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RESEARCH ARTICLE

The association between adverse childhood experiences and mental health, behaviour, and educational performance in adolescence: A systematic scoping review

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Abstract

Adverse childhood experiences (ACEs) are thought to have negative effects on mental health and well-being in adolescence. The definition of ACEs varies between studies, and their measurement is mainly based on questionnaires designed for adults to recall their childhood. This scoping review aimed to explore the research methods and findings from studies that quantitatively analysed the association between ACEs and mental health, behaviour, and educational performance in adolescence (ages 12–17). We sought to map and hypothesise the links or mechanisms between ACEs and these psychosocial outcomes by narrative synthesis of the methodologies and findings of the included studies, appraised with the Cambridge Quality Checklist. We searched MEDLINE, EMBASE, and PsychINFO from 1998 to July 2023 for relevant studies. We identified twenty studies that measured twenty-seven "ACEs" during childhood (ages 0–17), including abuse, neglect, household dysfunction, bullying, and other adversities. The definition of and measurement tools for ACEs and the analysis techniques were heterogeneous. ACEs were commonly analysed as the exposure of interest with factors around the child and family as confounders. Statistical techniques included regression modelling, mediation analysis, structural equation modelling, and decision tree classification. Eighteen studies estimated the cumulative effects of ACEs, either as ACEs count/score or latent classes; and four studies estimated individual ACE effects. Cumulative ACEs and most individual ACEs were positively associated with increased probabilities of negative adolescent psychosocial outcomes. Measuring ACEs during childhood and the associated impacts on adolescents appeared feasible in longitudinal studies and surveys. Heterogeneous ACE classification, psychometric properties of measurement tools, and the ACE score analysis approach limit the comparability and

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interpretation of findings. Future studies into the prevention or effects of ACEs on adolescent well-being and development should address factors leading to ACEs or mitigating their impacts on adolescent psychosocial development, and use triangulation in the research of ACEs.

Introduction

Despite the rapidly increasing number of studies into adverse childhood experiences (ACEs), a common theme from recent reviews [1–3] is the lack of consistent definitions of ACEs. This is partly due to or a reason for the different methods of measuring and analysing ACEs. For example, a wide range of questionnaires were used for measuring ACEs within and between studies [4,5], or a questionnaire was not used in a standardised manner, or that some studies used only selected items or modified some items [3]. These inconsistencies in collecting and synthesising the evidence make it difficult to compare the prevalence of ACEs and the associations between ACEs and outcomes later in life. Moreover, they could add difficulty and uncertainty to prioritising and evaluating interventions for those at higher risk of ACEs.

The most common types of data used to study ACEs in children (ages 0–17) are collected from 1) cross-sectional surveys with children and/or their parents or primary caregivers, at one or several time points; and 2) compiling data from routinely collected public service records, e.g., from health and social care services [1]. Collecting information about ACEs directly from children or their parents/caregivers involves ethical and methodological considerations and planning, e.g., ensuring confidentiality and obtaining appropriate informed consent, using acceptable questions or questionnaires with adequate reliability and validity. Additional challenges include providing support services and protecting children's welfare should maltreatment experiences be disclosed [2]. Some of the commonly used ACE measurement tools are not designed or validated for use in collecting information about children [6,7], e.g., the ACE International Questionnaire (ACE-IQ) [8]. Nonetheless, they are commonly used with children and their parents/caregivers. There are ongoing attempts to standardise methods for measuring ACEs [1,9,10].

Although some methodologies may be inadequate for inferring causal relationships between ACEs and their negative impacts on adults, e.g., retrospective recall of ACEs by adults [9], the accumulated evidence of the negative impact of ACEs on outcomes in later life is considered to be abundant [3,9,11]. Adolescence is the period when half of all lifetime mental disorders emerge [12]. Adolescence usually refers to the period between middle childhood (around age 10) and adulthood [13], but the age range varies between literature and policies. In this review, we regard adolescence to be ages 12 to 17, capturing the period when a child typically starts secondary school education, up to being legally regarded as an adult in most countries. This period reflects the rapid psychosocial, cognitive, and physical growth that happens while a child transitions into adulthood [13].

ACEs, especially long-term ACEs, have also been found to negatively alter children's brain development and neuroanatomy, subsequently hindering their overall development, health, behaviour, and school performance [14]. If ACEs affect outcomes in adolescence, this may continue in adulthood and contribute to later life outcomes, such as mental illnesses in adulthood.

Evidence gaps

Despite the increasing number of ACEs research articles published yearly [3], there is a lack of focus on adolescent mental health or well-being outcomes included the recent reviews [1–

3,15,16]. We searched Ovid databases, Google Scholar, Open Science Framework (https://osf.io/), and Prospero for reviews or review protocols that focus on the relationship between ACEs and mental health, social behaviour, or educational performance during childhood. To our knowledge, no reviews focus on the methodology of quantitative analyses of such in this field (search conducted May 2023). The scoping review by Park and colleagues [5] was similar but focused on young adults (i.e. ages 18–25). It reported that ACE measurements and the ACE categories varied between studies, with most including child maltreatment and "family dysfunction". Moreover, ACEs were strongly associated with mental health problems in young adults.

Furthermore, the existing literature on ACEs lacks a summary which systematically collates the evidence about three main issues relevant to studying and estimating the association or causal relationship between ACEs and psychosocial development and impacts in adolescence. First, information about ACEs can be sensitive topics to those who experienced them directly (e.g., children who experience ACEs or parents who cause ACEs) and indirectly (e.g., witnesses). Thus, understanding the reliability and validity of the ACE measurement tools and the feasibility of data collection methods is important for careful data collection and analysis planning. Second, not all people who develop mental health disorders have a history of ACEs, and not all people who have ACEs develop psychosocial problems or symptoms in life. Therefore, understanding the factors that can moderate or mediate, ideally mitigate, the ACE impacts in childhood and later life can help develop effective preventions and interventions. Finally, understanding the timing and duration of ACEs, e.g., first-1000 days vs middle childhood, may facilitate the interpretation of the temporal effects of ACEs on adolescents and strategise preventions and interventions of ACEs and their impacts. Only a few studies have compared the effects of different timing and duration of ACEs or childhood adversities on children using the life course epidemiological models, and there are limitations in the analysis methods for these models [17–21]. Hence, it will be beneficial to explore other methods for interpreting the temporal effects of ACEs.

