REVIEW

# Child Maltreatment and Metabolic Syndrome: A Systematic Review

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**Background:** Evidence suggests that child maltreatment (CM) is associated with an elevated risk of adult diseases in later life. Emerging evidence shows that CM in childhood is associated with metabolic syndrome (MetS) in adulthood. However, no study has systematically examined the evidence. Hence, this review aims to synthesise the evidence on the association between forms of CM and MetS in adulthood.

**Methods:** Electronic databases of CINAHL, Medline, PsychInfo, SOCINDEX, and Scopus were systematically searched using predefined key terms to identify relevant published studies on the association between CM and MetS from the beginning of indexing to 1st January 2024. Studies were included if they met the selection criteria. The quality of studies was appraised using suitable criteria for cross-sectional and prospective studies.

**Results:** The search revealed a total of 2411 studies. Five studies met the inclusion criteria and were included in the review. The findings revealed that there was an association between physical abuse and MetS in women across two studies and one study in men. In addition, one study reported an association between emotional abuse and the risk of MetS in men, while two studies revealed increased odds with CM. However, no significant associations were reported between MetS and childhood sexual abuse and neglect, respectively.

**Conclusion:** These findings suggest that some forms of CM may increase a person's risk of having MetS. However, there is a need for methodological improvements due to heterogeneity in studies, mainly on the assessment and definition of CM. Further research is needed on forms of CM and MetS to understand the underlying mechanisms of the associations found and to identify targeted strategies to prevent the impact of CM on MetS and subsequent future health.

**Keywords:** child maltreatment, metabolic syndrome, systematic review

## Introduction

Metabolic syndrome (MetS) is made up of a group of conditions, predominantly central obesity, high blood pressure, dyslipidaemia and impaired glucose tolerance.[1–5] In addition, obesity, age, genetics and health behaviours have consistently been reported as risk factors for MetS.[6–9] Moreover, evidence of increased risk of cardiovascular disease, type II diabetes and all-cause mortality has been attributed to MetS.[2,5,10–13] In some countries, the occurrence of MetS has been widespread. It is projected to be between 20 and 25%[14] and may vary (less than 10% to as much as 84%) in the adult population depending on the region, population (age, gender and ethnicity) and definition of MetS.[15] In the UK, the data reveals that 30–34% of adults between the ages of 40 and 75 are diagnosed with MetS.[16,17] There is emerging evidence that the occurrence of MetS is growing among all populations and is expected to increase in future;[18] thus, investigating other factors, such as child maltreatment (CM), may contribute towards early prevention of MetS. CM is often incorporated within the Adverse Childhood Experience (ACE) framework. Most literature examining the effects of ACEs on poor health outcomes has often incorporated all forms of ACEs rather than examining each form. Even though this approach is valid, it may imply that their effects on health are equivalent. Alternatively, this review will synthesise evidence on a specific group of ACEs, CM, while examining its effects on MetS. Generally, there are four forms of CM: (1) emotional abuse, (2) sexual abuse, (3) physical abuse and (4) childhood neglect.[19] CM represents a significant public

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health problem as it incorporates all deliberate forms of sexual, physical, emotional and neglectful treatment, whether knowingly or unknowingly, on the part of a parent or caregiver.[20,21] Studies reporting on the consequences of CM have highlighted the significance of examining childhood experiences due to their effect on health throughout the life course.[22–27]

Available evidence shows that the consequence of CM has lasting impacts on health over the short term or later in life in a range of health conditions, including mental and physical health in adulthood. The mental health impact includes anxiety[28] and an increased use of illicit drugs, alcohol and tobacco.[29,30] The consequences of CM exposure in relation to physical health have also been reported in adulthood in many studies, such as chronic diseases and cancer,[28,31–36] autoimmune disease[37] and even childhood injury, morbidity and sometimes subsequent death.[38–40] Despite these adverse effects, no systematic reviews exist on CM and MetS. While the previous reviews have comprehensively summarised literature on the effects of childhood adversity on various health outcomes,[41–43] notably sleep disorders,[44] cancer,[45] type II diabetes[46,47] and asthma,[48] there have, to date, been no systematic reviews on the association between CM and MetS. Consequently, there is a pressing demand to examine the relationship between CM and MetS systematically and whether this relationship is independent or dependent on known factors if a relationship exists. Therefore, this review aimed to systematically review the literature by synthesising findings on forms of CM on the risk of MetS and to ascertain potential gaps for future research.

