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Childhood maltreatment and depression: mediating role of lifestyle factors, personality traits, adult traumas, and social connections among middle-aged and elderly participants

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Abstract

Background Accumulating evidence has supported the associations between childhood maltreatment and increased risk of depression; however, the underlying mechanisms remain largely unclear. We aimed to explore the potential role of lifestyle factors, personality traits, adult traumas, and social connections in the association between childhood maltreatment and depression.

Methods We used a nationwide cohort data from the UK Biobank, involving half a million participants aged 37–73 years, recruited across 22 centers in the UK between 2006 and 2010. Participants with complete information on childhood experiences and who were free of depression were included. The Childhood Trauma Questionnaire was used to calculate the maltreatment for five subtypes: physical neglect, emotional neglect, sexual abuse, physical abuse, and emotional abuse. Multivariate logistic regression models were implemented to examine the association between childhood maltreatment and depression. A path analysis using structural equation modeling (SEM) was then performed to assess the mediating effects of lifestyle factors, personality traits, adult traumas, and social connections.

Results During a mean follow-up of 13.88 years, 5545 participants developed depression. Of the 109,401 participants included in the study (mean [standard deviation] age, 55.75 [7.76] years; 58,315 females [53.30%]), 48,923 participants reported experiencing at least one form of childhood maltreatment. We observed that higher childhood maltreatment scores (odds ratio [OR] 1.28, 95% confidence interval [CI] 1.25–1.31) and all five childhood maltreatment subtypes (physical neglect: 1.46, 1.36–1.56; emotional neglect: 1.78, 1.67–1.89; sexual abuse: 1.48, 1.36–1.61; physical abuse: 1.37, 1.29–1.47; emotional abuse: 1.88, 1.76–2.00) were associated with an increased risk of depression. The SEM results indicated that the effect of childhood maltreatment on depression was partly mediated by lifestyle factors ($\beta = 0.15$, $P < 0.001$), personality traits ($\beta = 0.12$, $P < 0.001$), adult traumas ($\beta = 0.50$, $P < 0.001$), and social connections ($\beta = 0.19$, $P < 0.001$), rather than having a direct effect on depression.

Conclusions We found that social environmental factors such as lifestyle, personality, adult traumas, and social connections mediate the relationship between childhood maltreatment and depression in middle-aged and elderly

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people. These findings suggest that addressing these factors may be relevant for mental health interventions in individuals with a history of childhood maltreatment.

Keywords Childhood maltreatment, Lifestyle factors, Personality traits, Adult traumas, Social connections, Depression

Background

Awareness of the detrimental effects of childhood maltreatment has become increasingly relevant over the past two decades, driven by a growing body of research investigating the prevalence of childhood maltreatment and its associations with adverse health consequences [1]. Childhood maltreatment, encompassing a spectrum of abuse and neglect endured during adolescence such as physical and emotional neglect, as well as sexual, physical, and emotional abuse, remains a pervasive public health issue [2, 3]. A meta-analysis of 206 studies across 22 countries reported that 60.2% of individuals had experienced at least one type of childhood maltreatment, and 16.1% had experienced four or more [4]. In the United Kingdom (UK), a nationwide survey found that 46.4% of participants had experienced childhood maltreatment [5]. Those who have experienced childhood maltreatment are prone to an earlier onset of mental disorders [6], exhibit more severe depression symptoms [7], and often show less responsiveness to conventional treatment [8]. The mechanisms underlying the associations between childhood maltreatment and depression are complex, involving biological, psychological, and social factors [9–11].

In this study, lifestyle encompasses factors such as smoking status, drinking habits, sedentary behavior, sleep quality, diet scores, physical activity, and body mass index (BMI), which are considered in relation to both childhood maltreatment and the risk of depression [12–15]. Personality development typically begins in infancy and manifests as relatively stable patterns of cognition, emotions, and behaviors throughout adulthood [16]. Individuals exposed to childhood maltreatment often exhibit lower levels of emotional stability, increased psychological vulnerability, and a predisposition towards neurotic personality traits [17]. Traits such as optimism, extraversion, and conscientiousness are considered protective factors against depression [18, 19], while neuroticism is a known risk factor [20]. Adult traumas related to childhood maltreatment are predictive of re-victimization, including homelessness [21], unemployment [22], and intimate partner violence [23], all of which are associated with poor mental health outcomes. Individuals with trauma may show heightened sensitivity to threats and adopt self-protective regulatory mechanisms, such as increasing social distance [24]. Robust evidence suggests that social connection factors are strongly associated with mental health outcomes, with particularly

compelling data regarding depression [25]. A systematic review conducted in 2022 concluded that there is a strong positive correlation between social connection factors, including social isolation and loneliness, and depression across all age groups [26]. In addition, individuals who have experienced childhood maltreatment tend to maintain interpersonal distance and limit social contact, thereby increasing their vulnerability to depression [27, 28].

We hypothesized that childhood maltreatment may exert enduring effects on the development of depression through multiple mediating pathways. These pathways include lifestyle factors (smoking status, drinking habits, sedentary behavior, sleep quality, diet scores, physical activity, BMI), personality traits (warmth, diligence, nervousness, sociability, and curiosity), adult traumas (adult confiding, physical violence, belittlement, sexual interference, financial security), and social connections (visit frequency, participation in social activities, emotional support, household size, and perceived loneliness). Although existing studies have explored the association between childhood maltreatment and depression in adulthood, these studies predominantly focused on isolated aspects and have not investigated the integrated mechanisms by which the four potential mediating factors contribute to childhood maltreatment-associated depression.

In this study, we utilized a large prospective cohort from the UK Biobank (UKB) to comprehensively examine the associations between childhood maltreatment and depression in middle-aged and elderly people. Additionally, we explored the potential mediating effects of lifestyle factors, personality traits, adult traumas, and social connections on these relationships.

Methods

Study design and population

This study used data from the UKB, a nationwide prospective cohort, with participants recruited between 2006 and 2010 across 22 centers in the UK. Multi-dimensional information covering lifestyle factors, health conditions, physical measurements, biological samples, brain imaging, and genotyping was collected from more than 500,000 participants aged 37–73 years through a series of interviews and questionnaires. The study was approved by the North West Multicenter Research Ethics

Committee (Reference number: 21/NW/0157), and all participants provided informed consent.

Among 153,543 participants with complete data available for the five childhood maltreatment-related questions of the Childhood Trauma Screener (CTS), those with missing data for lifestyle factors ($n = 27,628$), adult traumas ($n = 3,730$), personality traits ($n = 21$), social connections ($n = 3056$), and sociodemographic characteristics ($n = 628$), and those with a history of depression at baseline ($n = 9079$) were excluded. Ultimately, 109,041 participants were included in the primary analysis (Additional file 1: Fig. S1).