Aim and objectives of this review

This review aimed to systematically explore existing evidence from quantitative studies regarding the association or causal relationship between ACEs and mental health, social behaviour, and educational performance of adolescents (ages 12–17). We used this evidence to map and hypothesise the possible pathways between ACEs and outcomes in adolescence in a causal diagram to guide future research. The following objectives explain how this review attempted to find the evidence about the three highlighted issues relevant to studying and estimating the association ACEs and adolescent psychosocial outcomes.

The objectives were 1) to identify studies that conducted quantitative analysis of the association between ACEs (ages 0–17) and outcomes associated with mental health, social behaviour, and/or educational performance in adolescence (ages 12–17); 2) to describe the categories, definitions, and measurements of ACEs, mental health, social behaviour, and educational performance of children and adolescents used and analysed in the included studies, and the key findings of the reported relationship between ACEs and these outcomes; 3) to identify the explanatory factors, including confounders, mediators, and moderators, and outcomes included in the included studies, and which factors may play a role in the causal relationship between ACEs and our specified outcomes; 4) to identify the possible associations and links between the factors described above according to the quantitative analyses, and to map the pathways in a causal diagram.

Method

We conducted a systematic scoping review of quantitative studies about ACE. We used a narrative method to synthesise the methodology used to collect ACE data and to analyse the associations between ACEs and adolescent outcomes. This approach matches the aim of a scoping review to identify key characteristics or factors of a concept, clarify the key concepts or definitions, and examine the research methodology of the topic [22] (see protocol in S1 Appendix).

Search strategies and selection criteria

Eligible studies were quantitative analyses of empirical observational studies evaluating the relationship between ACEs and three types of psychosocial outcomes in adolescence, which met the criteria in Table 1. The criteria applied to the population, exposure, comparator, and outcomes (PECO), additionally, the sampling/settings, study designs, and publication status of the relevant studies.

Three electronic databases, Embase, Ovid MEDLINE(R) ALL, and APA PsycInfo, were searched on 17 July 2023 in the Ovid search engine to identify the relevant studies. Keywords, subject headings, and free-text terms relevant to the main exposure (i.e. adverse childhood experiences), population (i.e. children aged 0–17), and outcomes of interest (i.e. mental health or well-being, educational performance, and social behaviour) were used in the search strategy. Additionally, search filters for observational studies [23,24] and children populations [25,26] were used to increase the sensitivity and specificity.

The 11 categories of exposure listed in Table 1 are considered to be ACEs, defined in this review as adverse experiences that directly influence the child, or are directly inflicted on or witnessed by the child, in the context of relationships or personal interaction between the child and others, in their immediate environments at home and school [27,28]. They typically include the notions and actions of maltreatment, harm, and unpleasant or disadvantageous deviation from societal norms [28]. The first ten are the "classic-10 ACEs" categories measured in the first study of ACEs, CDC-Kaiser ACE Study [29,30], including abuse, neglect, household dysfunction, and the eleventh is bullying. The search terms for adverse childhood experiences aimed to find studies which used this term specifically to categorise the adversities in childhood, regardless of whether their included categories matched these 11 ACEs.

The first strategy compiled and tested was for searching in Embase, which was peer-reviewed by a Health Sciences Librarian. This strategy was refined and developed into the strategies for searching the MEDLINE and APA PsyInfo databases. The full search strategies for all databases are detailed in in S2 Appendix. If a record was a conference abstract, a search for the full-text report was conducted in Google Scholar.

Study selection process

The records identified in the literature searches were imported into EndNote (vX9.3.3) (Clarivate Analytics, Philadelphia, PA, USA). After removing the duplicates in EndNote, the remaining records were imported into the Rayyan web application (https://www.rayyan.ai/) (accessed July 2023) for study selection. The titles and abstracts of the records were screened and assessed against the eligibility criteria. The records which appeared eligible were assessed with their full-text reports. A second reviewer independently screened and assessed 10% (n = 300) of the records yielded from the literature searches. Any discrepancies in the screening and assessment were resolved by discussion.

Table 1. Eligibility criteria for study selection.