## Method

The systematic review was carried out in line with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement guidelines.[49] Specifically, after formulating the research question, a preliminary search was carried out in the Cochrane database of systematic reviews to identify any current review that might deal with the research question used in this study in line with the Centre for Reviews and Dissemination.[50]

## Inclusion and Exclusion Criteria

The inclusion criteria for the review were designed based on the Population, Exposure of interest and Outcome (PEO) methodology for quantitative reviews[51] (Table 1). For population, studies were included if they focused on CM that

**Table 1** A Summary of the Inclusion and Exclusion Criteria Based on the PEO Format

| PEO Strategy | Inclusion | Exclusion |
|---|---|---|
| Population | Cross-sectional studies, case-control studies and prospective and retrospective cohort studies; full test publications; studies published in English; reported effect size (odds ratio OR, hazard ratio HR, risk ratio RR with confidence intervals CIs) of the relationship between CM in childhood and MetS in adulthood. Agency reports, self-reports, interviews, and agency records in studies using any CM measurement; human studies and published in English. | Abstracts, Case reports, duplicate studies, editorials, reviews, grey literature, commentary, conference papers and books; studies not published in English; non-human studies. |
| Exposure | The exposure was CM, including type (physical abuse, emotional/psychological, sexual abuse and neglect) or number (one or more) of maltreatment and comparison made with individuals who did not experience CM; maltreatment happened before the age of 18 years. | Maltreatment occurred after the age of 18 years; neither physical, sexual, emotional/psychological abuse nor neglect; maltreatment happened after the age of 18 years. |
| Outcome | MetS as an outcome; a measure of MetS as defined by either WHO, NCEP or IDF; MetS occurred after age 18. Diagnosis of MetS was based on medical records. MetS happened after the age of 18 years. | The measure of MetS is not defined by either WHO, NCEP, or IDF. The diagnosis of MetS is not based on medical records; MetS occurs before the age of 18. |

**Abbreviations**: IDF, International Diabetes Federation; NCEP, National Cholesterol Education Program; WHO, World Health Organisation.

occurred in childhood; full test publications; reported effect size – odds ratio (OR), hazard ratio HR, risk ratio (RR) and with confidence intervals (CIs), of the relationship between CM in childhood and MetS in adulthood; human studies that were published in English. Exposure included all studies where the individual was subject to CM, including type (physical abuse, emotional/psychological, sexual abuse and neglect) or number (one or more) of maltreatment and comparison made with individuals who did not experience CM before the age of 18 years. The outcome of interest was MetS, which is a measure of MetS defined by the World Health Organisation (WHO), National Cholesterol Education Program (NCEP), and International Diabetes Federation (IDF). The diagnosis of MetS was based on medical records.

In addition, studies that reported estimates from similar samples and measures were scrutinised, and studies that best represent the population and inclusion criteria were considered. Meanwhile, agency reports, self-reports, interviews, and agency records in studies on CM were also considered relevant for inclusion. This review adopted the definition of CM as drawn from the WHO.[52] This is because successive primary research and reviews on adversity in childhood have been guided by this definition.[53]

## Search Strategy

The objective of the search strategy is to produce wide-ranging published primary articles that are appropriate for answering the research question. This is a vital aspect which can lead to the validity of the outcome.[50] At the same time, Polit and Beck suggested bibliography databases to be a good source for identifying peer-reviewed literature; Whittaker and Williamson attribute peer-reviewed studies to be among the best standards in quality research[54,55] A computerised search for peer-reviewed articles was conducted on bibliographic databases. The following databases were explored: CINAHL, Medline, PsychInfo, PsycArticles, SOCINDEX and Scopus (up to January 2024) to identify literature documenting a link between CM and MetS outcomes.

A three-step process was used to conduct the literature search as recommended by the Joanna Briggs Institute.[51] The first step involved the identification of keywords where further words were augmented from the titles and abstracts of studies relevant to the research. Wong et al reported that the single-word search terms were linked to the best specificity.[56] A comprehensive search term was carried out using a list of synonyms and combinations of the following keywords: "child maltreatment", "childhood abuse", "child trauma", "child adversity", "child maltreatment", "childhood experience", "stressful life experiences", "early stress", "physical abuse", "sexual abuse", "psychological abuse", "emotional abuse", "neglect", "emotional neglect" and "physical neglect". These keywords were further cross-referenced with terms such as: "metabolic syndrome", "clustering of metabolic syndrome", "syndrome X", "syndrome X" and "insulin resistance syndrome". The second step involved the development of keywords specific to each database (Table S1 in the Supplementary File). In the third step, all databases were further supplemented by manually searching the reference lists of eligible reviewed studies to identify any potentially omitted studies.

## Selection of Studies

The author (EO) conducted the study selection process to identify the relevant literature. Firstly, two authors (EO and EC) independently examined the titles and abstracts to eliminate studies whose topics were not relevant. Secondly, the full articles were also closely screened following the retrieval of articles that met the inclusion criteria, and the PEO framework was instrumental in selecting information from the data; AT resolved any conflict.