Assessment of childhood maltreatment

The exposure of interest was the childhood maltreatment scores, derived from the CTS in 2016, a shortened version of the Childhood Trauma Questionnaire assessed physical neglect, emotional neglect, sexual abuse, physical abuse, and emotional abuse through five questions [3, 29]. Participants responded using a 5-point Likert scale, ranging from never, rarely, sometimes, often, to very often (Additional file 1: Table S1) [30]. Physical neglect was assigned with 1 if participants answered never true, rarely true, sometimes true, or often true; emotional neglect was assigned with 1 if participants answered never true, rarely true, or sometimes true; sexual abuse, physical abuse, and emotional abuse were scored with 1 if the response indicated that it occurred more than rarely true. The childhood maltreatment scores were calculated by summing the score of experienced childhood maltreatment subtypes, resulting in a scale from 0 to 5, with a higher score indicating exposure to a greater number of childhood maltreatment types.

Definition and measurement of mediators

Lifestyle factors included smoking status, drinking habits, sedentary behavior, diet score, sleep quality, body mass index (BMI, calculated as weight in kilograms divided by height in meters squared), and physical activity, which were assessed at baseline. Smoking status was classified as current smokers and non-smokers. Drinking habits were categorized as daily or almost daily consumption versus less frequent drinking (healthy drinking group). Sedentary behavior was assessed by summing the total daily hours spent on television viewing, computer usage, and driving. The diet score was assessed using a touchscreen questionnaire that measured the frequency of consuming fruits, vegetables, fish, processed meat, unprocessed red meat, whole grains, and refined grains. The diet score ranged from 0 to 7, with a higher score indicating a healthier diet pattern [31]. Sleep quality was self-reported and included sleep duration, chronotype

preference, insomnia disorder, snoring, and daytime sleepiness, as detailed in previous studies [32]. Healthy sleep behaviors were defined as getting 7–8 h of sleep per day, being a morning or more morning than evening person, never or rarely experiencing insomnia, not snoring, and never/rarely or sometimes experiencing excessive daytime sleepiness. Each participant received one point per healthy sleep behavior, resulting in a total sleep score ranging from 0 to 5 [33]. Physical activity was measured in metabolic equivalent task (MET)-min per week, based on the MET score derived from the validated International Physical Activity Questionnaire (IPAQ) guidelines [34] (Additional file 1: Table S2).

Personality traits were derived from five questions in the online Big Five Questionnaire at baseline (2006–2008), including warmth (agreeableness), diligence (conscientiousness), nervousness (neuroticism), sociability (extraversion), and curiosity (openness), and were already well established and validated [35, 36]. Each question contributed one point to the whole score for the respective personality trait; scores for warmth and nervousness range from 0 to 5, and scores for diligence, sociability, and curiosity range from 0 to 4. The selected questions and cut-off points for each personality trait were summarized in Additional file 1: STable 3.

Adult traumas were defined using five items from the UKB mental health questionnaire, which assessed adult experiences corresponding to the early life experiences measured by the CTS in 2016 [37], and was examined in previous literature [38]. These items indexed emotional, physical, and sexual abuse in interpersonal relationships as well as poor closeness of relationships and financial security after age 16 [37]. The response to every question contains never true, rarely true, sometimes true, often true, and very often true. Each individual type was scored 0 or 1 according to the cutoff points derived from validation studies [39]. Thus, the cumulative score ranged from 0 to 5, with a higher score indicating more frequent adult traumas (Additional file 1: Table S4). Reliability analysis of childhood maltreatment and adult traumas scales can be seen in the Additional file 1: Table S5.

Social connections were calculated by incorporating information on social supports and mental health from five questions at baseline (2006–2010): (1) Frequency of friend/family visits, (2) Leisure/social activities, (3) Able to confide, (4) Number in household, (5) Loneliness, isolation: “Do you often feel lonely?” (1 point for no). Each level of the 5 metrics was scored 1 for the group of better social connections, and were scored 0 for the group of lower social connections, consistent with previous studies [40–42]. Each of the five questions was scored 1 for better social connections and 0 for lower social connections (Additional file 1: Table S6).

Assessment of outcome

The primary outcome of this study was depression, identified based on the “first occurrences” dataset (category ID: 1712) in the UKB. This dataset included information from self-reports, hospital admissions, and death registries (International Classification of Diseases Tenth Revision codes F32-F33). Participants were followed from their baseline assessment (2006–2010) until either a diagnosis of depression or the end of the follow-up period on April 1, 2023, whichever came first.

Covariates

Covariates included birth year (in years), sex (female or male), ethnicity (White or non-White), educational attainment (college/university degree or other degrees), Townsend deprivation index (TDI), number of siblings, and family history of depression. The TDI is a composite measure of socioeconomic deprivation, incorporating housing conditions, social class by zip code, and employment status; higher values indicate lower socio-economic status [43]. The number of siblings was calculated by summing the total number of both adopted and biological sisters/brothers, and then categorized into four groups: no siblings, one sibling, two siblings, or three or more siblings. Family history of depression was defined as having at least one family member (e.g., mother, father, or sibling) with a documented history of depression. In this study, participants with missing values for any covariate were excluded to ensure the integrity and comparability of the data.

Statistical analysis

Descriptive analysis was conducted to evaluate the sociodemographic characteristics, overall and by depression, using means with standard deviation (SD) for continuous variables and numbers with percentages for categorical variables. Multivariate logistic regression was used to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) for the associations between childhood maltreatment scores (both as a continuous variable and ordinal variable: 0, 1, 2, 3, 4, and 5) and depression risk. Separate analyses were performed for childhood maltreatment subtypes and their associations with depression using multivariate logistic regression. For all analyses, participants with a childhood maltreatment score of 0 served as the reference group, and a sequence of regression models were constructed: (1) adjusted for birth year, sex, and ethnicity; (2) further adjusted for educational attainment and TDI; (3) further adjusted for the number of siblings, and family history of depression.

Path analysis was conducted to explore potential pathways linking childhood maltreatment scores (as a continuous variable) to depression, allowing for statistical

inference of hypothesized relationships between variables. Four potential indirect effect paths were first constructed, including four mediators—lifestyle factors, personality traits, adult traumas, and social connections. Indirect effects were represented by a chain of paths, such as childhood maltreatment scores → lifestyle factors → depression, with corresponding path coefficients “a” for childhood maltreatment scores → lifestyle factors, and “b” for lifestyle factors → depression, which were equivalent to standard regression coefficients. Specifically, in the path analysis of childhood maltreatment scores → lifestyle factors → depression, smoking status and drinking habits were considered as categorical variables, while sedentary behavior, diet score, sleep quality, BMI, and physical activity were considered as continuous variables. For the pathway of childhood maltreatment scores → personality traits → depression, all five variables representing personality traits were used as continuous variables. For pathways of childhood maltreatment scores → adult traumas → depression and childhood maltreatment scores → social connections → depression, the five respective variables representing adult traumas and social connections were used as categorical variables in the paths.