Characteristics	Inclusion criteria	Exclusion criteria
Population	Children aged 12–17 (i.e. adolescents) at time points for the eligible outcome measurement. Human sample only.	Children aged 0–11 or adults (age 18 or above) at time points for outcome measurement.
Exposure	Explicitly use the term "adverse childhood experiences" to refer to adversities that happened and measured/recalled from birth to age 17, and investigated at least two ACEs listed below: 1) Emotional abuse by parent/caregiver; 2) Physical abuse by parent/caregiver; 3) Sexual abuse and exploitation; 4) Emotional neglect by parent/caregiver; 5) Physical neglect by parent/caregiver; 6) Domestic abuse (parent/caregiver being treated violently or by coercion control within the home by his/her partner); 7) Parental/caregiver's substance abuse; 8) Parental/caregiver's mental illness; 9) Parental separation; 10) Parental/caregiver's incarcerated (or prosecuted); 11) Peer victimisation (experienced bullying, assault, physical intimidation, or emotional victimisation by a non-sibling peer).	ACEs were not the main exposure of interest or analysed as explanatory factors. The adversities were not termed as "adverse childhood experiences (ACEs)".
Comparator	Children who were not exposed to any "ACEs" in the study, or were exposed to variation in ACEs can be compared with variation in the outcome, e.g., combination or number of ACEs experienced.	
Outcomes	At least one eligible outcome listed below was measured with validated measures, self/proxy-report, or reported in routine records, and collected during adolescence (ages 12–17) of the child participants: a) Self/proxy-reported mental well-being and psychological distress; b) Mental health or well-being concerns or diagnosed conditions (self/proxy-reported or confirmed with health records) regarding anxiety, depression, eating disorders, self-harm, suicidality, loneliness, distress, post-traumatic stress disorder, psychosis-like symptoms; c) Educational performance and/or attainment from formal education qualifications or commonly recognised examination results, e.g., GCSE in UK, GPA in USA; d) Social behaviour (conduct and/or peer relationship issues) regarding pro-/anti-social behaviour, criminal behaviour, conduct problems, or peer problems.	Sexual behaviours or health risk behaviours, e.g., smoking, substance abuse. Neurodiverse conditions, e.g., attention deficit hyperactivity disorder (ADHD), tic disorders, autism, dyslexia.
Sampling/ settings	Any sampling method from any setting that did not target the existing and known outcomes of this review's interest.	Targeting people already experiencing problems in mental health, social behaviour, and educational performance, e.g., attending mental health services, and criminal offenders.
Study designs	Prospective or retrospective longitudinal cohort studies, or cross-sectional studies, in any setting. Primary empirical studies of quantitative analysis of the relationship between ACEs and the outcomes. Statistical quantification of the relationship between ACEs and the outcomes of interests, analysed by statistical modelling or classification techniques and reported the quantitative results, i.e. not only in a summary statement.	Analysis of only prevalence, descriptive statistics, or hypothesis testing (including Chi^2 test, t-test, ANOVA) of ACEs and outcomes.
Publication restrictions	Peer-reviewed, full-text journal articles published in 1998 or later.	Any article or reports which are not full-text journal-published article, e.g., thesis only, conference abstract only. Any full-text journal articles published before 1998.

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Data collection process

Details relating to the participant characteristics, measures of correlates and outcomes, and quantitative analysis methods were extracted from each included study using NVivo (Release 1.7.1; QSR International, 2022) then exported into Microsoft Excel (version 2402) for narrative synthesis. Full details of extracted data are listed in S3 Appendix.

Data summary and synthesis of results

The extracted data were mapped in tabular form (e.g., tables, matrices) in Microsoft Excel and in graphical form (e.g., flowcharts, causal diagrams) using Microsoft PowerPoint or Word (version 2402) (Microsoft Corporation, Redmond, Washington, USA). The characteristics of excluded studies table was produced via our EndNote library. We synthesised the extracted data using frequencies (counting occurrence) and narrative synthesis of the details about methodologies and findings from the included studies. The details being summarised and reported aimed to address this review's objectives. One reviewer extracted and synthesised the data, whilst another reviewer independently checked the extracted and synthesised details.

Cambridge Quality Checklist (CQC)

We used the revised version [31] of the Cambridge Quality Checklist (CQC) [32] to evaluate the quality of each included study. In this review, the only "measure of correlate" assessed were the ACEs (exposure) measured in each included study, i.e. we did not assess the measures of other correlates, e.g., confounding factors included in the quantitative analyses. The ACE categories were classified into three groups–"classic-10 ACEs", "bullying", and "other ACEs" to be assessed separately. We considered the correlate domain to be "adequate" if all three groups were assessed as "adequate". A high score on each checklist implies a higher quality of the evidence. The authors of the CQC suggested the high scores as listed in Table 2 [31,32]. To assess whether the risk factor was adequately balanced in the causal risk factor checklist, three topic-specific key confounding factors which precede the risk factors, namely ACEs, were selected a priori. They were 1) familial and/or maternal socioeconomic status (including income and/or educational attainment) [2,33–36], 2) maternal ethnicity and/or child's ethnicity [2,33,36], and 3) child's sex or gender [2,33–36]. These factors are commonly accounted for the social patterning of ACEs [2]. Two reviewers independently appraised all the included studies. In case of discrepancies, they discussed to reach a consensus.

Results

We followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) statement when conducting and reporting this review [37] (See S1 Table).

Study selection

There were 3939 records resulting from the literature searches. Deduplication removed 942 records. The remaining 2997 were screened against the eligibility criteria. 2943 records were judged as ineligible according to the titles and abstracts, and 54 records relevant to the

Table 2. Cambridge quality checklist assessment.

Checklist (Total score range)	High score (s)	High-score study methodology
Correlate (0–5)	4–5	If ≥4 of the following items are judged "adequate" (score 1 for each adequate item): Sampling method, response rates, sample size, measure of correlate, measure of outcome.
Risk factor (1–3)	3	Risk factors data were measured at time point(s) before the outcomes (Prospective data).
Causal risk factor (1–8)	7–8	Study with variation in the risk factor and adequately balanced with analysis of change; or Randomised experiment and targeting a risk factor.