## Data Extraction

Firstly, the titles and abstracts were examined to eliminate studies whose topics were not relevant. Secondly, the full-text articles were closely examined following the retrieval of articles that met the inclusion criteria, and the PEO framework was instrumental in selecting information from the data. Findings from these studies were retrieved using a standardised data gathering sheet in the form of an Excel spreadsheet adopted from Fisher and Hosang.[57] The use of an Excel spreadsheet enabled the adjustment of the collected data. Data were extracted under the following headings: author(s), publication year and country, study location, study design, participants, sample size at baseline, age, sex, type of CM, measure of MetS, measure of CM, cumulative CM, effect size, and author's conclusion. In addition, the measure of associations between CM and MetS outcomes based on adjusted analyses (ie, risk, odds ratios, and hazard ratios) was

utilised. The author (EO) extracted the data, ensuring the extracted details met the narrative synthesis requirement. The authors (EC and AT) verified the retrieved data independently and resolved any conflicts.

## Study Quality Assessment

The quality scale from the Agency for Healthcare Research and Quality Scale (AHRQ) was used to assess cross-sectional studies.[58] The scale is made up of 11 elements, where each quality criterion matched by the selected studies was attributed to 0 or 1 point. On the other hand, the Newcastle-Ottawa Scale[59] quality assessment tool was used to assess the quality of all prospective studies. The Newcastle-Ottawa Scale is extensively used to evaluate the risk of bias in observational (non-randomised) studies,[60,61] providing grading from zero (lowest quality) to nine (highest quality) for each study. It assigns four points for the quality of participant selection and measures of exposure, three points for examination of outcomes and adequacy of follow-up, and two points for cohorts' comparability based on the design or analysis. Relevant studies were appraised by the author (EO). The authors (EC and AT) independently resolved any disagreements regarding ratings.

# Results

## Search Results

A total of 2411 studies were found from the databases (CINAH, MEDLINE, PsycINFO, PSYARTICLES, SCOINDEX, and SCOPUS). Twenty-six studies were assessed for full-text eligibility, while five studies met the inclusion criteria and were included in the systematic review. Figure 1 shows the entire process of study selection (PRISMA flowchart). We conceptualised and organised the findings using a life-course theory model developed by Kuh and Smith.[62] Life-course is an approach used to study how biological, behavioural, and psychosocial factors impact the risk of diseases across the course of life.

## Quality Appraisal

All relevant studies were graded based on the appropriate quality scale in the quality appraisal. All included studies (cross-sectional and cohort studies) scored more than 5 points, indicating good methodological quality (Tables S2 and S3 in the Supplementary File).

## Study Characteristics

Table 2 shows the characteristics of the included studies. There are five studies on the association between types of CM (physical, sexual, emotional/psychological abuse and neglect) and MetS. Of the five studies, two were carried out in the United States,[63,64] one in the United Kingdom,[65] one was conducted in New Zealand,[66] and one in the Netherlands.[67] Three studies[63,64,67] used a cross-sectional study design, and two studies[65,66] were prospective. Unexposed groups in all included studies were participants who did not experience any form of CM. The included studies reported varying sample sizes, and the largest sample used was from Li et al.[65] One study[64] considered only female participants, while the other four studies[63,65–67] included both males and females. Different measures were used to assess CM, while four studies[63–66] utilised NCEP III criteria except for one study,[67] which adopted IDF as a measure of MetS. In addition, most studies used CTQ as a measure of CM. In most studies, questionnaire surveys were completed by participants and teachers. The quality assessment showed that all eligible studies scored higher points, indicating good methodological quality (Tables S2 and S3 in the Supplementary File). The study findings are grouped by types of CM in relation to the risk of MetS.