A three-step analysis was performed to identify mediating variables. First, multivariate logistic regression was used to calculate ORs and 95% CIs for the associations between childhood maltreatment scores and two lifestyle variables (smoking status, drinking habits), all adult traumas and social connections variables, adjusting for sex, birth year, ethnicity, educational attainment, TDI, number of siblings, and family history of depression. Beta coefficients and 95% CIs for the associations between childhood maltreatment scores and other lifestyle factors (sedentary behavior, diet score, sleep quality, BMI, and physical activity), and five personality traits were determined through multivariate linear regression adjusted for the same covariates. Second, multivariate logistic regression was used to assess the associations of mediators with depression risk. Third, mediation analysis was performed on lifestyle factors, personality traits, adult traumas, and social connections significantly associated with childhood maltreatment scores and depression [44]. The R package “mediation” with 1000 simulations was used to estimate the mediation proportions and corresponding 95% CIs, adjusting for sex as per previous studies [30]. In addition, we implemented the four-way effect decomposition proposed by Discacciati et al. [45] to disentangle mediation-interaction dynamics. This approach quantifies (i) pure direct effects, (ii) pure interaction effects, (iii) mediated interaction effects, and (iv) pure mediation effects, to ensure non-overlapping quantification of pathway-specific contributions.

Structural equation modeling (SEM) was constructed to explore the relationships between childhood maltreatment scores, lifestyle factors, personality traits, adult traumas, social connections, and depression, aiming to elucidate the potential mechanisms linking childhood maltreatment scores to depression. In order to reduce the measurement error between factors representing respective mediators [46], four latent variables were created using confirmatory factor analysis in the SEM [47]. The latent variables were derived from factors significantly associated with both childhood maltreatment scores and depression in the SEM, and the results were presented as standardized coefficients using the R “Lavaan” package. The goodness of fit model was assessed using several statistics including Comparative Fit Index (CFI), Goodness-of-Fit Index (GFI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR).

Several sensitivity analyses were conducted. First, childhood maltreatment scores for sexual abuse, emotional abuse, and physical abuse were assigned values from 0 to 4, representing the responses from “never true” to “very often true”; the scores for physical neglect and emotional neglect were reversed. The cumulative childhood maltreatment scores (ranging from 0 to 20) were calculated as the sum of these five questions (0–4 for each question); in primary analysis, cumulative and specific-type childhood maltreatment scores were considered as continuous variables. An alternative grouping strategy, such as a binary variable (childhood maltreatment scores ≥ 2 , <2 [reference group]), or multiple categorical variables (childhood maltreatment scores ≥ 2 , 1, 0 [reference group]), was used. Second, depression was assessed using the Patient Health Questionnaire-9 (PHQ-9) questionnaires, and response ranged from “not at all” to “almost every day” scored from 0 to 3, respectively, for a cumulative score of 0–27. As described in previous study, a score of 10 or higher was used to define depression [48]. Third, participants who developed depression within the first 2 years following the baseline survey were excluded to minimize reverse causality. Fourth, the missing data for all covariates were imputed using multiple imputation by chained equations approach to assess its effect. Finally, several stratified analyses were conducted to examine the associations between childhood maltreatment subtype and depression by age (≤ 60 or > 60 years), sex (female or male), and TDI (low socioeconomic status or high socioeconomic status); significant differences in the stratified analysis were further assessed by including an interaction term into models to examine whether the associations varied by these factors.

All the analyses were conducted using STATA 16 statistical software and R software (version 4.1.3). The statistical significance was set as $P < 0.05$ (two-sided test).

Results

Baseline characteristics of participants

In our analytic sample of 109,401 participants (mean [SD] age at baseline, 55.75 [7.76] years; 58,315 [53.30%] females), including 48,923 (44.71%) reported experiencing at least one form of childhood maltreatment, while 9252 (8.45%) reported experiencing childhood maltreatment more than three times. Among the participants, 5545 (5.1%) had depression. There were substantial differences in the characteristics of those with and without depression—a higher proportion of depressive participants experienced at least one childhood maltreatment and had a family history of depression. Participants with depression were more likely to be younger and female and have a higher TDI score (Table 1).

Associations between childhood maltreatment scores and depression

The risk of depression increased with childhood maltreatment scores, and adjustment for educational attainment and TDI made little difference to this association. Adjustment for the number of siblings and family history of depression slightly attenuated the association but remained significant (OR 1.28, 95% CI 1.25 to 1.31, Table 2). This association was similar when childhood maltreatment scores were treated as a categorical variable, with the highest risk of depression among participants with a childhood maltreatment score of five (3.47, 2.82 to 4.26, in the fully adjusted model). Furthermore, comparable estimates showed that the strongest childhood maltreatment types associated with depression were emotional abuse (1.88, 1.76 to 1.89) and emotional neglect (1.78, 1.67 to 1.89, Table 2).

Relationships between childhood maltreatment and multiple-dimensional factors

In the association analyses adjusting for all covariates, childhood maltreatment scores and each childhood maltreatment subtype were independently associated with four mediators and almost all factors within these mediators, although the direction of associations varied (Fig. 1, Additional file 1: Table S7). For example, the childhood maltreatment scores were positively associated with sedentary behavior (β 0.13, 95% CI 0.12 to 0.15), diet score (0.01, 0.01 to 0.02), BMI (0.27, 0.24 to 0.29), and physical activity (0.02, 0.01 to 0.02), but negatively related to smoking status (-0.16 , -0.18 to -0.14) and sleep quality (-0.04 , -0.04 to -0.03). For personality traits, the childhood maltreatment scores showed a positive relationship

Table 1 Baseline characteristics of the study population

Characteristics	Depression		Overall (<i>n</i> = 109,401)
	No (<i>n</i> = 103,856)	Yes (<i>n</i> = 5545)	
Birth years, years (SD)	1952.38 (7.75)	1952.83 (7.86)	1952.40 (7.75)
Age, mean (SD)	55.77 (7.76)	55.31 (7.86)	55.75 (7.76)
Sex, female (%)	54,662 (52.63%)	3653 (65.88%)	58,315 (53.30%)
Ethnicity, <i>n</i> (%)			
White	101,133 (97.38%)	5426 (97.85%)	106,559 (97.40%)
Non-white	2723 (2.62%)	119 (2.15%)	2842 (2.60%)
TDI, mean (SD)	− 1.79 (2.78)	− 1.47 (2.99)	− 1.78 (2.79)
Educational attainment, <i>n</i> (%)			
College or university	53,002 (51.03%)	3178 (57.31%)	56,180 (51.35%)
Other degrees	50,854 (48.97%)	2367 (42.69%)	53,221 (48.65%)
Number of siblings, <i>n</i> (%)			
0	12,900 (12.42%)	688 (12.41%)	13,588 (12.42%)
1	30,926 (29.78%)	1582 (28.53%)	32,508 (29.71%)
2	27,088 (26.08%)	1415 (25.52%)	28,503 (26.05%)
≥ 3	32,942 (31.72%)	1860 (33.54%)	34,802 (31.81%)
Childhood maltreatment scores, <i>n</i> (%)			
0	58,098 (55.94%)	2380 (42.92%)	60,478 (55.28%)
1	26,240 (25.27%)	1420 (25.61%)	27,660 (25.28%)
2	11,181 (10.77%)	830 (14.97%)	12,011 (10.98%)
3	5210 (5.02%)	526 (9.49%)	5736 (5.24%)
4	2475 (2.38%)	276 (4.98%)	2751 (2.51%)
5	652 (0.63%)	113 (2.04%)	765 (0.70%)
Family history of depression, <i>n</i> (%)	14,272 (13.74%)	1256 (22.65%)	15,528 (14.19%)
Follow time (years)	14.10 (1.03)	9.73 (4.58)	13.88 (1.73)

SD standard deviation, TDI Townsend deprivation index

with nervousness (0.14, 0.13 to 0.15), whereas the childhood maltreatment scores showed a negative relationship with warmth (−0.16, −0.17 to −0.15), curiosity (−0.09, −0.10 to −0.09), sociability (−0.03, −0.03 to −0.02), and diligence (− 0.09, −0.09 to −0.09). Detailed results for childhood maltreatment subtype are provided in Additional file 1: Table S7.

