipose tissue (SAT). While VAT seems to be associated with diabetogenic and atherogenic abnormalities (Ibrahim, 2010; Markus et al., 2017), SAT seems to be more innocuous. There is initial evidence, that CM is associated with increased VAT in a sample of 75 individuals with and without CM-exposure (Li et al., 2015).

Second, there is a substantial knowledge gap with respect to the moderating role of sex/gender in the association between CM and overweight/obesity in adulthood (Danese & Tan, 2014; Hemmingsson et al., 2014). Both exposure (i.e., CM) and outcomes (e.g., BMI, body weight composition, body fat distribution), as well as their association (Fuller-Thomson et al., 2013) show pronounced sex differences. For instance, women compared to men exhibit higher overall rates of CM-exposure (Felitti et al., 1998; Klinger-König et al., 2022) and are more likely to be exposed to more severe forms of abuse such as childhood sexual abuse (Moody et al., 2018). Furthermore, women compared to men have a higher prevalence of obesity (i.e., BMI $\geq$ 30 kg/m^2) (GBD, 2017), higher relative proportions of FM and lower FFM (Lemieux et al., 1993), higher SAT and lower VAT (Power & Schulkin, 2008). Finally, a large population-based study revealed an increased risk of being obese only in women with CM-exposure compared to women without CM-exposure, while no such association was found in men (Fuller-Thomson et al., 2013).

Accounting for these sex-differences, we thus analyzed the sex-specific associations of CM-exposure with anthropometric indicators of overweight/obesity (i.e., height, weight, BMI, WC and hip circumference [HC], waist-to-hip ratio [WHR], waist-to-height ratio [WHtR]) and direct measurements of body fat by magnetic resonance imaging (i.e., VAT, SAT) and bioelectrical impedance (i.e., FM, FFM) in a large, population-based cohort in Northern Germany, the Study of Health in Pomerania (SHIP)(Völzke et al., 2022).

2. Materials and methods

2.1. Study population - The Study of Health in Pomerania (SHIP)

The present cross-sectional study is based on data from the population-based Study of Health in Pomerania (SHIP) which was conducted in Northeastern Germany (Volzke et al., 2022) in an ethnically homogeneous (i.e., Caucasian White) population. The study design and recruitment strategy have been described elsewhere (John et al., 2001; Volzke et al., 2011). Our analyses are based on data obtained from the second independent cohort, SHIP-TREND-0, established between 2008 and 2012 (Volzke et al., 2011). In brief, a stratified random sample of 8826 adults, aged 20 to 79 years, was selected from the population of West Pomerania, the north-eastern region of Germany. Participation in the first SHIP cohort (SHIP-START) was an exclusion criterion. In total 4420 subjects participated in SHIP-TREND-0 (response rate 50.1 %).

Of the 4420 individuals examined in SHIP-TREND-0, we excluded 414 individuals with missing data in the Childhood Trauma Questionnaire, education, or anthropometric measurements resulting in a study population of 4006 individuals (2067 women, 51.6 %) aged 20 to 84 years. Among them, 3907 subjects (2024 women; 51.8 %) aged 20 to 84 years, underwent a bioelectrical impedance analysis (BIA) and 1866 individuals (958 women, 51.3 %), aged 21 to 82 an abdominal magnetic resonance imaging (MRI) examination (Supplementary Fig. S1). All participants gave written informed consent. The study was approved by the Local Ethics Committee of the University of Greifswald and followed the Declaration of Helsinki.

2.2. Childhood maltreatment

Participants provided self-reports about CM-exposure using the German version of the Childhood Trauma Questionnaire (CTQ) (Bernstein et al., 1998; Wingenfeld et al., 2010), a well-established instrument to retrospectively assess early experiences of abuse and neglect. The CTQ captures five different types of CM: emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect. For each CTQ-subscale, 5 items provide frequency ratings on 5-point Likert scales (i.e., 1 = *"never true"* – 5 = *"very often true"*). Thus, each CTQ-subscale can range between 5 and 25, with higher scores indicating higher severity of the respective CM-category. Additionally, we computed a continuous total CTQ score (range: 25–125) by adding all individual frequency ratings across all 25 items. High internal consistency for the German version of the CTQ and its subscales (Cronbach's α CTQ total score: 0.94; Cronbach's α CTQ subscales: 0.89–0.96) with the exception of the physical neglect scale (Cronbach's α: 0.62) was previously established (Wingenfeld et al., 2010).

For the main analyses, we used the total CTQ score as the primary exposure variable. Additionally, we performed secondary analyses using the continuous CTQ-subscales to explore possible abuse or neglect specific effects.