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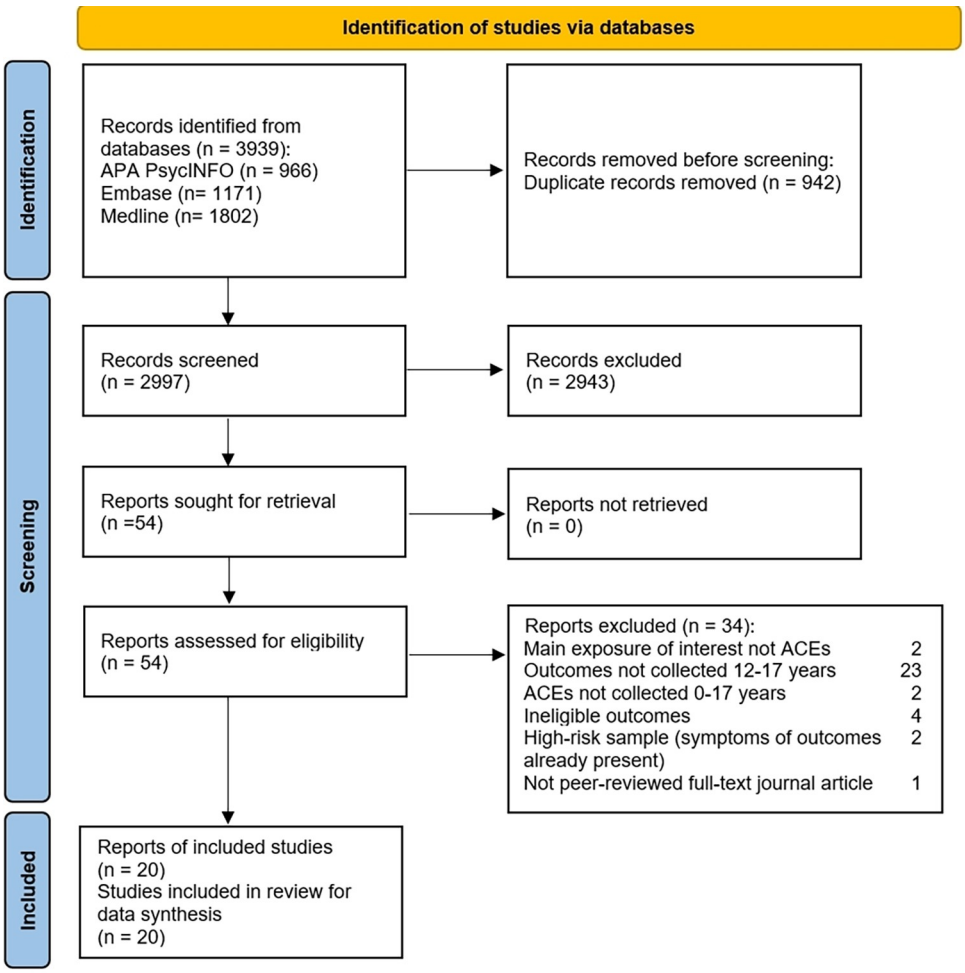

Fig 1. PRISMA flow diagram showing identification and selection of studies.

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eligibility criteria; hence, their full-text reports were assessed. Twenty studies met the eligibility criteria and were included in this review for data synthesis (see **Fig 1**, PRISMA diagram).

Included studies

The 20 included studies were published between 2016 and 2023 (see Table 3). Studies originated from USA (11 studies, 7 datasets), UK (5 studies, 3 datasets), China, Hungary, Portugal, and Slovakia (1 study and 1 dataset each). Twelve were longitudinal studies that used data from a birth cohort [38–49]. One other longitudinal study used only routine records [50], while another collected recalled ACE data a year before collecting outcome data [51]. Six studies used data from single time point cross-sectional surveys [52–57]. In total, 14 cohorts and datasets were included. Each included study aimed to estimate the relationship between ACEs and adolescent mental health or well-being and/or behaviour by conducting quantitative analyses with statistical modelling techniques.

The adolescents included in all the studies were born between 1984 and 2007, and their ages at the last outcome data collection ranged between 13 and 17 years. The sex ratio in most studies was around 1:1. No study analysed ACE data which covered the whole childhood (ages 0–17) of all of its participants (see Tables 4 and S2). The study sample size ranged from 480 to

Table 3. Characteristics of included studies.

Study (first author and published year)	Study Location	Study design	Indexed terms relevant to ACEs (as reported)	Population (Data source)	Sample size recruited and analysed (n = number of children)	Data collection period	Children's age (years) during data collection period	Sex	Ethnicity or Race (of children, as reported)
Fagan 2018 [41]	Baltimore, Chicago, San Diego, Seattle, and Chapel Hill, USA	L		Sampled from LONGSCAN study, Black and White child participants who provided outcome data at age-16 follow-up.	Recruited n = 1075 (of the 2 racial groups) Analysed n = 466–598 (demographic data n = 620)	~1984 to ~2002, every 2 years	0 to 16 (over time)	Girls 52%	Black 69% White 31%
Leban 2021 [46]	Baltimore, Chicago, San Diego, Seattle, and Chapel Hill, USA	L	Keywords: adverse childhood experiences, aces	Sampled from LONGSCAN study, children and their caregivers who provided outcome data at age-16 follow-up.	Recruited n = 1354 Analysed n = 868	~1984 to ~2002, every 2 years	0 to 16 (over time)	Girls 51.6%	Black 56.6% White 23.4% Hispanic 10.3% Other racial groups 9.8%
Morrow 2019 [47]	Baltimore, Chicago, San Diego, Seattle, and Chapel Hill, USA	L	Keywords: ACEs	Sampled from LONGSCAN study, dyads who completed caregiver and youth interviews at age 14 and 16.	Recruited n = 1354 Analysed n = 592	~1984 to ~2002, every 2 years	4–6 to 16 (over time)	Girls 49.7%	White 26% Black 55% Hispanic/Latino 6% Mixed/Other 13%
Russell 2019 [48]	Southwest England, UK	L	Keywords: adverse childhood experiences	ALSPAC child participants whose CRP and IL6 data were collected at age 9.	Recruited n = 13988 (original core cohort) Analysed n = 4308	1991–1992 (birth) to 2001–2003 (age 9) & 2008–2009 (age 16)	0–9 & 16 (over time)	Girls 48.9%	White British 98.1%
Choi 2019 [40]	20 large cities in USA	L	Keywords: Adverse childhood experience	Sampled from FFCWS based on the family's poverty status during the first three years of the child's life.	Recruited n = 4898 Analysed n = 2750	1998–2000 (birth) to ~2013–2015 (age 15), through FUs at ages 1, 3, 5, 9	0–15 (over time)	Girls 46.9%	Children's ethnicity or race not reported. Mother vs father's races: White 15.3% vs 12.5% Black 55% vs 57.2% Hispanic 27% vs 27.6% Other 2.7% vs 2.7%
Choi 2021 [39]	20 large cities in USA	L	Keywords: adverse childhood experience, bullying victimization	FFCWS—the entire cohort.	Recruited and analysed n = 4898	1998–2000 (birth) to ~2013–2015 (age 15), through FUs at ages 1, 3, 5, 9	0–15 (over time)	Girls 47.2%	Children's ethnicity or race not reported. Mother vs father's races: White 21.0% vs 17.7% Black 47.6% vs 49.7% Hispanic 27.5% vs 27.6% Other 3.9% vs 4.4%