Associations with lifestyle factors, personality traits, adult traumas, social connections, and depression

As shown in Additional file 1: Table S8, the lifestyle factors including longer sedentary time (OR 1.07, 95% CI 1.06 to 1.08), higher BMI (1.05, 1.04 to 1.06), and being a current drinker (1.16, 1.08 to 1.24) were associated with higher risk of depression in middle-aged and elderly people, whereas nonsmokers (0.68, 0.62 to 0.75) and better sleep quality (0.76, 0.73 to 0.79) were associated with a lower risk. Among personality traits, nervousness (1.49, 1.46 to 1.52) was associated with an increased risk of depression, whereas warmth (0.69, 0.67 to 0.70), curiosity (0.60, 0.58 to 0.62), sociability (0.62, 0.60 to 0.64), and diligence (0.71, 0.69 to 0.73) were associated with reduced

risks. Adult traumas were associated with an elevated risk of depression, with ORs ranging from 1.27 to 1.69 across different types of trauma. In addition, social connections such as absence of loneliness (OR 0.44, 95% CI 0.41 to 0.47), family visits (0.89, 0.80 to 0.98), confiding in others (0.82, 0.76 to 0.88), participation in leisure activities (0.79, 0.75 to 0.84), and not living alone (0.83, 0.77 to 0.89) were consistently and significantly associated with a reduced risk of depression.

Mediation analysis

The mediation of lifestyle factors, personality traits, adult traumas, and social connections in the associations between childhood maltreatment scores and depression in middle-aged and elderly people are shown in Fig. 2 and Additional file 1: Tables S9–12. BMI explained the largest proportion of the association between childhood maltreatment scores on depression among lifestyle factors (4.8%, 95% CI 3.9 to 6.0%). For personality traits, warmth accounted for 21.5% (19.2 to 24.0%), curiosity for 5.3% (4.4 to 6.0%), sociability for 14.7% (13.2 to 17.0%), nervousness for 18.2% (16.3 to 21.0%), diligence for 10.4% (9.0

Table 2 The association of childhood maltreatment scores and childhood maltreatment subtype with depression risk

Childhood maltreatment	Events	OR (95% CIs) ^a		
		Model 1	Model 2	Model 3
Childhood maltreatment subtypes				
Physical neglect	1140	1.54 (1.44, 1.65)	1.49 (1.39, 1.59)	1.46 (1.36, 1.56)
Emotional neglect	1778	1.88 (1.78, 2.00)	1.85 (1.74, 1.96)	1.78 (1.67, 1.89)
Sexual abuse	718	1.56 (1.44, 1.69)	1.54 (1.42, 1.67)	1.48 (1.36, 1.61)
Physical abuse	1303	1.45 (1.35, 1.54)	1.42 (1.33, 1.51)	1.37 (1.29, 1.47)
Emotional abuse	1388	1.99 (1.87, 2.12)	1.96 (1.84, 2.09)	1.88 (1.76, 2.00)
Childhood maltreatment scores (continuous, 0–5)				
0	2315	1 (Reference)	1 (Reference)	1 (Reference)
1	1373	1.34 (1.26, 1.44)	1.33 (1.24, 1.42)	1.31 (1.22, 1.40)
2	795	1.82 (1.68, 1.98)	1.78 (1.64, 1.94)	1.73 (1.59, 1.88)
3	510	2.42 (2.19, 2.67)	2.35 (2.12, 2.59)	2.25 (2.03, 2.48)
4	267	2.64 (2.31, 3.01)	2.53 (2.22, 2.89)	2.40 (2.10, 2.74)
5	108	3.91 (3.18, 4.80)	3.73 (3.04, 4.59)	3.47 (2.82, 4.26)
Per 1 increment	5545	1.31 (1.29, 1.34)	1.30 (1.27, 1.33)	1.28 (1.25, 1.31)

Model 1, adjusted for sex, birth year (years), and ethnicity (White or others)

Model 2, further adjusted for qualification (college/university or others), and TDI

Model 3, further adjusted for number of siblings (including biological and adopted siblings), and family history of depression (yes or no)

OR odd ratio, CIs confidence intervals, TDI/Townsend deprivation index

^a Odd ratios with 95% CI were derived from logistic regression

to 12.0%), and collectively explained 70.1% of the association. Similarly, adult traumas significantly mediated the association between childhood maltreatment scores and depression, with adult confiding explaining 11.9% (9.8 to 14.0%) and being belittled explained 6.7% (5.0 to 8.0%). For social connections, absence of loneliness explained the largest proportion of the association (13.4%, 11.6 to 15.0%). Notably, exposure-mediator interactions predominantly function as modifiers of effect magnitude rather than direction. The directions of all pure mediator effects are consistent with the mediation analysis and significant mediated effects, although some factors exhibit significant interaction terms (Additional file 1: Table S13).

Pathway analysis between childhood maltreatment scores and depression mediated by lifestyle factors, personality traits, adult traumas, social connections

Goodness-of-fit statistics for confirmatory factor analysis indicated a relatively strong fit (GFI = 0.970, CFI = 0.922, RMSEA = 0.035, and SRMR = 0.031, Additional file 1: Table S14), and the factor loadings were relatively strong and statistically significant. The primary components of the lifestyle latent variable were identified as smoking status (β 0.17, $P < 0.001$), sedentary behavior (β - 0.42, $P < 0.001$), sleep quality (β 0.19, $P < 0.001$), BMI (β - 0.34, $P < 0.001$), and drinking habit (β 0.07, $P < 0.001$). The latent variable for personality traits, the factors included

warmth (β 0.59, $P < 0.001$), curiosity (β 0.45, $P < 0.001$), sociability (β 0.56, $P < 0.001$), nervousness (β - 0.59, $P < 0.001$), and diligence (β 0.35, $P < 0.001$). The adult traumas latent variable was represented by adult confiding (β 0.57, $P < 0.001$), physical violence (β 0.21, $P < 0.001$), belittlement (β 0.54, $P < 0.001$), sexual interference (β 0.54, $P < 0.001$), and financial security (β 0.19, $P < 0.001$). Additionally, loneliness was identified as the primary component of social health latent variable (β 0.67, $P < 0.001$, Additional file 1: Table S15).