## Assessment of Childhood Maltreatment

Although all included studies reported on a measure of CM, varying tools were used. The most common tool utilised was the Childhood Trauma Questionnaire (CTQ). Two studies[63,64] reported the validity and reliability of the tool used to measure CM. Midei et al[64] reported CTQ as having substantial reliability test–retest. Moreover, validity (convergent) with clinical interview and therapist ratings and information collected from participants via CTQ showed strong internal
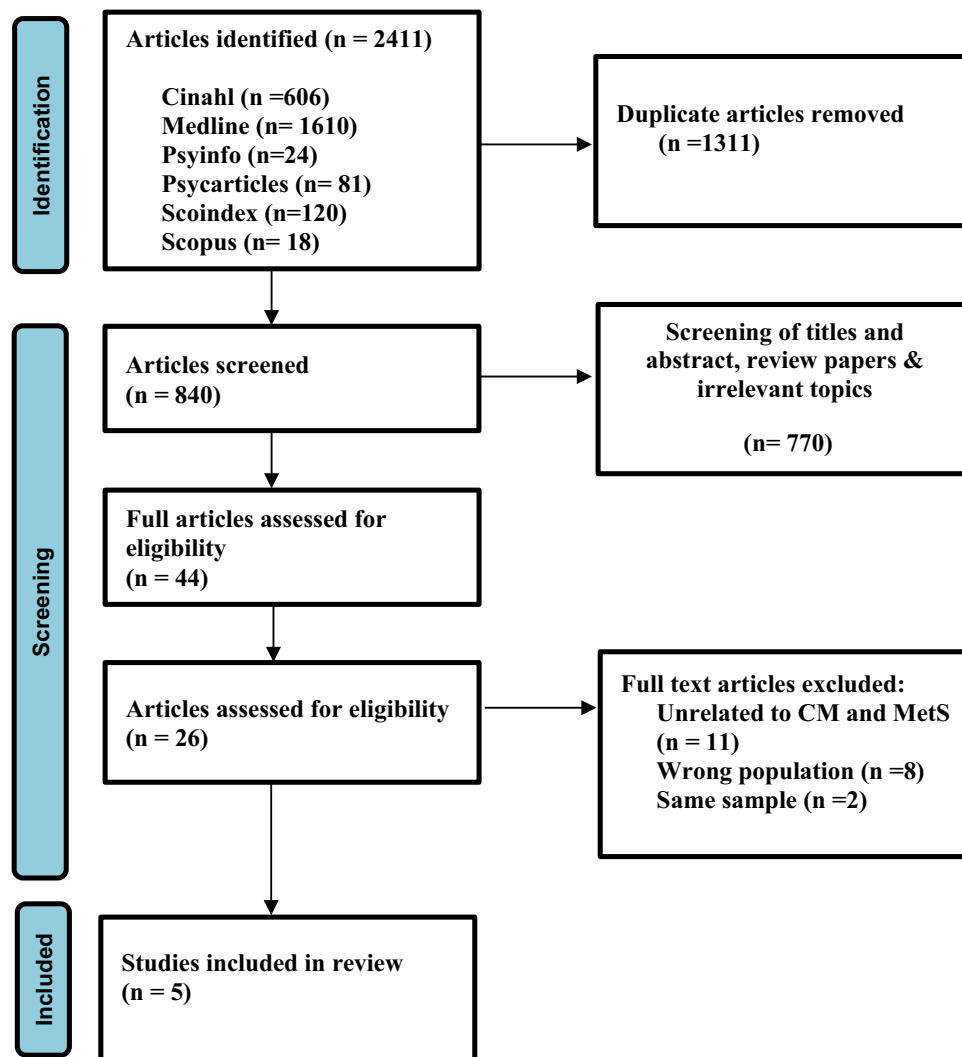
**Figure 1** Prisma flow diagram showing a selection of research studies.
**Notes**: Adapted from M. J. Page et al, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews", *The BMJ*. 2021.[49]

consistency (Cronbach's alpha 0.80 to 0.94, respectively), while Lee et al[63] reported correlations between the three types of CM to range from 0.30 to 0.57 for men and from 0.40 to 0.67 for women.

## Types of Child Maltreatment and Metabolic Syndrome in Adulthood

The outcome of interest for this systematic review is MetS or clustering of MetS. Table 2 shows the results of the association of each type of CM as well as cumulative CM in relation to MetS extracted from the included studies.

## Physical Abuse

Table 2 shows that of the five studies examined, three[63–65] reported the association between physical abuse and MetS. Midei et al[64] found an association between childhood physical abuse and the incidence of MetS in midlife women. The authors used a sample from the study of women's health across the nation (SWAN), and their result shows that after the initial control for age at baseline and ethnicity and time-dependent menopausal status, women who were physically abused in childhood were found to be more than twice likely to develop MetS than those who did not experience any form of physical abuse in childhood. Although there was evidence of attenuation in the relationship with further step-by-step inclusion of factors (such as cigarette smoking, physical activity, alcohol abuse, depressive symptoms, childhood socioeconomic status (SES), and adulthood SES), the result remained significant (HR 2.02, 95% CIs 1.02–4.02). However, it is uncertain whether the non-