(*Continued*)

Table 3. (Continued)

Study (first author and published year)	Study Location	Study design	Indexed terms relevant to ACEs (as reported)	Population (Data source)	Sample size recruited and analysed (n = number of children)	Data collection period	Children's age (years) during data collection period	Sex	Ethnicity or Race (of children, as reported)
James 2021 [45]	20 large cities in USA	L	Keywords: adverse childhood experiences	FFCWS participants who lived with their mothers and had outcome data recorded at age 15.	Recruited n = 4898 (original cohort) Analysed n = 3038	1998–2000 (birth) to ~2013–2015 (age 15)	0–15 (over time)	Girls 49%	Mother's race/ ethnicity: White 20% Black 51% Hispanic 25% Other 4% Parents race same as child 86%
Lowthian 2021 [50]	Wales, UK	L	Keywords: Adverse childhood experiences	Children in the WECC, born in Wales between Jan 5, 1998, and Oct 7, 2012, whose hospital admissions data, GP, and household member data were available through data linkage. Those moved away or died before 12 Oct 2012 were censored.	Analysed n = 191035	5 Jan 1998 to ~ Oct 2013 (born Jan 1998-Oct 2012, and ≥1 year follow-up)	0–15 (over time, length varied depended on birth year)	Girls 48.5%	Not reported.
Fava 2022 [42]	Michigan, USA	L	Keywords: adverse childhood experiences	Adolescents from the Michigan Longitudinal Study with available delinquency data during late adolescence.	Analysed n = 480	~1985 (age 3–5) to ~1997 (age 15–17), every 3 years	3–5 to 15–17 (over time)	Girls 28.7%	White 86.3%
Straatmann 2020 [49]	UK	L	None found in report.	Households in the UK MCS participated at S6 FU (children aged 14) and had valid outcome data.	Recruited n = 18818 (original cohort) Analysed n = 10645	2000 (9 months) to 2015 (age 14), every 2 or 3 years	0–14 (over time)	Not reported.	Not reported.
Jackson 2022 [43]	UK	L	Topics (article webpage): Adverse Childhood Experiences	Households in the UK MCS participated at S6 FU (children aged 14) and had valid outcome data.	Recruited n = 18818 (original whole cohort) Analysed n = 11313	2004 (age 3) to 2015 (age 14), every 2 or 3 years	3–14 (over time)	Girls 50.6%	White 79.9% Asian 10.8% Black 3.2% Mixed race 4.7% Other race 1.4%
Jackson 2023 [44]	UK	L	Keywords: adverse childhood experiences	Households in the UK MCS participated at S6 FU (children aged 14) and had valid outcome data.	Recruited n = 18818 (original cohort) Analysed n = 11192	2004 (age 3) to 2015 (age 14), every 2 or 3 years	3–14 (over time)	Girls 50.7%	White 79.9% Asian 10.9% Black 3.1% Mixed race 4.7% Other race 1.4%
Amorim 2023 [38]	Porto, Portugal	L	Keywords: Childhood adversity, Household dysfunction, violence	Portuguese population-based birth cohort—Generation XXI (mother and child)	Recruited n = 8647 Analysed n = 4640	2005 to 2020, follow-up every 3 years, 5 time points	0–13 (over time)	Girls 49% (of recruited sample)	Not reported.

(*Continued*)

Table 3. (Continued)

Study (first author and published year)	Study Location	Study design	Indexed terms relevant to ACEs (as reported)	Population (Data source)	Sample size recruited and analysed (n = number of children)	Data collection period	Children's age (years) during data collection period	Sex	Ethnicity or Race (of children, as reported)
Balistreri 2016 [52]	50 states and the District of Columbia, USA	C	Keywords: Adverse childhood experiences, Family functioning	NSCH selected from US households with children under 18 years old.	Recruited n = 34601 Analysed n = 33747	2011–2012	12–17 (any age between)	Not reported.	Not reported.
Bomysoad 2020 [53]	50 states and the District of Columbia, USA	C	Keywords: Adverse childhood experiences	NSCH selected from US households with children under 18 years old.	Analysed n = 29617	2016–2017	12–17 (any age between)	Girls 49.2%	White 78% Black or African-American 6.7% American Indian or Alaska Native 0.8% Asian 5.5% Native Hawaiian, other Pacific Islander 0.4% Other race 2.6% Two or more races 6.2%
Weller 2022 [57]	50 states and the District of Columbia, USA	C	Keywords: Adverse childhood experiences	NSCH selected from US households with children under 18 years old, who were identified as having more than one race.	Analysed n = 1231	2016–2017	12–17 (any age between)	Girls 46.9%	Identified as having more than one race, specific racial combinations details unavailable from the dataset.
Kim 2021 [54]	50 states and the District of Columbia, USA	C	Keywords: Adverse childhood experiences	NSCH selected from US households with children under 18 years old.	Recruited and analysed n = 21496	2017–2018	12–17 (any age between)	Girls 47.9%	White 70.1% Black 6.8% Hispanic 11.1% Asian 5.1% Other/Multi-racial 6.9%
Lackova Rebicova 2021 [56]	Slovakia	C	Keywords: adverse childhood experiences	Random sample of about 43.0% of all children participating in the Health Behaviour in School-aged Children (HBSC) study conducted in 2018 in Slovakia	Analysed n = 2839	2018	13–15 (any age between)	Girls 50.4%	Not reported.
Kovács-Tóth 2021 [55]	Hungary	C	Keywords: adverse childhood experiences	Grade 7 to 10 students from 12 schools, of 7 settlements in Hungary.	Recruited and analysed n = 516	2018–2020	12–17 (any age between)	Girls 59.7%	Not reported.
Chen 2022 [51]	Huaibei City, Anhui Province, China	L	None found in report.	Grade 7 students selected by random cluster-sampling from a middle school	Recruited n = 1814 Analysed n = 1687	2019 and 2020	~12–13	Girls 39.6%	Not reported.