2.3. Anthropometric measurements

Manual anthropometric measurements were performed as part of the regular study protocol of SHIP by trained study nurses in compliance with a standard operating procedure (SOP) and included height, weight and waist and hip circumference. Weight was measured to the nearest 0.1 kg in light clothing and without shoes using standard digital scales. Body height was measured to the nearest 0.1 cm using a portable stadiometer (Soehnle Industrial Solutions, Backnang, Germany). Subsequently, BMI was calculated using the standard formula (BMI = weight (kg)/height^2 (m^2)). In accordance with WHO recommendations (WHO, 2011), WC and HC were measured with a flexible, non-stretchable graduated tape. Subjects were instructed to stand upright with the study nurse standing in lateral position behind the participants. To determine WC the examiner palpated the iliac crest and the lowest rip at the lateral part of the body. Measurements were made in the middle of these two landmarks. To assess HC the examiner palpated the most lateral point of the greater trochanter and the iliac crest. Measurements were performed in the middle of these reference points. From these data, we calculated WHR as well as WHtR.

2.4. Bioelectrical Impedance Analysis (BIA)

Absolute FM and FFM (in kg) were calculated by BIA using a multifrequency Nutriguard-M device (Data Input, Pöcking, Germany) and the NUTRI4 software (Data Input, Pöcking, Germany) in participants without pacemakers. Electrodes were placed on hand, wrist, ankle, and foot. The test frequency was measured at 5, 50, and 100 kHz following the manufacturer's instructions (Kyle et al., 2004).

2.5. Abdominal magnetic resonance imaging (MRI)

For the assessment of body fat distribution, i.e., VAT and SAT, participants underwent a standardized whole-body MRI examination, which was performed on a 1.5-Tesla MR system (Magnetom Avanto, Siemens Healthcare AG, software version syngo MR B15). Two trained technicians performed all examinations in a standardized manner. VAT and SAT volumes were determined using a two-echo chemical shift-encoded gradient echo sequence in axial orientation acquired by covering the abdomen in three stacks (each with 64 slices) with the following imaging parameters: repetition time: 7.5 ms; echo time: 2.4/4.8 ms; flip angle: 10°; voxel size: 1.64 × 1.64 × 3.0 mm; slice gap: none; field of view: 420 × 288 mm; matrix: 256 × 120; bandwidth: 290 Hz per pixel; and parallel imaging with an effective acceleration factor of 2.0. Data analysis was performed with 'ATLAS' (Automatic Tissue Labelling Analysis Software), which was specifically programmed for this purpose (Müller et al., 2011), followed by a manual correction of the results. The manual correction included setting the upper (left diaphragm) and lower margins (bladder) for the abdominal fat analyses, correcting misclassified fat labels and removing fat labels that did not belong to the abdomen (i.e. arms, breast fat and parenchyma, bone marrow of pelvis and spine). It was performed by certified medical students (intraclass correlation coefficient > 0.997). VAT and SAT are presented as volumes in liters (L).

2.6. Sociodemographic information

Sociodemographic information was obtained through computer-assisted personal interviews (Völzke et al., 2011). During the interview, participants provided information about their age, self-identified sex/gender, and years of school education. A categorical variable was then created for education indicating low (<10 years), medium (10 years), and high (>10 years) level of school education.

2.7. Statistical analyses

Characteristics of the study population were presented stratified by sex as mean values (M) ± standard deviation (SD) for continuous variables and as percentages for categorical variables. Tests for significant sex-differences are based on the Kruskal-Wallis tests for continuous variables and the chi-squared test for categorical variables, respectively. Total CTQ scores and CTQ subscales were associated with body composition markers by sex-stratified linear regression models adjusted for age and school education. Models for

FFM as outcome were further adjusted for FM. A $p < .05$ was considered as statistically significant. All analyses were conducted with Stata 17.0 (Stata Corporation, TX, USA).

3. Results

The final analytic sample consisted of 4006 individuals. Sex-stratified descriptive data on sociodemographic variables, anthropometrics, BIA, and MRI measures as well as CM of the study participants is shown in Table 1. Women were slightly overrepresented (51.6 %). The mean age was similar between both sexes. Significant sex-differences were observed for anthropometric markers and measures of body composition and fat distribution. More specifically, body height, weight, BMI, WC, WHR, WHtR, FFM, and VAT were higher in men compared to women (see Table 1). FM and SAT were higher in women than in men (Table 1). The only anthropometric marker with no significant sex-difference was HC (Table 1). We did observe a small but significant sex-difference in the total CTQ score, with women reporting more severe overall CM-exposure compared to men. Considering the CTQ subscales, women reported a higher severity in emotional abuse and sexual abuse, while men reported higher severity of physical abuse and emotional as well as physical neglect (Table 1).

3.1. Associations of total CTQ scores with anthropometric markers and measures of body fat

The sex-stratified analyses for the associations between overall CM-exposure and anthropometric outcomes revealed a highly sex-specific pattern of results, which is shown in Table 2 and Figs. 1 and 2.

In men, while the total CTQ score showed positive associations with WHtR (β = 0.04; 95 % CI: 0.01; 0.08; p = .030; Fig. 1E) and VAT (β = 0.02; 95 % CI: 0.01; 0.04; p = .032; Fig. 2D), there was a significant inverse association with body height (β = −0.05; 95 % CI: −0.08 to −0.01; p = .010; Fig. 1A).