These latent variables were subsequently included in the SEM to evaluate their mediating effects on the associations between childhood maltreatment scores and depression. As shown in Fig. 3, after adjusting for covariates, there was a significant positive indirect relationship between childhood maltreatment scores and depression as mediated by adult traumas (β 0.50, $P < 0.001$), and significant negative indirect effects as mediated by lifestyle factors (β - 0.15, $P < 0.001$), personality traits (β - 0.12, $P < 0.001$), and social connections (β - 0.19, $P < 0.001$). No significant direct effects of childhood maltreatment scores were found on depression.

Sensitivity analyses and stratified analyses

First, whether we used a cumulative childhood maltreatment score range of 0–20, grouped participants with childhood maltreatment scores of 2 or more versus those with less than 2, or compared those with no childhood

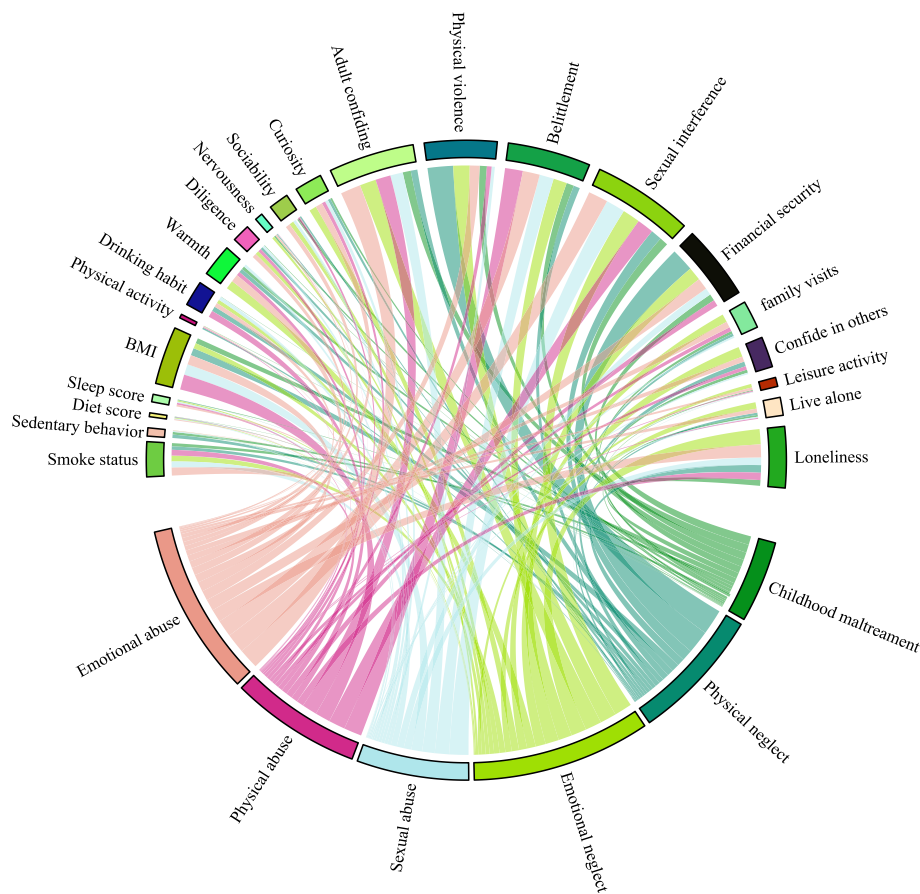


Fig. 1 Relationships between the childhood maltreatment scores, lifestyle factors, personality traits, adult traumas, and social connections. Each connection in the chord diagram reflects a statistical relationship between childhood maltreatment scores, childhood maltreatment subtypes, and 22 variables across lifestyle factors, personality traits, adult traumas, and social connections, based on data from the UK Biobank database. Continuous variables, such as sedentary behavior, diet score, sleep quality, BMI, physical activity, and personality traits, were modeled using multivariate linear regression to calculate standard regression coefficients and 95% CIs. For other lifestyle factors, adult traumas, and social connections variables, multivariate logistic regression was applied to estimate the odds ratios and corresponding 95% CIs. All analyses were adjusted for sex, birth year, ethnicity, education attainment, TDI, number of siblings, and family history of depression. Confiding: Been in a confiding relationship as an adult; Physical violence: Physical violence by partner or ex-partner as an adult; Belittlement: Belittlement by partner or ex-partner as an adult; Sexual interference: Sexual interference by partner or ex-partner without consent as an adult; Financial security: Able to pay rent/mortgage as an adult; Visit frequency: Frequency of friend/family visits; Confide: Able to confide; Leisure activity: Leisure/social activities; Live alone: Number in household; Lonely: Loneliness, isolation. *BMI* body mass index, *CIs* confidence intervals, *TDI* Townsend deprivation index

maltreatment to those with scores of 1 or 2 and above, the findings did not change (Additional file 1: Tables S16 and 17). Second, the relationship between childhood maltreatment scores and depression symptoms, as measured by PHQ-9, remained consistent with the main analysis (Additional file 1: Table S18). Third, participants who experienced emotional neglect (OR 2.85, 95% CI 2.67 to 3.03) or emotional abuse (OR 2.78, 95% CI 2.61 to 2.97) had the highest risk of depression. Excluding participants with depression in the last 2 years did not materially change the results (Additional file 1: Table S19). Fourth, multiple imputation to address the missing values of selected mediators yielded largely similar results

(Additional file 1: Table S20). Stratified analyses showed a more pronounced association of emotional neglect scores with depression among participants aged ≤ 60 years than those aged > 60 years (P for interaction = 0.001) (Additional file 1: Table S21), while the associations between childhood maltreatment scores and risk of depression were not modified by sex and TDI (P values for interaction > 0.05) (Additional file 1: Tables S22 and 23).