Notes: Studies are ordered by the data collection period, which also reflects the ascending order of children's birth year. ~ = Estimated according to available information, ACE = Adverse Childhood Experience, ALSPAC = Avon Longitudinal Study of Parents and Children, C = Cross-sectional study, CIS-R = Clinical Interview Schedule-Revised, CRP = C-reactive protein, FFCWS = Fragile Families & Child Wellbeing Study, FU = Follow-up, HBSC = Health Behaviour in School-aged Children, IL-6 = interleukin-6, L = Longitudinal study, LONGSCAN = Longitudinal Studies of Child Abuse and Neglect, MCS = Millennium Cohort Study, n = number of child participants, NSCH = National Survey of Children's Health, WECC = Wales Electronic Cohort for Children.

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Table 4. Adverse childhood experience and outcome measured time periods in the included studies.

	Classic-10 ACEs										Bullying	Other ACEs																	
Study	1) Emotional abuse	2) Physical abuse	3) Sexual abuse and exploitation	4) Emotional neglect	5) Physical neglect	6) (Witnessed) domestic abuse	7) Substance abuse	8) Mental illness	9) Parental separation	10) incarcerated/ criminal conviction	11) Peer victimisation	Close person died (inc. parent)	child ill/ injured	Got into trouble in school	Difficulty at school	Financial probs	Family illness/ injury	Witnessed violence/ crime	Discrimination	Parental problems	Parent absence/ separated from parent	Friendship problems	Peer conflicts	Sibling substance use	Verbal maltreatment by parents	Moved home/ school	Child victimisation leading to hospitalisation	Outcomes
Russell 2019 [48]	**0 to 9y**	**0 to 9y**	**0 to 9y**			**0 to 9y**	**0 to 9y**	**0 to 9y**	**0 to 9y**	**0 to 9y**	8y																	Self-harm @16y
Choi 2021 [39]	2 to 5y	2 to 5y	4 to 5y	*3 + 5y*	2 to 5y	**0 to 5y**	**0 to 5y**	**0 to 5y**	**0 to 5y**	**0 to 5y**	*?only 9y*																	Depressive symptoms @15y
Amorim 2023 [38]	10y+13y	10y + 13y				10y + 13y			**0 to 13y**	**0 to 13y**	10y + 13y	0y + 10y + 13y	**0 to 13y**	10y + 13y	7y + 10y + 13y	7y + 10y + 13y	0y + 10y + 13y												Depression @13y
Balistreri 2016 [52]						**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***		**0 to any age 12-17y***				**0 to any age 12-17y***		**0 to any age 12-17y***	**0 to any age 12-17y***									Emotional problems, anxiety, depression @12-17y
Kim 2021 [54]						**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***		**0 to any age 12-17y***				**0 to any age 12-17y***		**0 to any age 12-17y***	**0 to any age 12-17y***									Anxiety, depression, or anxiety-depression @12-17y
Chen 2022 [51]	**0 to 13y**	**0 to 13y**	**0 to 13y**	**0 to 13y**	**0 to 13y**	**0 to 13y**			**0 to 13y**			**0 to 13y**			*?Any age 12-13y*	**0 to 13y**	**0 to 13y**			**0 to 13y**	**0 to 13y**	*?Any age 12-13y*	*?Any age 12-13y*					Depression @–13y
Leban 2021 [46]	**0 to 12y**	**0 to 12y**	**0 to 12y**		**0 to 12y**	6y + 8y + 12y	*4y - 12y*	4y + 6y + 8y + 12y		5 to 12y		5 to 12y					5 to 12y												Internalising behaviours, externalising behaviours @12,14,16y
James 2021 [45]	**0 to 9y**		**0 to 9y**	**0 to 9y**	**0 to 9y**	3 to 5y + 7 to 9y	4 to 5y + 8 to 9y	4 to 5y + 8 to 9y		3 to 5y + 7 to 9y																			Internalising behaviours, externalising behaviours @15y
Lowthian 2021 [50]							**0 to 12y**	**0 to 12y**				**0 to 12y**															**0 to 12y**	Internalising symptoms, eating disorders, externalising symptoms @0-15y
Straatmann 2020 [49]		**0 to 5y**				**0 to 5y**	2 to 5y	3y + 5y	**0 to 5y**																**0 to 5y**			Socioemotional behavioural problems @14y
Bomysoad 2020 [53]						**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***		**0 to any age 12-17y***				Any age 11-17y*		**0 to any age 12-17y***	**0 to any age 12-17y***									Anxiety, depression, behavioural/ conduct problems @12-17y
Weller 2022 [57]						**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***		**0 to any age 12-17y***																		Anxiety, depression, behavioural problems @12-17y
Lackova Rebicova 2021 [56]						**0 to any age 13-15y***	**0 to any age 13-15y***		**0 to any age 13-15y***			**0 to any age 13-15y***	**0 to any age 13-15y***				**0 to any age 13-15y***				**0 to any age 13-15y***					**0 to any age 13-15y***		Emotional problems, behavioural problems @13-15y
Kovács-Tóth 2021 [55]	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***	**0 to any age 12-17y***																		Health complaints (including psychological symptoms), emotional symptoms, peer relationship problems, conduct problems @12-17y
Fagan 2018 [41]	**0 to 12y**	**0 to 12y**	**0 to 12y**		**0 to 12y**	**0 to 12y**	**0 to 12y**	4y + 6y + 8y + 12y		5 to 12y		5 to 12y					5 to 12y												*Violent behaviours, arrests @16y*
Morrow 2019 [47]	**0 to 14y**	**0 to 14y**	**0 to 14y**		**0 to 14y**	**0 to 14y**	4 to 14y	4y + 6y + 8y + 12y + 14y		5 to 14y																			*Delinquent and violent behaviour @17y*
Choi 2019 [40]	2 to 3y	2 to 3y		2 to 3y	2 to 3y	**0 to 3y**	**0 to 3y**	**0 to 3y**	**0 to 3y**	**0 to 3y**																			*Behavioural problems @15y*
Fava 2022 [42]		**0 to 11y**	**0 to 11y**			2 to 11y	3 to 11y	2 to 11y		**0 to 11y**	**0 to 11y**	**0 to 11y**				2 to 11y		2 to 11y						2 to 11y				*Delinquent behaviours @15-17y*