**Table 2** Methodological Characteristics of the Included Studies

| Authors (Year) | Country | Age at Follow-Up | Study Design | Sample Size at Baseline | Measure of CM | Measures of MetS | Type of CM | Gender | OR/HR (95% CI) | Authors Conclusion |
|---|---|---|---|---|---|---|---|---|---|---|
| Danese et al (2009)[66] | New Zealand | 32years | Cohort | 1037 | Self-rated Childhood Maltreatment Questionnaire (CMQ) | NCEP ATP III | Cumulative abuse (physical abuse and sexual abuse) | Male and female | OR 1.39, 95% CIs (1.01–1.93) | Significant association |
| Midei et al (2013)[64] | United States | Mean-45.7yrs | Cross-sectional | 342 | Self-rated Childhood Maltreatment Questionnaire (CMQ) | NCEP ATP III | Physical abuse | Female only | HR 2.02, 95% CIs (1.02–4.02) | Significant association. |
| | | | | | | | Emotional abuse | Female only | HR 1.37, 95% CIs (0.75–2.53) | No significant association |
| | | | | | | | Sexual abuse | Female only | HR 1.29, 95% CIs (0.63–2.62) | No significant association |
| Lee et al (2014)[63] | United States | 35–86yrs | Cross-sectional | 1234 | Self-rated Childhood Maltreatment Questionnaire (CMQ) | NCEP ATP III | Physical abuse | Men Women | OR 2.40 95% CIs (1.29–4.44) OR 1.47 95% CIs (0.90–2.41) | Significant association in men No significant association |
| | | | | | | | Emotional abuse | Men Women | 2.24, 95% CIs (1.07 4.68) 1.30, 95% CIs (0.80–2.11) | Significantly associated with MetS in men only No significant association |
| | | | | | | | Sexual abuse | Men Women | 0.84, 95% CIs (0.43–1.63) OR 1.20, 95% CIs (0.79-0.182) | No significant association No significant association |
| | | | | | | | Cumulative abuse (physical and sexual, emotional/ psychological abuse) | Men | OR 1.11 95% CIs (1.00–1.24) | Significant association |
| | | | | | | | | Women | OR 1.05 95% CIs (0.98–1.14) | No significant association |
| Li et al (2019)[65] | United Kingdom | 45yrs | Cohort | 18558 | ACE Questionnaire and single questions | NCEP ATP III | Physical abuse | Male and female | OR1.14, 95% CIs (0.81–1.62) | No significant association |
| | | | | | | | Sexual abuse | Male and female | 1.37 (0.45–4.20) | No significant association |
| | | | | | | | Emotional abuse | Male and female | 1.16 (0.91–1.47) | No significant association |
| | | | | | | | Neglect | Male and female | 1.08 95% CIs (0.89–1.32) | No significant association |
| | | | | | | | ≥3 forms of CM (physical, sexual, emotional/ psychological abuse and neglect) | Male and female | 1.10 95% CIs (0.96–1.26) | No significant association |
| Willemen et al (2022)[67] | Netherland | 18–70yrs | Cross-sectional | 21,617 | Short self-report questionnaire- derived from the NEMESIS Trauma questionnaire | IDF | ≥4 forms of CM (physical, sexual, emotional/ psychological abuse and neglect) | Male and female | 1.136 95% (0.78–1.63 | No significant association |

**Abbreviations**: NCEP-ATPIII, National Cholesterol Education Program Adult; Treatment Panel III; IDF, International Diabetes Federation.

inclusion of women who were actually experiencing menopause in midlife would have or not skewed the findings in Midei et al[64] as women had to be pre- or peri-menopausal for the study. On the contrary, using data from the Biomarker sub-study (MIDUS II) of Midlife Development (MIDUS) in the US survey, Lee et al[63] found no significant association in women (OR 1.47 95% CIs 0.90–2.41) as adjusting for the mediators diminished the disparity between the groups. The non-association in Lee et al included a subset of women who were menopausal in their study; however, they did not examine if the menopause status or the hormonal therapy influenced their findings. Moreover, it is also possible that the strength of an association may have been altered by therapeutic interventions, hence the non-significant finding. Further analysis from Lee et al[63] found men who were physically abused in childhood at greater risk (more than twice likely) (OR 2.40 95% CIs 1.29–4.44) to have MetS in adulthood compared to those who were not. This finding was independent of adult SES, harmful stress responses and unhealthy behaviours. The authors went further by highlighting that although the association diminished, the finding remained significant. Meanwhile, Li et al[65] used the 1958 British birth cohort. They investigated the effect of CM and biomarkers for cardio-metabolic disease and found no significant association (OR1.14, 95% CIs 0.81–1.60) in both men and women when unadjusted and adjusted for early life factors measured prospectively. The authors utilised a large sample size (>1800) and a range of factors to capture early life environments such as birth weight for gestational age, childhood social class, household crowding and housing tenure, birth weight for gestational age, social class at birth, overcrowding and social housing.

## Emotional/Psychological Abuse

As shown in Table 2, three studies examined the relationship between childhood emotional/psychological abuse and MetS in adulthood.[63–65] There was no significant association (HR 1.37, 95% CIs 0.75–2.53) between emotional abuse and MetS in midlife women in Midei et al[64] after the initial adjustment for age at baseline, ethnicity and time-dependent menopausal status. Likewise, no significant finding (OR 1.30, 95% CIs 0.80–2.11) was shown in women in Lee et al[63] and among men and women (OR 1.16 95% CI 0.91–1.47).[65] However, further findings from Lee et al study[63] show that men who were also emotionally abused in childhood were more than twice likely (OR 2.24, 95% CIs 1.07–4.68) to develop MetS in adulthood in comparison to those who did not have the experience after controlling for mediators (sleep problems, stress-induced eating, depressive symptoms, smoking, drinking alcohol and lack of exercise).