In contrast, women's total CTQ scores exhibited significant positive associations with all anthropometric and body fat measures except body height, FFM, and VAT (Table 2 and Figs. 1 and 2). More specifically, CM-exposure was associated with higher body weight (β = 0.07; 95 % CI: 0.01 to 0.14; p = .018; Fig. 1B), BMI (β = 0.03; 95 %-CI: 0.01; 0.05; p = .013: Fig. 1C), WC (β = 0.07; 95 %-CI: 0.02; 0.12; p = .005; Fig. 1D), HC (β = 0.05; 95 %-CI: 0.01; 0.09; p = .046), WHR (β = 0.03; 95 %-CI: 0.01; 0.06; p = .015), WHtR (β = 0.04; 95 %-CI: 0.01; 0.08; p = .006; Fig. 1E), FM (β = 0.06; 95 %-CI: 0.02; 0.10; *p* = .006; Fig. 2A) and SAT (β = 0.02; 95 %-CI: 0.01; 0.05; p = .041; Fig. 2C). Consequently, in women, CM-exposure is associated with increased likelihood of being overweight or obese in adulthood.

3.2. Associations of CTQ subscales with anthropometric markers and measures of body fat

In men, we found inverse associations of body height with emotional abuse (β = −0.15; 95 % CI: −0.29; −0.01; p = .049) and physical neglect (β = −0.15; 95 % CI: −0.27 to −0.04; p = .015). Moreover, emotional abuse was positively associated with WHR (β =

Table 1
Sample characteristics of study variables stratified by sex (*n* = 4006).

	Men	Women	p-Value[a]
N (%)	1939 (48.4)	2067 (51.6)	
Age (years)	51.94 (15.48)	50.77 (15.00)	0.144
Level of education (N, %)			<0.001
Low (<10 years)	441 (22.7)	410 (19.8)	
Medium (10 years)	937 (48.3)	1175 (56.9)	
High (>10 years)	561 (28.9)	482 (23.3)	
Body height (cm)	176.55 (7.14)	163.98 (6.82)	<0.001
Body weight (kg)	89.04 (15.20)	73.95 (15.09)	<0.001
Body mass index (kg/m^2)	28.57 (4.63)	27.55 (5.67)	<0.001
Waist circumference (cm)	97.26 (12.89)	85.09 (13.50)	<0.001
Hip circumference (cm)	102.16 (9.00)	102.79 (12.04)	0.984
Waist-to-hip ratio	0.95 (0.07)	0.83 (0.06)	<0.001
Waist-to-height ratio	0.55 (0.08)	0.52 (0.09)	<0.001
Body fat mass (kg) (*n* = 3907)	21.77 (8.08)	26.06 (10.33)	<0.001
Body fat-free mass (kg) (n = 3907)	67.18 (8.71)	47.82 (5.72)	<0.001
Subcutaneous adipose tissue (L) (*n* = 1866)	6.85 (2.87)	8.94 (3.73)	<0.001
Visceral adipose tissue (L) (n = 1866)	5.30 (2.82)	2.83 (1.87)	<0.001
Total CTQ score	33.16 (8.39)	33.29 (10.58)	<0.001
Emotional abuse	6.00 (1.97)	6.45 (2.83)	0.072
Physical abuse	5.69 (1.69)	5.67 (2.09)	<0.001
Sexual abuse	5.08 (0.66)	5.34 (1.66)	<0.001
Emotional neglect	9.19 (4.33)	8.83 (4.40)	<0.001
Physical neglect	7.19 (2.56)	7.01 (2.61)	0.002

Note: Data are shown as M (SD) for continuous variables and as percentages for categorical variables/frequencies.
Abbreviations: CTQ = Childhood Trauma Questionnaire.
[a] p-values are based on the chi-squared test for categorical variables and the Kruskal-Wallis tests for continuous variables.

Table 2
Adjusted* ß-coefficients (95 % confidence intervals) of the sex-specific associations of total CTQ scores and CTQ subscale scores with body composition.