(*Continued*)

Table 4. (Continued)

	Classic-10 ACEs										Bullying	Other ACEs																
Study	1) Emotional abuse	2) Physical abuse	3) Sexual abuse and exploitation	4) Emotional neglect	5) Physical neglect	6) (Witnessed) domestic abuse	7) Substance abuse	8) Mental illness	9) Parental separation	10) incarcerated/ criminal conviction	11) Peer victimisation	Close person died (inc. parent)	child ill/ injured	Got into trouble in school	Difficulty at school	Financial probs	Family illness/ injury	Witnessed violence/ crime	Discrimination	Parental problems	Parent absence/ separated from parent	Friendship problems	Peer conflicts	Sibling substance use	Verbal maltreatment by parents	Moved home/ school	Child victimisation leading to hospitalisation	Outcomes
Jackson 2022 [43]		**0 to 7y**				**0 to 7y**	**0 to 7y**	*5y + 7y*	**0 to 7y**																**0 to 7y**			*Police stop, officer warning/cautions, arrest @14y*
Jackson 2023 [44]		**0 to 7y**				**0 to 7y**	**0 to 7y**	*5y + 7y*	**0 to 7y**																**0 to 7y**			*Delinquent activities @14y*
Count of studies =	10	13	9	5	8	19	18	17	13	14	4	10	2	1	2	6	5	4	3	1	2	1	1	1	3	1	1	

Notes:— = any age between, + = and, ~ = approximately, * = cross-sectional data collection hence age range applied to anyone within that,? *italic* font = cannot confirm the period which data were collected for, **bold font** = can infer as covering the period since birth, @ = age when outcome was measured, shaded cells = the specific ACE not measured in the study, y = years of age.

. Outcomes underlined and written in non-italic font (of 1st-6th studies) = outcomes included both mental health and behaviour, outcomes written in normal font (of 7th-14th studies) = outcomes include behaviour only, *outcomes underlined and written in italic font* (of 15th-20th studies) = outcomes include mental health only. Otherwise, studies are ordered by the data collection period, which also reflects the ascending order of children's birth years.

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191,035. ACE data reported by parents or caregivers were collected throughout various periods of childhood, whilst ACE data were collected from children directly from age 8 as the youngest.

Excluded studies

There were 34 records [58–91] excluded for six reasons (see **Fig 1** and S3 Table).

Studies' methodology

In the following sections, we summarised the details found in the 20 included studies about the methods for 1) measuring ACE occurrence, 2) measuring adolescent psychosocial outcomes, and 3) quantitative analyses of estimating the association between ACEs and the outcomes of interest.

ACEs occurrence data. Fourteen longitudinal studies [38–51] aimed to collect data at multiple time points during childhood to collate a total number of ACEs across childhood (i.e. ACE score). Four studies [38,39,42,48] collected ACE data from parents from early years to early adolescence and from children of ages 8–12. Three others [41,46,47] used maltreatment data from the USA Child Protective Service (CPS) routine records together with data reported by parents and children. Four studies collected ACE data during early childhood (i.e. before age 8) from parents only [40,43,44,49]. One study used only UK National Health Service (NHS) routine records of the children and their families from birth up to age 15. However, the timeframe in some of these measures did not cover the whole of childhood, or the whole period being studied in some included studies, e.g., physical and psychological abuse data were collected for the past year at age three [39,40] but inferred from birth to age three (see Table 4). Six cross-sectional studies [52–57] collected ACEs by participants' recalling ACE information at one time point. These studies conducted surveys with adolescents in school settings [51,55,56] or with parents of adolescents in the USA National Survey of Children's Health (NSCH) [52–54,57].

All the data reported by parents or children were collected from surveys or interviews using questionnaires. The two studies [39,40] using the Fragile Families and Child Wellbeing (FFCW) study dataset stated that data were also obtained from home observations but did not report the collection method details. In the five studies that used routine records, relevant ACE information in the records was first identified and then constructed into ACE categories.

A total of 27 categories were measured during childhood and reported as ACEs in the 20 included studies (see Tables 4 and S2). Between two and ten of the classic-10 ACEs were reported in each study. Bullying was reported in four studies [38,39,42,48]. In general, if the studies used the same dataset, e.g., MCS [43,44,49], or same study design, e.g., NSCH [52–54,57], the number of included ACEs and the definition of each ACE were usually the same. Other ACEs were measured and reported in 13 studies [38,41–44,46,49–54,56], including child or family member was ill, injured, or died, child had difficulty at school, family financial problems, discrimination, parent absence or separation from parent for a long period, and peer conflicts.

Most studies detailed the meaning or definition of the ACE categories with examples or references to the ACE measure questions used (see S2 Table). The most commonly referenced ACE measure was the ACE Study Questionnaire (ACE-Q) [30,92–94] used in 11 studies [38–40,43,44,49,52–55,57]. Other cited measures included 1) the Childhood Trauma Questionnaire-Short Form [95] was adapted in one study [51], 4) Conflict Tactic Scale (CTS) (Straus & Gelles, 1990, cited in Dube *et al.* [30]) was adapted in 4 studies [39–42], and 3) the WHO ACE-IQ [8] was adapted in one study [48]. Parts of the former two questionnaires were included in the CDC-Kaiser ACE Study questionnaire [30]. The Modified Maltreatment

Coding System [96] was used for categorising routine data into four classic-10 ACE categories about abuse and neglect in four studies [41,45–47].