## Sexual Abuse

Three studies examined the association between sexual abuse in childhood and MetS in adulthood (Table 2).[63–65] The three studies found no significant association between those who were sexually abused in childhood and MetS in adulthood. There was no association (HR 1.29, 95% CIs 0.63–2.62) in women of midlife age after adjustment for age at baseline, ethnicity, and time-dependent menopausal status in the study of Midei et al.[64] Similarly, in Lee et al,[63] there was no significant relationship in men (OR 0.84, 95% CIs 0.43–1.63) and women (OR 1.20, 95% CIs 0.79–1.82) when unadjusted and adjusted for covariates and mediators. Meanwhile, in men and women, the association was not significant (OR 1.37 95% CIs 0.45–4.20) in Li et al.[65]

## Childhood Neglect

As shown in Table 2, one study from a prospective British birth cohort study, the National Child Development Study (NCDS) of 1958, examined the association between childhood neglect and MetS.[65] There was no significant association (OR 1.08 95% CIs (0.89–1.32)) in individuals who were neglected in childhood in relation to MetS in adulthood.

## Cumulative Abuse

In Table 2, four studies[63,65–67] reported on the cumulative effects of (physical, sexual CM, emotional/psychological abuse and neglect). Of these studies,[63] only two[63,66] reported significant associations. Lee et al[63] reported an association between cumulative abuse (physical abuse, sexual abuse, emotional/psychological abuse) in childhood and MetS in adulthood in men (OR 1.11, 95% CIs 1.00–1.24), indicating that the effects of cumulative childhood abuse can lead to increased odds of having MetS in men. Similarly, in both men and women, there was a 39% odds of having MetS cumulatively (physical abuse and sexual abuse) in adulthood in the study of Danese et al (OR 1.39, 95% CIs 1.01–1.93).[66] However, the positive finding was in combination with other components of ACEs (such as maternal rejection, harsh discipline and changes in the

child's primary caregiver), not covered within the scope of this work. Meanwhile, in three studies, there were no significant associations. In Midei et al,[64] no significant association was found in women (OR 1.05, 95% CIs 0.98–1.14) and men (OR 1.11 95% CIs (1.00–1.24)); likewise, in the study of Li et al,[65] no association was significant in women (OR 1.10 95% CIs 0.96–1.26). Willemen et al[67] used a multi-ethnic urban cohort, with their findings indicating that CM was not significantly linked with the risk of MetS in individuals with depressed mood.

## Discussion

This review aimed to examine the forms of CM associated with MetS. This is the first review to systematically evaluate the scientific literature on the relationship between CM and the risk MetS in adulthood. Overall, the quality of the included studies was good, with cohort scoring more than cross-sectional studies. From examining the included studies, there was evidence of associations between forms of CM (physical and emotional) and risk MetS in adulthood. In addition, cumulative CM was also associated with the risk of MetS. These findings indicate that individuals with a history of one or more forms of CM are likely to be at greater risk of MetS in adulthood compared to individuals who were not exposed. To further assess these relationships, this review will evaluate the evidence in the framework of Bradford Hill's criteria, as the studies included are observational.[68] In epidemiology, Hill postulated nine criteria; however, only four crucial criteria will be used to determine the nature of the relationship between each form of CM and the risk of MetS in adulthood. Thresholds such as small, moderate and large will be used to allow for inferential assertions about magnitude.[69,70] Also, the use of magnitude is considered a good practice as it will facilitate the interpretation of the importance of a research result with a large and small magnitude, indicating practical significance and limited practical implications.

### Strength of Association

Cross-sectional studies showed small to moderate association with physical abuse in both men and women[63,64] and emotional abuse in men.[63] In all these studies, although the strength of the association diminished with adjustments for covariates, however, their associations remained. However, other studies showed weak to small associations with cumulative maltreatment (exposure to more than one form of CM) in both men and women;[63,66] only one study[66] has been recognised as having an association due to its prospective nature. However, the positive association included other measures not covered within the scope of this review, such as maternal rejection, harsh punishment, changes to child's primary caregiver in addition to CM. It is uncertain whether the inclusion of other measures precluded the evidence of a direct association or whether there was evidence of an actual association.