	Total CTQ Score β (95 %-CI)	Emotional abuse β (95 %-CI)	Physical abuse β (95 %-CI)	Sexual abuse β (95 %-CI)	Emotional neglect β (95 %-CI)	Physical neglect β (95 %-CI)
	Men					
Body weight; kg	0.03 (−0.06; 0.11)	0.10 (−0.24; 0.45)	0.13 (−0.27; 0.53)	0.18 (−0.84; 1.19)	0.05 (−0.11; 0.21)	0.01 (−0.27; 0.29)
Body height; cm	**−0.05 (−0.08; −0.01)***	**−0.15 (−0.29; −0.01)***	−0.16 (−0.33; 0.01)	−0.18 (−0.61; 0.25)	−0.06 (−0.13; 0.01)	**−0.15 (−0.27; −0.04)***
Body mass index; kg/m^2	0.02 (−0.01; 0.05)	0.08 (−0.02; 0.18)	0.09 (−0.03; 0.20)	0.12 (−0.18; 0.42)	0.04 (−0.01; 0.08)	0.05 (−0.03; 0.14)
Waist circumference; cm	0.04 (−0.02; 0.11)	0.17 (−0.09; 0.44)	0.19 (−0.12; 0.50)	−0.05 (−0.83; 0.73)	0.08 (−0.04; 0.20)	0.07 (−0.15; 0.28)
Hip circumference; cm	0.01 (−0.04; 0.05)	0.02 (−0.18; 0.22)	0.02 (−0.21; 0.25)	−0.01 (−0.60; 0.58)	0.01 (−0.08; 0.10)	0.01 (−0.15; 0.17)
Waist-to-hip ratio*100	0.03 (−0.01; 0.07)	**0.15 (0.01; 0.30)***	0.16 (−0.02; 0.33)	−0.04 (−0.48; 0.39)	0.06 (−0.01; 0.12)	0.04 (−0.08; 0.15)
Waist-to-height ratio*100	**0.04 (0.01; 0.08)***	0.14 (−0.01; 0.29)	0.15 (−0.02; 0.33)	0.00 (−0.44; 0.45)	0.07 (−0.01; 0.13)	0.09 (−0.03; 0.21)
Fat mass; kg	0.00 (−0.04; 0.05)	0.02 (−0.16; 0.21)	0.00 (−0.21; 0.21)	−0.05 (−0.59; 0.50)	0.00 (−0.08; 0.09)	0.01 (−0.14; 0.15)
Fat-free mass; kg	0.01 (−0.03; 0.05)	0.01 (−0.15; 0.16)	0.07 (−0.12; 0.25)	0.22 (−0.25; 0.69)	0.02 (−0.05; 0.09)	−0.01 (−0.13; 0.12)
Subcutaneous adipose tissue; L	0.01 (−0.01; 0.03)	0.06 (−0.04; 0.16)	0.06 (−0.05; 0.17)	0.00 (−0.24; 0.25)	0.01 (−0.03; 0.06)	−0.00 (−0.08; 0.08)
Visceral adipose tissue; L	**0.02 (0.01; 0.04)***	0.06 (−0.02; 0.15)	**0.10 (0.01; 0.20)***	0.19 (−0.02; 0.40)	0.04 (−0.01; 0.08)	0.03 (−0.04; 0.10)
	Women					
Body weight; kg	**0.07 (0.01; 0.14)***	**0.42 (0.19; 0.65)*** **	**0.58 (0.27; 0.88)*****	0.23 (−0.16; 0.62)	0.06 (−0.09; 0.21)	0.09 (−0.16; 0.35)
Body height; cm	−0.00 (−0.03; 0.02)	0.03 (−0.06; 0.13)	0.06 (−0.06; 0.19)	0.02 (−0.14; 0.18)	−0.01 (−0.08; 0.05)	−0.06 (−0.17; 0.04)
Body mass index; kg/m^2	**0.03 (0.01; 0.05)***	**0.14 (0.06; 0.23)****	**0.19 (0.08; 0.30)****	0.07 (−0.06; 0.21)	0.03 (−0.02; 0.08)	0.06 (−0.03; 0.15)
Waist circumference; cm	**0.07 (0.02; 0.12)***	**0.36 (0.17; 0.55)*****	**0.41 (0.16; 0.67)****	**0.36 (0.04; 0.68)***	0.08 (−0.05; 0.20)	0.14 (−0.07; 0.35)
Hip circumference; cm	**0.05 (0.01; 0.09)***	**0.28 (0.10; 0.45)****	**0.39 (0.16; 0.62)****	0.14 (−0.15; 0.43)	0.02 (−0.09; 0.13)	0.10 (−0.09; 0.30)
Waist-to-hip ratio*100	**0.03 (0.01; 0.06)***	**0.13 (0.03; 0.22)****	0.10 (−0.03; 0.22)	**0.23 (0.07; 0.39)****	0.06 (−0.01; 0.12)	0.05 (−0.06; 0.15)
Waist-to-height ratio*100	**0.04 (0.01; 0.08)***	**0.21 (0.09; 0.33)*****	**0.23 (0.07; 0.39)****	**0.22 (0.02; 0.42)***	0.05 (−0.03; 0.13)	0.11 (−0.03; 0.24)
Fat mass; kg	**0.06 (0.02; 0.10)***	**0.31 (0.15; 0.47)*****	**0.39 (0.18; 0.60)*****	0.17 (−0.10; 0.43)	0.06 (−0.04; 0.16)	0.12 (−0.05; 0.30)
Fat-free mass; kg	−0.01 (−0.02; 0.01)	−0.03 (−0.09; 0.03)	0.02 (−0.06; 0.10)	−0.02 (−0.12; 0.08)	−0.01 (−0.04; 0.03)	**−0.07 (−0.14; −0.01)***
Subcutaneous adipose tissue; L	**0.02 (0.00; 0.05)***	**0.11 (0.02; 0.19)***	0.08 (−0.04; 0.20)	0.03 (−0.11; 0.17)	0.04 (−0.01; 0.10)	0.09 (−0.01; 0.19)
Visceral adipose tissue; L	0.01 (−0.01; 0.02)	**0.04 (0.01; 0.08)***	0.02 (−0.03; 0.07)	0.02 (−0.04; 0.08)	0.02 (−0.01; 0.04)	0.04 (−0.01; 0.08)

Note: *β coefficients are derived from sex-stratified linear regression models adjusted for age and education. Models for fat-free mass as outcome are further adjusted for fat mass. CI = confidence interval; CTQ = Childhood Trauma Questionnaire. *p < .05; **p < .01; ***p < .001.