Discussion

In this study, we found that higher childhood maltreatment scores, as well as each subtype of childhood maltreatment, were associated with an increased risk of

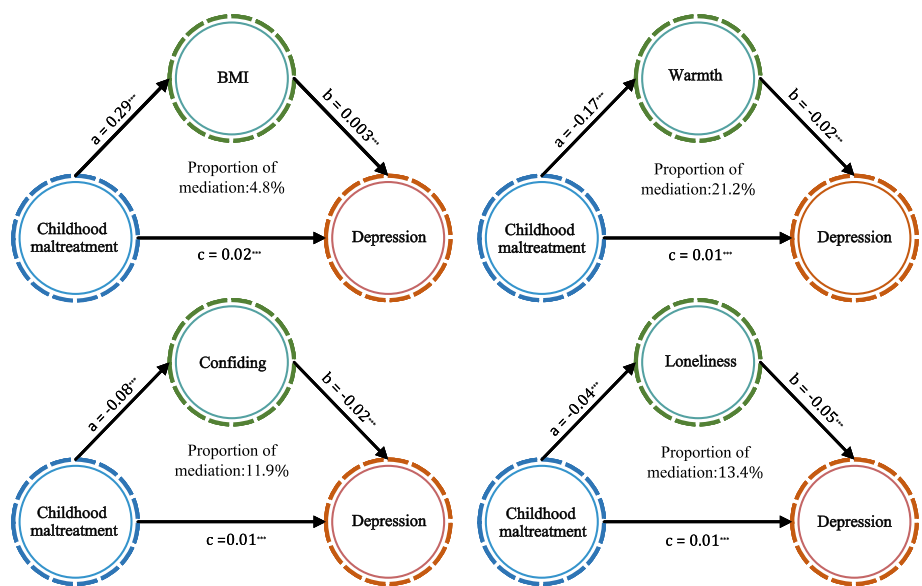
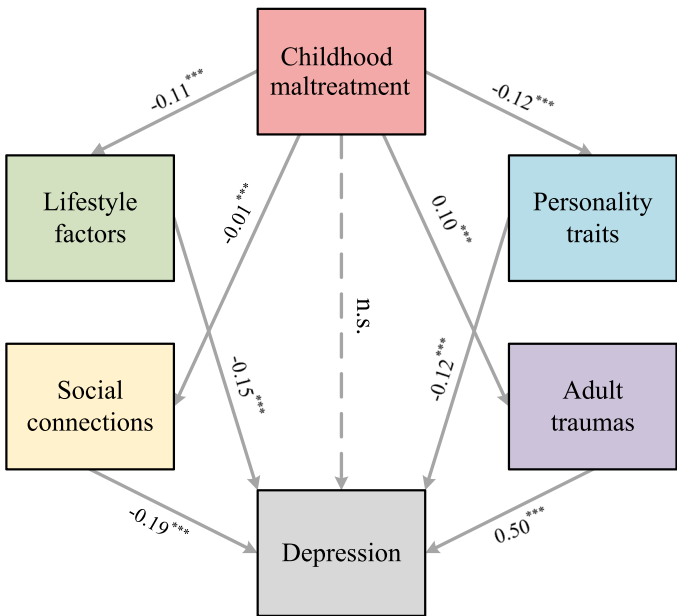


Fig. 2 Mediation effects of lifestyle factors, personality traits, adult traumas, and social connections on the association of childhood maltreatment scores with risk of depression. The mediation analysis was performed with the R package mediation with 1000 simulations, and data were standardized regression coefficients with adjustment for covariates. Covariates included sex only. The red circles indicate exposure variable, blue circles indicate outcome, and green circles indicate mediators. *a*: standardized regression coefficients from childhood maltreatment to mediators; *b*: standardized regression coefficients from mediators to depression; *c*: standardized regression coefficients from childhood maltreatment to depression. **P* < 0.05, ***P* < 0.01, ****P* < 0.001



Childhood maltreatment	1.00	Depression	1.00
Lifestyle factors		Adult traumas	
Current non-smoker	0.17	Adult confiding	0.43
Sedentary time	-0.42	Physical violence	0.28
Sleep score	0.19	Belittlement	0.33
BMI	-0.34	Sexual interference	0.33
Drinking habit	0.07	Financial security	0.21
Personality traits		Social connections	
Warmth	0.59	Family visits	0.11
Curiosity	0.45	Confide in others	0.17
Sociability	0.56	Leisure activity	0.06
Nervousness	-0.58	Live alone	0.19
Diligence	0.35	Loneliness	0.67

Fig. 3 Path analysis using structural equation modeling of depression associated with childhood maltreatment scores. Data represent standardized β -coefficient values. Latent variables, including lifestyle factors, personality traits, adult traumas, and social connections, are represented by magenta, pink, grey, green, and blue ellipses, respectively. Solid arrows indicate statistically significant paths, and dotted arrows indicate nonsignificant paths. **P* < 0.05, ***P* < 0.01, ****P* < 0.001

depression in middle-aged and elderly people, particularly emotional abuse and emotional neglect. These findings highlight the importance of Routine Enquiry about Adversity in Childhood training program in raising awareness of childhood maltreatment to enhance public health efforts in the UK [49] and emphasize the potential of prevention and early intervention to mitigate the long-term adverse impacts of childhood maltreatment. Moreover, the associations between childhood maltreatment and depression were mediated by lifestyle factors, personality traits, adult traumas, and social connections, rather than a direct effect of childhood maltreatment scores on depression. These findings suggest potential avenues for secondary prevention strategies when childhood maltreatment is identified (Fig. 4).

The associations between childhood maltreatment, childhood maltreatment subtype, and depression have been extensively studied worldwide. Our findings

corroborate previous studies showing that individuals who have experienced childhood maltreatment are at a higher risk of depression compared to those who have not experienced childhood maltreatment [50–52]. In addition, our results align with those of a 2023 meta-analysis that reported a dose–response relationship between the number of childhood maltreatment experiences and the risk of depression, with a more pronounced increase in individuals with high childhood maltreatment scores compared to those with lower scores.

By examining the indirect effects of childhood maltreatment on depression through multiple and parallel pathways, our study identified four potential pathways that elucidate how adult psychological and social variables mediate these associations. The SEM indicated that a healthy lifestyle buffers the psychological impacts of childhood maltreatment, revealing a complex relationship between childhood maltreatment and health