### Consistency of Association

Fewer studies showed associations but with small effect sizes. Of the five included studies, three reported a small to moderate associations between CM and MetS.[63,64,66] The consistency of associations varied by CM types and MetS, with findings markedly cross-sectional[63,64] and prospective[66] in nature. Although significant findings were reported for physical abuse in two studies, the gender difference was also evident; while one study reported significant findings on women,[64] the other reported on men only.[63] One prospective study showed weak association;[66] however, this study included other ACE measures not covered within the scope of this review, such as maternal rejection, harsh punishment, and changes to child's primary caregiver in addition to forms of CM. To uphold the criterion of consistency, findings from epidemiological studies should be repetitive, as one study cannot prove causation. Hence, the consistency of a causal association could not be ascertained as it can only be upheld when studies report consistent associations from varying locations and populations. Arguably, the positive association may be linked to the broader array of ACEs incorporated in the analysis.[66] In summary, although a few studies did not lend support to these associations, these findings indicate that associations may vary by type of CM, age of the participants, sex and type of cohort and the type and number of covariates included. Meanwhile, despite the likely variation in form and degree of exposure, this systematic review aligns with previous systematic reviews on the associations between CM and poor health.[43,47,48] Nevertheless, estimates of the incidence and severity of CM remain uncertain globally as significant levels of

maltreatment against children remain either unreported or hidden due to fear and stigma.[71] The lack of reporting of this sensitive problem may reflect the number of data available for researchers on specific types of CM.

## Temporal Relationship

For temporality to be upheld, exposure must precede the outcome. The observed association between CM and MetS indicates evidence of an association, as shown in a few studies.[63,64,66] However, only one study[66] was prospective and therefore supported a temporal association, indicating that exposure preceded the outcome, even though this study did not differentiate the effect of CM from the broader group of ACEs. Moreover, as the majority of the studies were cross-sectional, some research has shown that cross-sectional studies may not ascertain a temporal relationship between children exposed to maltreatment and the MetS risk in later life. Other studies have also suggested that CMs are mostly under-reported rather than over-reported[72] and that there is a possibility that more individuals may have experienced CM than reported.

## Biological Gradient (Dose–Response Relationship)

It was a challenge to acquire enough information on the frequency and duration of each type of CM to ascertain the possible dose–response relationship between each type of CM and MetS due to the heterogeneity of the studies and the number of studies that satisfied the inclusion criteria. The underlying biological processes that may lead to MetS onset following childhood exposure to abuse remain an ongoing issue. Meanwhile, animal models of exposure to CM are scarce, rendering understanding the biological mechanism a challenge. However, rather than through experiments, the availability of data on association allows for some understanding of the mechanism. There have been suggestions that most ill health in adulthood stems from disturbances in biological composition and development in childhood.[73] This means that events in childhood can significantly influence health later in life. This may be through biological means during sensitive developmental periods or cumulative damage over time.[74] Reviewed studies showed small to moderate association with one type of CM[63,64] or cumulative CM.[63,66] Equally, the lack of studies showing an association does not exclude, in reality, the likelihood of a dose–response relationship.[75]

## Biological Plausibility

Although previous studies have demonstrated the impact of early life adversity on health, the potential pathway linking CM and the risk of MetS development in adulthood remains unclear. In this review, physical, emotional and cumulative CM was found to have a small to moderate associations with MetS risk in adulthood and how some factors have partially mediated the associations. Previous research shows that forms of CMs are related to some known MetS risk factors (high-risk behaviours) such as smoking,[76] sedentary lifestyle,[77] and alcohol usage,[78] which suggest that there may be potential causal pathways from which CM may influence the risk of the components of MetS, signifying the need for interventions to promote health and prevent disease occurrence in affected individuals. Another pathway may be through biological means.[79] The pathways linking CM to cardiovascular disease risk could also be plausible in the relationship between CM and MetS risk. Previous literature shows that dysregulation of the hypothalamus-pituitary-adrenal axis (HPA) leads to elevated cortisol levels due to increased exposure to forms of CM documented.[80,81] The stimulation of the adipose tissue by the cortisol promotes energy storage as fat in the presence of inflammation, subsequently causing an increased risk of MetS components and altered general health.[82] The involvement of biomarkers of inflammation further highlights the need for timely attention to the risk of inflammation due to its involvement in the disease process of many illnesses.

## Strengths and Limitations

A few strengths are attributed to this systematic review. It highlighted the association between each form of CM and the risk of MetS. Compared with participants who had not experienced maltreatment in childhood, notable small to moderate effects were observed in the association with specific types of CM (physical and emotional) and cumulative in relation to the risk of MetS. Secondly, this review carried out an up-to-date and reproducible search of the existing literature examining CM and the risk of MetS based on the included criteria. Thirdly, the included study used medical tests to

confirm evidence of MetS and was not self-reported. Notably, the analysis by specific type of CM provided insights into the varying associations of the MetS with CM. In general, all studies used in the review presented estimates and findings from different models that were later adjusted, leading to the gradual or total reduction of the effect of CM on the risk of MetS. This is in agreement with the study of Widom et al, which highlighted the importance of further controlling factors due to their role in reducing or increasing the associations;[83] however, the influence of confounding factors in studies may not be entirely eradicated.