0.15; 95 % CI: 0.01 to 0.30; p = .045) and physical abuse with VAT (β = 0.10; 95 % CI: 0.01 to 0.20; p = .028). There was no other significant association of any neglect category or sexual abuse with any anthropometric or body fat marker (Table 2, Supplemental Figs. S2-S3).

In women, exposure to emotional abuse was positively associated with all anthropometric measures, except body height, and with all MRI and BIA measures except FFM (Table 2). Exposure to physical abuse revealed significant positive associations with five anthropometric and body fat parameters but not body height, WHR, FFM, SAT, and VAT. (Table 2). Exposure to sexual abuse revealed significant positive associations with three anthropometric outcomes: WC (β = 0.36; 95 % CI: 0.04 to 0.68; p = .027), WHR (β = 0.23; 95 % CI: 0.07 to 0.39; p = .005) and WHtR (β = 0.22; 95 %-CI: 0.02; 0.42; p = .035). Interestingly, there was an inverse association of physical neglect with FFM (β = −0.07; 95 %-CI: −0.14; −0.002; p = .044). There was no other significant association of any neglect category with any anthropometric or body fat marker (Table 2, Supplemental Figs. S2-S3).

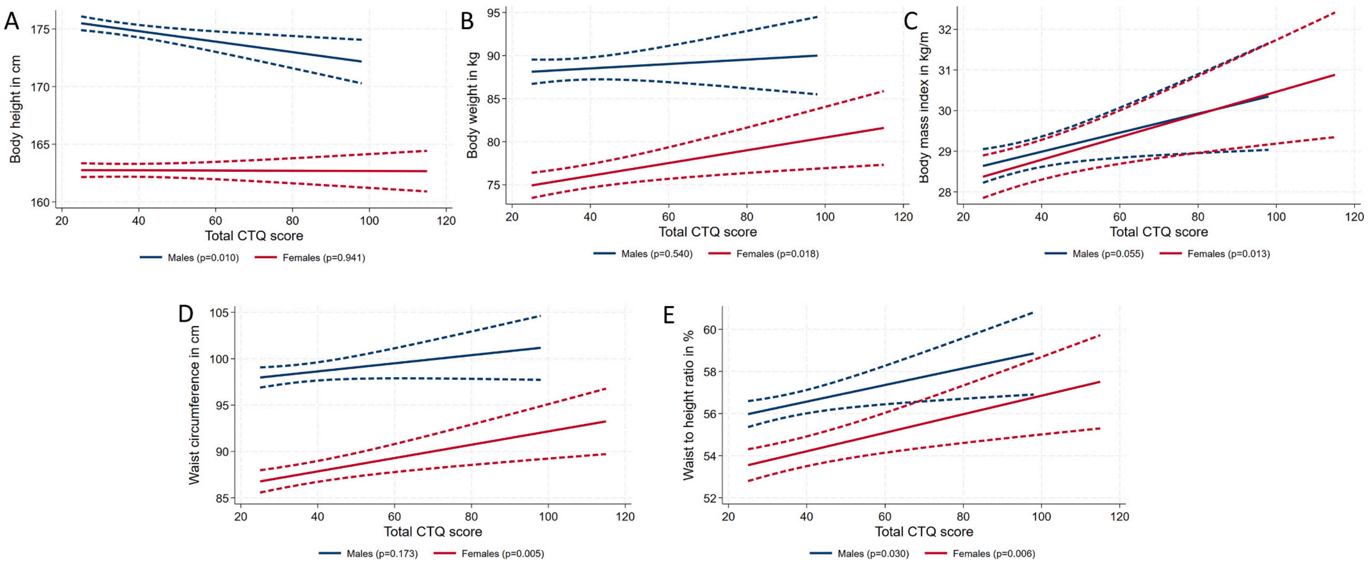

Fig. 1. Regression model lines (95 % confidence interval)* for total CTQ scores and (A) body height, (B) body weight, (C) BMI, (D) waist circumference, and (E) waist-to-height ratio disaggregated by participant self-reported sex/gender. X-axis represents total CTQ scores (range 25–125).
*Linear regression models are adjusted for age and education.
BMI = Body mass index; CTQ = Childhood Trauma Questionnaire.