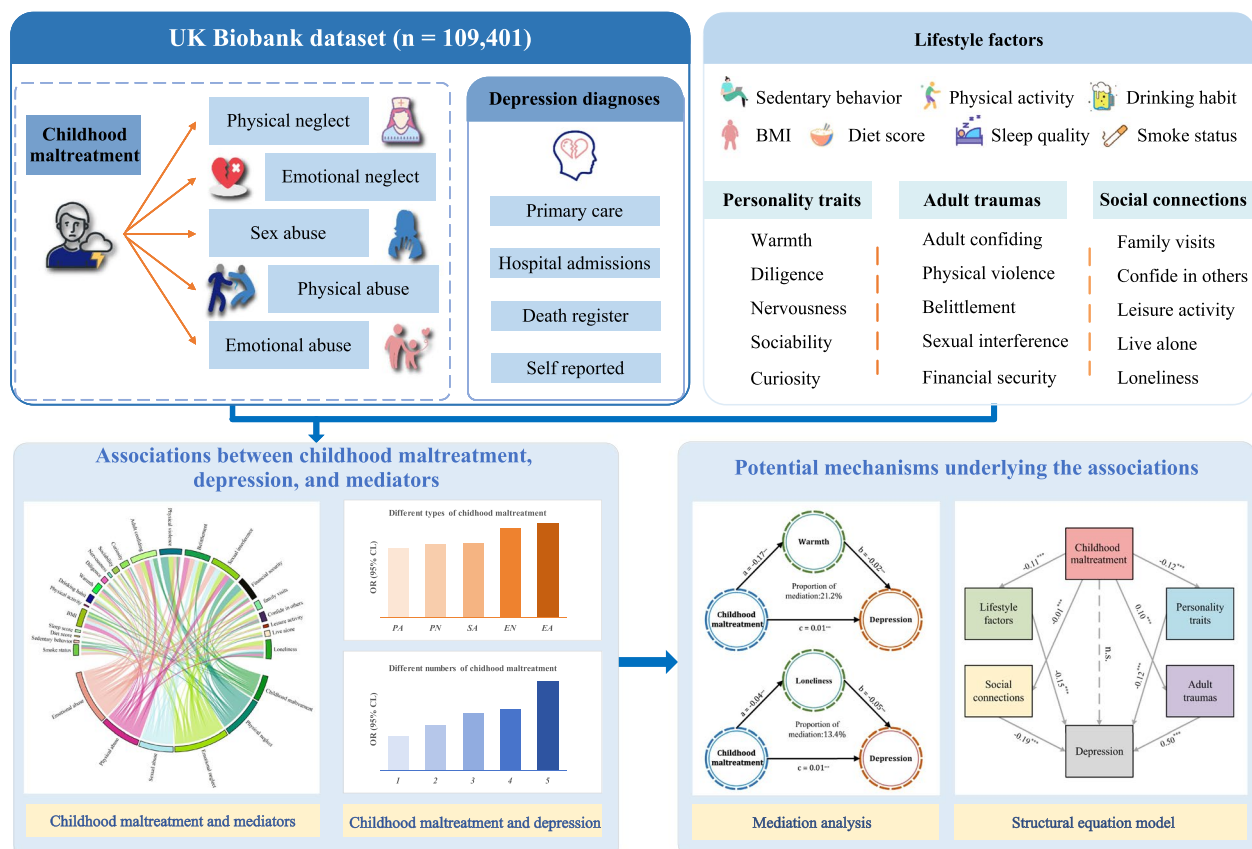


Fig. 4 Summary of the study. The study includes 109,401 participants from the UK Biobank to explore the association between childhood maltreatment, lifestyle factors, personality traits, adult traumas, and social connections and depression. The top two boxes present the definition of exposure, outcome, and mediators variables. The childhood maltreatment data in this study were obtained from Childhood Trauma Questionnaires and included five questions. The mediators of interest were lifestyle factors, personality traits, adult traumas, and social connections. Bottom left, regression models, including logistic and linear models, were used to examine the associations of childhood maltreatment and mediators and depression. The thickness of the string and the height of the column respectively reflect the strength of the correlation. Bottom right, we estimated the mediating effects for childhood maltreatment–depression association. OR odds ratio; CI confidence interval

behaviors. Individuals who have experienced childhood maltreatment may be more aware of health risks. Health behaviors, as a form of self-regulation or stress management, can alleviate the psychological stress associated with childhood maltreatment by improving a healthier diet and increasing physical activity [53, 54]. Moreover, positive personality traits such as warmth and sociability could foster adaptive coping mechanisms. Conversely, the adverse effects of childhood maltreatment are compounded by traumatic events in adulthood, further increasing the risk of depression, but strong social networks can alleviate these negative effects.

Clinical implications

Our findings suggest that lifestyle factors, including smoking status, sedentary behavior, sleep quality, BMI, and drinking habits, might mediate the association between childhood maltreatment and depression. There is some evidence that individuals with a history of childhood maltreatment were more likely to engage in unhealthy lifestyles, such as frequent smoking, physical inactivity, and inadequate sleep, which increased their risk of depression [55, 56]. The underlying mechanisms linking an adverse lifestyle to depression risk are intricate and multifaceted, involving genetic, behavioral, and neurobiological aspects. A previous study demonstrated that these unfavorable lifestyle factors might disrupt neurotransmitter processes and immuno-inflammatory pathways, both of which have been associated with depression [57]. Specifically, life stressors such as inadequate physical activity and sleep deprivation are associated with altered metabolite levels and may contribute to the onset and exacerbation of depressive symptoms through dysregulated immune metabolism [58]. Additionally, candidate genes for depression are primarily concentrated in the neurotransmitter systems, the hypothalamic–pituitary–adrenal (HPA) axis, and brain-derived neurotrophic factor (BDNF). Genetic variants can lead to structural and functional abnormalities in brain regions involved in emotion regulation, cognitive control, and reward processing, thereby influencing the development of psychiatric disorders [59, 60]. This also reveals a possible complex mechanism between childhood maltreatment and health behaviors. Participants who have experienced childhood maltreatment may be more aware of health risks. Health behaviors, as a form of self-regulation or stress management, can alleviate the psychological stress associated with childhood maltreatment by promoting a healthier diet and increasing physical activity [53, 54].

A plausible mechanism underlying personality traits indicates that childhood maltreatment is associated with reduced levels of warmth, curiosity, sociability, diligence, and increased nervousness. These factors are also

linked to an elevated risk of depression. Childhood maltreatment and chronic psychological stress have been associated with immediate emotional distress but also profoundly shape children's worldview and interpersonal relationships [61, 62]. These experiences may contribute to the development of maladaptive personality traits and dysfunctional cognitive patterns [19, 56, 63], making it difficult to manage stress and regulate emotions effectively [64], ultimately increasing the risk of depression. For instance, sociability can mitigate stress through engagement in multiple social activities aimed at reducing depressive symptoms [65], whereas heightened neuroticism, coupled with low conscientiousness and extraversion, may reduce resilience, thereby increasing vulnerability to depression [66]. Previous research findings have shown discrepancies. A study on adults showed that neuroticism, extraversion, conscientiousness, and agreeableness play a minor mediating role between childhood maltreatment and early-onset depression [67]. Conversely, a cross-sectional study involving participants aged 10–17 years found that only neuroticism and extraversion mediated this relationship [64]. These discrepancies may be attributed to differences in childhood maltreatment measurement tools, study design (longitudinal vs. cross-sectional), and the demographic characteristics of the study population (adolescents vs. adults).

The exploration of social connections as a potential mediator between childhood maltreatment and depression reveals significant insights. Social connections and support are critical for mental health and overall well-being [68]. Childhood maltreatment can hinder the development of adult social networks and the ability to adapt to societal norms [69], which may limit access to social connections and increase vulnerability to depression and other psychiatric conditions in adulthood [70, 71]. Emotional neglect and the stigma associated with abuse have been linked to personal insecurity [71], unsatisfactory social interactions, and negative attitudes towards seeking social connections [72]. These findings align with our results, highlighting their mediating role and emphasizing their importance in addressing depression stemming from childhood maltreatment. Moreover, the presence of traumatic events may narrow differences in social connections between the sexes, making it possible for both men and women to benefit from increased social connections in their psychological responses to trauma exposure [73]. Given the changing environment, whether there are differences in access to social connections among transgender people who experience childhood maltreatment still deserves further exploration.