The results of this study should be considered in light of the limitations of this systematic review and the individual studies. Given that this systematic review included studies of different study designs to capture the full range of reported evidence, there was variability in the definition and measures of CM and MetS as there are no national standards, especially regarding reporting of statistical analyses, assessment of exposure, and assessment of CM. Although all studies reported on different measures used to assess CM, only two studies reported on reliability and validity;[63,64] therefore, it is challenging to compare measures as they may be attributed to varying amounts of interpretations. As the study excluded studies not published in English, there is a potential for a biased result.

Based on the study criteria, some studies were excluded due to multiple studies from the same data and the use of different data analysis methods. Also, some estimates on the forms of CM (physical, sexual, emotional abuse and neglect) with MetS, which were not presented as HR or OR and 95% of CIs; their effect sizes were excluded from the review. Meanwhile, some studies used a cumulative CM instead of different types of CM experience; it was essential to acknowledge these findings even though it was not one of the study's aims. Only two studies were prospective; the unavailability of prospective studies demonstrates the need for further examination of the association between CM and MetS prospectively.

Three studies were cross-sectional, limiting the understanding of the causal relationship between CM and MetS. Cross-sectional studies are known to be susceptible to or likely to result in recall and other perceptual biases.[84] Since childhood experiences measured prospectively are less sensitive to bias associated with individual features, their validity may be restricted due to other sources of misclassification, such as under-detection or underreporting.[85] This confirms the findings by Wildeman et al that most evaluations from prevalence studies regarding adversities in early life are most often underreported; hence, it is most likely that the real extent of the association between CM and the development of MetS could be higher than the evidence in the included studies suggests.[86,87] The validity problem associated with many study designs in determining the health impact of CM is still an ongoing debate.[88,89] Due to significant heterogeneity and the included studies originating only from the UK, US, New Zealand and the Netherlands, the findings from this review may not be generalisable to a larger population. Also, although it is desirable to have a pre-registered protocol, it is imperative to note that the review protocol was not published, hence the inclusion of this as one of the study's limitations.

## Implication for Research

This is the first time these studies have been verified in aggregate proportion, and conclusions have been made based on the limited number of studies. Notwithstanding the limitations, this review embraces some implications. This systematic review included both large-scale longitudinal and small-scale studies. Although cross-sectional studies have been reported to be less valuable on the foundation that the deductions that can be reached may be limited, it was deemed imperative to recognise these studies based on their findings and the number of overall studies that met the inclusion criteria. Moreover, the number of these small-scale studies also highlights the need for more research in this field.

Even though the findings from this review suggest a small to moderate association between forms or cumulative CM and risk of MetS despite the limited studies, there is a need for detailed, well-designed, longitudinal, prospective research studies in the future. Most studies included information on the impact of mediating factors on the risk of MetS, thus helping to understand potential prevention strategies. However, more research is needed to consolidate the relationship further by including more confounding and mediating factors for CM with MetS. Understanding the possible mediating factors represents an area for further research.

The age of the study sample is also crucial to consider. Although limited studies report on the association, there is a need to consider the age of the study sample in future research. While the age of the participants varied with prospective data obtained between 32 and 45 years, the age of the study samples may have affected the non-significant findings as cases of

MetS increase with age in most individuals from 50 and above[17] and concentrating on the population of older adult may reveal different findings. In addition, while there appeared to be some uniformity in including social, lifestyle or economic factors, variation exists in their adjustments, with some factors not measured in most, such as race/ethnicity and maternal behaviours. Hence, a more common approach or standardisation in research is needed to ensure that future studies consistently adjust these factors to recognise their impact as they relate to CM and, subsequently, to MetS. Also notable was the lack of inclusion of childhood neglect as a form of maltreatment in the reviewed studies, but one study,[65] despite being the most common form of maltreatment. Future research is needed to ascertain the association, as it is unclear why much empirical research has not measured childhood neglect in relation to MetS. Summarily, the limited number of studies, disparities in CM classification, reporting, and adjustment methods for variables (confounding and mediating) all impact the review conclusions.

## Conclusion

This study presents a systematic review of the forms of CM associated with MetS. There was a small to moderate association relating to CM and MetS. However, evidence shows that some forms of CMs are associated with the risk of MetS in adulthood and that there are no general links between CM and MetS except by type of CM, cohort, sex, and age of the participants. Further research is needed on forms of CM and MetS to understand the underlying mechanisms and to identify targeted strategies for affected individuals to prevent the impact of CM on MetS and subsequent future health.

## Data Sharing Statement

All data analysed during this study are included in this article, and further inquiries can be directed to the corresponding author.

## Author Contributions

EO conceptualised the study and all authors contributed to the design, analysis and interpretation, drafting or revising the article, and have agreed on the journal to which the article has been submitted; gave final approval of the version to be published and agree to be accountable for all aspects of the work.

## Disclosure

The authors report no conflicts of interest in this work.

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