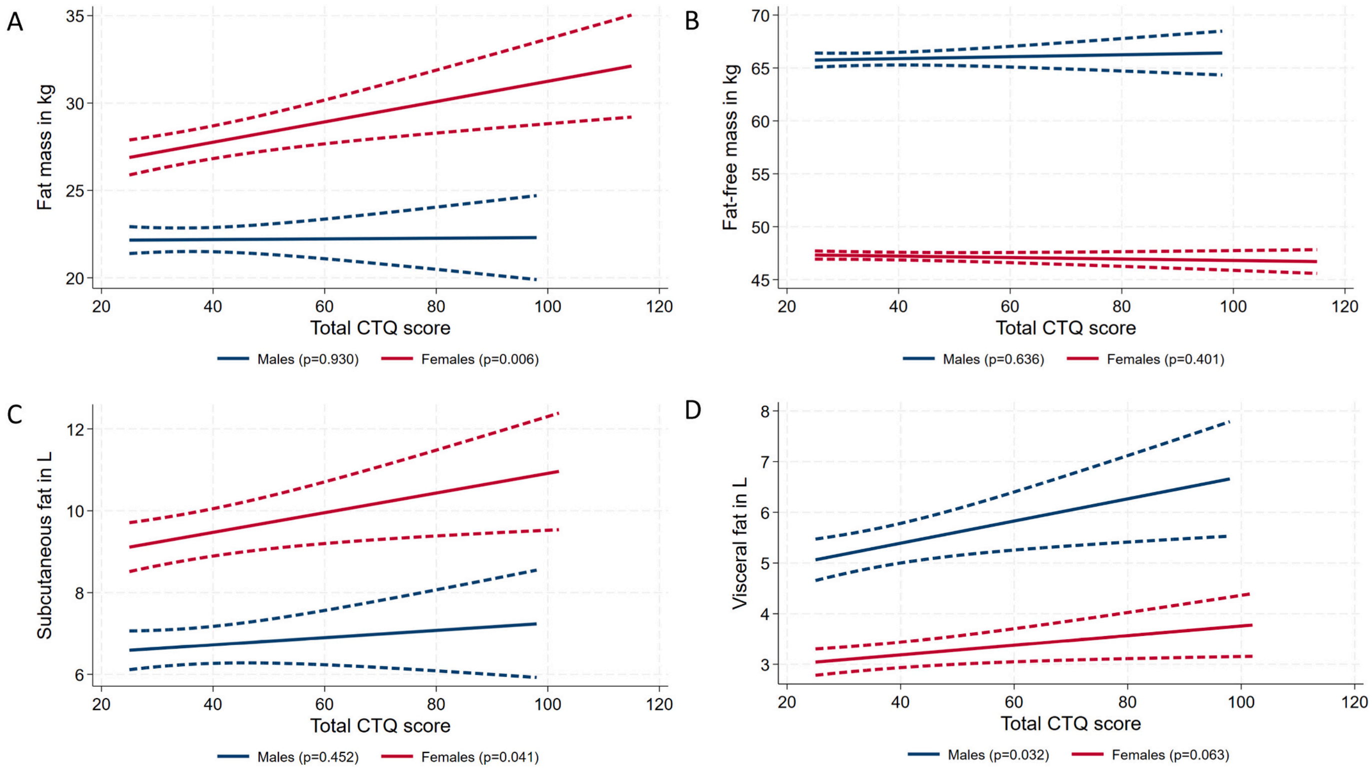

Fig. 2. Regression model lines (95 % confidence interval)* for total CTQ scores and (A) fat mass, (B) fat-free mass, (C) subcutaneous fat, and (D) visceral fat disaggregated by participant self-reported sex/gender. X-axis represents total CTQ scores (range 25–125).
* Linear regression models are adjusted for age and education. Models for fat-free mass as outcome are further adjusted for fat mass.
CTQ = Childhood Trauma Questionnaire.

4. Discussion

The aim of the present study was to explore sex-specific associations of CM with anthropometric markers and direct measures of body fat in a community sample of adults. We found that CM-exposure was strongly associated with most of the anthropometric and body fat outcomes in women but rarely in men.

In men, we found an inverse association of overall CM-exposure with body height and a positive association with WHtR. Furthermore, overall CM-exposure and exposure to physical abuse were positively associated with VAT. Importantly, the emerging pattern in men was different when compared to women with almost no overlap between the sexes.

In women, CM-exposure may predispose to an adult phenotype characterized by general overweight/obesity (i.e., increased body weight, BMI), visceral adiposity (i.e., increased WC, HC, WHR, WHtR), and increased FM and SAT. In addition, emotional abuse (but neither the total CTQ score nor any other CTQ-subscale) was significantly positively associated with increased VAT in women. The observed pattern in women was mainly driven by the severity of exposure to emotional and physical abuse during childhood and to a lesser extent by exposure to sexual abuse. Exposure to either emotional or physical neglect had, with the exception of a negative relation with FFM, no effect in women.