The interplay among these adult factors suggests a dynamic system in which the absence or presence of one factor is significantly associated with the trajectory

of depressive symptoms. The underlying mechanisms likely entail complex interactions among psychological, social, and environmental processes that shape an individual's resilience to depressive disorders. Our study is pioneering in demonstrating the joint mediation effects of lifestyle, personality traits, adult traumas, and social connections. These factors, which are associated with childhood maltreatment, collectively show statistical associations with depression in our analysis, though the direct pathway from childhood maltreatment to depression is not significant. The prevention and management of depression should prioritize improving daily habits, such as maintaining regular sleep patterns and engaging in moderate exercise, to fortify physiological health. Additionally, fostering positive personality traits, including optimism and resilience, can equip individuals with the necessary psychological resources to manage challenges effectively and reduce the risk of depression. Furthermore, fostering close interpersonal relationships and expanding social networks can mitigate feelings of loneliness and provide emotional support. For individuals with a history of secondary trauma, particular attention is required to address their psychological well-being through early interventions, thereby mitigating potential long-term effects. Finally, implementing interventions such as psychological counseling and cognitive-behavioral therapy, coupled with enhanced mental health education, can alleviate depressive symptoms and challenge social stigma.

Strengths and limitations

The study was conducted based on the UKB cohort, which possesses several strengths. The utilization of this database inherently offers advantages such as prospective design, large sample size, and rich, diverse data sources to explore the multi-domain mediating mechanisms of lifestyle, personality traits, adult traumas, and social connections simultaneously in the association between childhood maltreatment and depression. Nevertheless, the study also has certain limitations. First, given that the majority of participants were White and considering the potential healthy volunteer effect, the sample may not be representative of the general population, particularly individuals from other racial or ethnic groups. Second, although this study attempted to adjust for potential confounding factors as comprehensively as possible, unmeasured pre-exposure confounders that influence both mediators and outcomes (e.g., baseline personality traits) may still introduce residual bias. Third, although we cannot establish a causal relationship between childhood maltreatment and depression using cross-sectional data, the relatively good model fit allows us to infer potential associations between childhood adversity

and depression. Fourth, in the present study, the measurement of childhood maltreatment was predicated on retrospective self-reporting in adulthood, which may introduce recall bias, potentially distorting the observed associations. However, existing studies have confirmed the consistency between retrospective and prospective measurements of childhood maltreatment and have identified it as having strong psychometric properties and temporal stability [74, 75]. Thus, further prospective cohort studies and objective measurements are urgently needed to measure childhood maltreatment early in life. Fifth, the cross-sectional data may not fully capture dynamic changes in lifestyle factors, personality, adult traumas, and social connections over time, potentially resulting in reporting bias. Longitudinal assessments may help provide deeper insights into the progressive effects of childhood maltreatment on depression development and strengthen causal inferences. Sixth, although the definitions of personality traits do not strictly align with the standard BFI assessment scales, the UKB questionnaires provide validated and reliable estimates of the BFI for participants, as confirmed by studies cited in other contexts [16]. Seventh, given the potential for complex interactions between exposure and mediators in this study, caution is needed when interpreting the mediation results. Despite these complexities, significant pure indirect effects were observed. Eighth, the potential multicollinearity among variables and reliance on linear assumptions in SEM may affect parameter stability, rendering the analysis exploratory in nature. Moreover, our findings were limited to individual characteristics, social and environmental factors at both the meso and macro-levels, which may overlook the role played by biomarkers and brain MRI indicators at the micro-level, which are associated with childhood maltreatment and depression. Future research with comprehensive consideration is encouraged to expand our exploration of various dimensional factors to mitigate the adverse effects of childhood maltreatment on depression.

Conclusions

In conclusion, this large-scale cohort study offers valuable insights into the association between childhood maltreatment and depression. The findings indicate that childhood maltreatment is significantly associated with an increased risk of depression, particularly emotional neglect and emotional abuse. Lifestyle factors, personality traits, adult traumas, and social connections in adulthood may act as potential mediators in the relationship between childhood maltreatment and depression. These results have important implications for enhancing the understanding, care, and treatment of individuals with a history of childhood maltreatment.

By emphasizing the role of social and environmental factors, this study highlights promising avenues for targeted interventions, thereby contributing to improved mental health outcomes for affected individuals.

Abbreviations

BDNF	Brain-derived neurotrophic factor
BMI	Body mass index
CFI	Comparative Fit Index
CI	Confidence interval
CTS	Childhood Trauma Screener
GFI	Goodness-of-Fit Index
HPA	Hypothalamic-Pituitary-Adrenal
IPAQ	International Physical Activity Questionnaire
MET	Metabolic equivalent task
OR	Odds ratio
PHQ-9	Patient Health Questionnaire-9
RMSEA	Root Mean Square Error of Approximation
SD	Standard deviation
SEM	Structural equation modeling
SRMR	Standardized Root Mean Square Residual
TDI	Townsend deprivation index
UK	United Kingdom
UKB	UK Biobank

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12916-025-04147-2>.

Additional file 1: Table S1. Assessment of childhood maltreatment. Table S2. Assessment of lifestyle factors. Table S3. Assessment of personality traits. Table S4. Assessment of adult traumas. Table S5. Reliability analysis of childhood maltreatment and adult traumas scales. Table S6. Assessment of social connections. Table S7. Association of childhood maltreatment scores and childhood maltreatment subtype with all potential mediators. Table S8. Association between potential mediators and adult depression. Table S9. Mediation effects of lifestyle factors on the association of childhood maltreatment scores and adult depression. Table S10. Mediation effects of personality traits on the association of childhood maltreatment scores and adult depression. Table S11. Mediation effects of adult traumas on the association of childhood maltreatment scores and adult depression. Table S12. Mediation effects of social connections on the association of childhood maltreatment scores and adult depression. Table S13. 4-way decomposition analysis of lifestyle factors, personality traits, adult traumas, social connections in the association of childhood maltreatment and depression. Table S14. Model fitting index. Table S15. Confirmatory factor analysis results. Table S16. Sensitivity analyses of associations of cumulative childhood maltreatment scores with adult depression. Table S17. Sensitivity analyses of association between different levels of childhood. Table S18. Sensitivity analyses of association between childhood maltreatment as measure by PHQ-9 and adult depression. Table S19. Sensitivity analyses of association between childhood maltreatment and adult depression by excluding participants with depression in the last two years. Table S20. Sensitivity analysis of associations of childhood maltreatment with risk of depression after interpolating the covariates. Table S21. Associations of childhood maltreatment scores with adult depression, stratified by age. Table S22. Associations of childhood maltreatment scores with adult depression, stratified by sex. Table S23. Associations of childhood maltreatment scores with adult depression, stratified by TDI. Figure S1. Flowchart of study participant.

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Authors' contributions

XW and ZC conceived, designed, conduct of the study and the analysis and interpretation of the results, and wrote the first draft of the manuscript. CX and TS conceived, designed, conduct of the study and the analysis and interpretation of the results and secured funding. TD and SY have made critical revisions to the manuscript for important intellectual content. CX is the guarantor of this work. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The studies involving human participants were reviewed and approved by NHS National Research Ethics Service (NW/0382). Patients/participants provided their written informed consent to participate in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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