Our results are consistent with previous studies (Danese & Tan, 2014; Ernst et al., 2019; Fleischer et al., 2021; Fuller-Thomson et al., 2013), corroborating the notion that the association of CM with overweight/obesity in adulthood might be sex-specific and more pronounced in women (Danese & Tan, 2014; Fuller-Thomson et al., 2013). More specifically, our results confirm the results of a previous community-based study in 12,590 adult men and women showing that childhood physical abuse was associated with a higher obesity risk (i.e., BMI $\geq$ 30 kg/m^2) in women but not in men (Fuller-Thomson et al., 2013). Another analysis of two pooled German cohorts (KORA and SHIP) reported significant positive associations between overall CM-exposure using the childhood trauma screener (CTS) (Grabe et al., 2012) and WHtR in both sexes (Fleischer et al., 2021). We were able to replicate this finding. Contrary to our results however, the study by Fleischer et al. (2021) showed that after further adjustment for socioeconomic variables (age, education, and occupation) the effect of overall CM-exposure on WHtR remained significant only in men (Fleischer et al., 2021). This discrepancy might result from the fact that included covariates differed between the studies. Moreover, the operationalization of CM-exposure was similar (CTS vs. CTQ), yet different. The CTS captures the five CTQ-scales using only one item per scale. Furthermore, our sample was substantially larger and thus provided larger statistical power.

Several studies including two meta-analyses (Danese & Tan, 2014; Hemmingsson et al., 2014) reported that exposure to childhood sexual abuse is consistently related to anthropometric markers of overweight/obesity in adulthood. We were able to demonstrate this association in women (but not men) for three anthropometric markers of visceral obesity (WC, WHR, and WHtR) but neither for general obesity (i.e., BMI) nor for any of the direct body fat measurements. Compared to the consistency and magnitude of effects of emotional and physical abuse on adult obesity-related traits in women, the effect of sexual abuse was rather limited. This unexpected observation might partly result from the fact that the severity of sexual abuse was relatively low in our cohort. Moreover, the sub-sample with available MRI data (n = 1.866) was substantially smaller than the total sample. Together, these circumstances have contributed to a reduced statistical power to observe significant associations of sexual abuse with more anthropometric and body fat markers. Finally, we are not aware of any study showing a sex-specific association between CM-exposure and direct measures of body composition or body fat distribution by BIA and/or MRI. CM has previously been shown to associate with increased VAT in a small sample without disaggregating the data by participant sex (Li et al., 2015).

There are several plausible and inter-connected behavioral, neurobiological, neuroendocrine, and immunological pathways that may explain the association of CM-exposure and overweight/obesity in adulthood (Wiss & Brewerton, 2020). For instance, CM-exposure is associated with psychiatric conditions such as MDD (Nanni et al., 2012), food addiction, disordered eating (Caslini et al., 2016; Imperatori et al., 2016), and decreased levels of physical activity (Felitti et al., 1998), all of which have been shown to be associated with increased levels of obesity and subsequent cardiometabolic risk. However, some of these associations (e.g., MDD and obesity) are complex and reciprocal in nature (Luppino et al., 2010) and so is the multitude of possible mediators conferring increased obesity-related risk after CM-exposure. Given the cross-sectional design of our cohort, we were not able to establish longitudinal associations of mediating pathways linking CM-exposure to overweight/obesity. At the neurobiological level, CM-exposure may become biologically embedded and induces structural and functional alterations in brain circuits that underlie self- and stress regulation (e.g., frontolimbic circuits) (Lupien et al., 2009). These CM-associated changes have been shown to increase the risk for adult stress susceptibility with underlying alterations in hypothalamic-pituitary-adrenal axis (HPA-axis) activity (Heim et al., 2000) and increased inflammation (Baumeister et al., 2016), which through dysregulation in metabolic homoeostasis, may additionally contribute to overweight/obesity and cardiometabolic risk. Unfortunately, the role of sex and gender in these mechanisms is insufficiently understood (Tiwari & Gonzalez, 2018) and should be investigated more thoroughly.

With respect to the unexpected finding that CM-exposure is related to lower adult body height in men, we were not able to identify any previous study reporting this sex-specific effect. However, there is evidence from independent cohorts that CM may interfere with body growth in both men and women predisposing them to reduced body height in adulthood (Abajobir et al., 2017; Denholm et al., 2013). Body growth is a dynamic, highly sex-specific process that occurs during an extended period of time, i.e., from the prenatal period until early adulthood. During early development, a period of increased vulnerability to environmental stressors (e.g., CM), hypothalamic expression and release of growth hormone (GH) is under tight control of several endocrine mechanisms, which mediate adaptation to chronic stress-exposure such as CM (i.e. glucocorticoids), sexual differentiation (i.e., sex-steroids), and metabolism (i.e., insulin) (Mousikou et al., 2023; Veldhuis et al., 2005). Their complex age-and sex-dependent interactions may differentially affect growth trajectories for men and women after CM-exposure, which needs further investigation. Related to this finding and as stated above, most studies investigating the associations between CM and anthropometric markers of overweight and obesity focus on BMI as the outcome. Our study may add an interesting perspective to this body of work, since CM predicts increased weight (but not height) in women and reduced body height (but not weight) in men. What follows from this is that, at least in our cohort, CM exposure may place CM-exposed individuals on trajectories of increased BMI, regardless of their sex/gender, however via sex-specific pathways: through increased weight in women and through reduced body height in men.

There are several limitations that need to be considered, when interpreting our results. First, we consider our study exploratory in nature and acknowledge the need of independent replication to validate the results of our study. Another limitation is the fact that the individual CTQ scales as well as most outcome measures show moderate to strong intercorrelations (Supplemental Tables S1 and S2). In order to achieve exposure-specific prediction by, e.g., only emotional abuse, we would have to adjust for all other subscales of the CTQ in the individual regression models. This appears problematic because of the risk of multicollinearity and subsequent variance inflation. In addition, there has been controversy surrounding the reliability of retrospective self-reports of CM (Baldwin et al., 2019; Moog et al., 2021). The time lag between the exposure to and the ascertainment of CM, the sensitivity of the topic, clinical conditions associated with CM such as MDD or posttraumatic stress disorder, as well as emotional states often reported by survivors of CM such as shame and guilt, may constitute sources of reporting bias, non-disclosure, and recollection errors. For practical reasons however and given the methodological challenges inherent to prospective measures of CM (Moog et al., 2021), retrospective self-reports of CM-exposure continue to have an important role in research on the long-term health outcomes associated with CM. Finally, our cohort is highly homogenous in terms of race/ethnicity. All participants were white German nationals in a Northeastern region of Germany (Western Pomerania). This circumstance limits generalizability of our study to other populations of different ethnic, racial, cultural or geographical background, where configurations of CM-exposure and associated long-term risk may systematically deviate from the SHIP cohort.

A major strength of our study is the fact that we obtained direct measures of body fat through BIA and MRI in a large community-based sample. Given that body fat tissue, and especially VAT, is the "true culprit" for the increased cardiometabolic risk in obese individuals (Ibrahim, 2010), the present study may provide important novel insights how CM contributes to an increased risk for chronic diseases in adulthood for both men and women. Contrary to the overall pattern that the CM-obesity associations are more pronounced in women than men, we found a positive association of CM-exposure (i.e., total CTQ) with VAT in men, an effect that was driven by exposure to physical abuse. This may have implications for cardio-metabolic health in men after CM-exposure, since VAT is linked to insulin-resistance and T2D (Ibrahim, 2010). Consistent with our observation, men have a higher risk for T2D after CM-exposure compared to women (Duncan et al., 2015).

Given the sexually dimorphic nature in most anthropometric markers, body composition, and body fat distribution, we propose that our sex-sensitive analyses are likely more appropriate for the research question than merely adjusting for sex as a covariate. We would further suggest that certain obesity-related markers are likely more appropriate than others when interested in sex-specific CM-obesity associations. As can be seen in Fig. 1, regression lines (and 95 %-Cis) reveal substantial overlap for some traits (e.g., BMI), while others (e.g., WC, FM) are clearly distinguishable, i.e., show a high degree of sex-dimorphism. With few notable exceptions (Ernst et al., 2019; Fleischer et al., 2021; Fuller-Thomson et al., 2013), most of the previous studies on CM-obesity associations include sex only as a covariate, while not testing for CM-sex-interactions directly or stratifying the data by sex or use BMI as the main outcome (Danese & Tan, 2014) which may mask important insights into sex-specific obesity risk after CM-exposure. Fortunately, there is an increasing awareness in biomedical research about the importance of sex and gender in health and disease (Mauvais-Jarvis et al., 2020) and appropriate analytical methods to investigate them (Tannenbaum et al., 2019).

To conclude, our study contributes to the growing body of evidence that CM is an important and highly prevalent risk factor for compromised health across the lifespan (Felitti et al., 1998; Hughes et al., 2017). The particular focus on sex-specific cardiometabolic health risks associated with CM, has identified differential disease risks for men and women in highly prevalent conditions such as CVD (Soares et al., 2020) and T2D (Duncan et al., 2015). Given these emerging data, future research should clearly continue to systematically address sex and gender (and other dimensions of diversity) to improve prevention, diagnosis, prognosis, and treatment for common chronic diseases in people with exposure to CM, regardless of their sex or gender.

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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CRediT authorship contribution statement

Philipp Töpfer: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Ulrike Siewert-Markus:** Writing – original draft, Writing – review & editing. **Johanna Klinger-König:** Formal analysis, Resources, Conceptualization, Writing – review & editing. **Hans J. Grabe:** Conceptualization, Data curation, Project administration, Writing – review & editing. **Sylvia**

Stracke: Writing – review & editing. **Marcus Dörr:** Writing – review & editing. **Henry Völzke:** Data curation, Funding acquisition, Project administration, Supervision, Writing – review & editing. **Till Ittermann:** Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Marcello R.P. Markus:** Formal analysis, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

HJG has received travel grants and speakers honoraria from Fresenius Medical Care, Neuraxpharm, Servier and Janssen Cilag as well as research funding from Fresenius Medical Care.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chiabu.2024.106704.

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