Only one study [55] used the whole set of questions of the cited questionnaire (shortened version of ACE Study questionnaire (ACE-SQ or ACE-10), cited in [97,98]) without modification. Bespoke questionnaires compiled with a mix of validated questionnaires or bespoke questions were used in 14 studies [38–42,45–47,51–54,56,57]. The categorisation of ACEs was data-driven and ad hoc in five studies which used the existing datasets of the MCS [43,44,49] and ALSPAC [48] birth cohorts, and the Walsh Secure Anonymised Information Linkage [50]. This approach and process appeared to depend on the availability of details and accuracy of the existing records.

The severity or frequency of ACEs was measured in 11 studies using Likert scales, then dichotomised for the occurrence of emotional abuse, physical abuse, bullying, domestic violence, household substance abuse, household mental problem symptoms, or family financial problems [39–41,43–47,49,52,54]. This is similar to the scoring methods in the ACE-Q [30] and ACE-IQ [8]. However, the exact questions asked to participants varied between studies, and some studies did not report the questions or definitions of the included ACEs (e.g., Amorim *et al.* [38], Chen *et al.* [51]). Therefore, the severity, frequency, and duration of each measured ACE varied and were difficult to distinguish or match between studies.

In studies where existing multiple questions were considered relevant to a single ACE category, e.g., ALSPAC and MCS studies, the ACE was assumed to have occurred if indicated in any one of these questions, even if inconsistently answered between the questions or time points. Moreover, some questions sounded less indicative of an ACE. For instance, when inferring emotional neglect, "*How often shouts at child when naughty*? *Daily or often*" was classified as verbal maltreatment [43,44,49], which differed from the approach and questions in the ACE-Q and ACE-IQ in which questions about more severe events are asked to illustrate and indicate each ACE.

Outcome measures. The outcome measures used to evaluate mental health, mental well-being, and behaviour are listed in S4 Table. Fifteen of the 20 included studies measured symptoms of at least one characteristic of internalising behaviours, including anxiety [53,54,57], depression [38,39,51,53,54,57], emotional problems [39,52,55], eating disorder [50], self-harm [48], subjective health complaints (e.g., psychological symptoms, fatigue) [55], or general internalising behaviours [45,46,49,50,56]. Fifteen studies measured externalising behaviours, including behavioural problems [39,40,53,55,57], peer relationship problems [55], delinquency [41,42,44,45], police contact (e.g., stopped or warning by police) [41,43], juvenile arrests [47], or general externalising problems [45,46,49,50,56]. No included study measured educational attainment or performance.

Most of the studies (n = 13) obtained the outcomes by self-report from the adolescents [38,39,41–48,51,55,56]. The other seven studies obtained outcomes from the parents or caregivers, i.e. proxy-report [39,40,49,52–54,57]. Lowthian *et al.* [50] obtained all outcomes from routine records via data linkage. This study estimated the risk of child mental health diagnosis from birth to adolescence (up to age 15) by obtaining the diagnosis from healthcare routine records and modelling with Cox regression. Although the diagnoses were not distinguished between before adolescence and during adolescence in the report, the interpretation of such analysis is similar to measuring whether a child had ever been diagnosed with any mental illness during adolescence. Therefore, this study was included in this review.

Analysis methods. The classification and conceptualisation of exposures, outcomes, and other correlates differed between studies and their analyses. ACEs were mostly conceptualised and analysed as the exposure of interest associated with psychosocial outcomes in adolescence. Nevertheless, in three longitudinal studies [39,49,50], ACEs were conceptualised to mediate

the effects of earlier social and environmental factors, e.g., neighbourhood disadvantage and sociodemographic factors of family, on adolescent outcomes. The common confounding factors were factors around the child and family, including socioeconomic status, and their characteristics, e.g., ethnicity/race and child's sex. Potential mediators between the association of ACEs and adolescent outcomes included the child being bullied, resilience, social and emotional behaviour and controls, educational performance, antisocial peers, sleep problems, and substance use. Some of these factors were also considered and analysed as moderators, e.g., child's sex, health or cognitive disability, and deprivation (see S4 Table). All these were assumed to precede the outcomes though they might have been measured simultaneously, e.g., in Fagan and Novak [41], Fava *et al.* [42].

Four main approaches were used to statistically analyse the effects of ACEs, namely regression, mediation, structural equation modelling (SEM), and decision tree. Regression modelling, including linear, logistic, Poisson, and Cox regression, were used in 15 studies. Ten studies [38,40,41,45,46,52–55,57] analysed the effects of ACEs by regression models only; whilst five studies [43,44,48,50,56] also conducted mediation analysis based on their regression models. Three studies [42,49,51] conducted mediation analysis only. Only two studies indicated the mediation analysis framework of the method, namely counterfactual-based framework [49] and Karlson–Holm–Breen method [44]. Choi *et al.* [39] performed SEM with latent variables to estimate the effects of ACEs on the outcomes. Morrow *et al.* [47] used decision tree classification to identify the interactions of predictor variables for the outcomes.

These analyses estimated multiple ACEs by either cumulating their effects or the individual effect of each ACE. Thirteen studies [39–46,48,49,52–54] only used the counts of ACEs reported, i.e. ACE scores as categories or continuous scores, for analysing the cumulative effects, which is commonly used to estimate and compare cumulative ACE effects [5,50]. Two other studies [48,54] estimated the cumulative effect and the effect of each individual ACE in separate models. To estimate the individual ACE effect, each model only included a single ACE as exposure without accounting for other ACEs, e.g., if ten ACEs were measured, ten separate models were used to analyse the relative effect of each ACE for comparison between them. Three studies [38,51,57] used latent class analysis to group multiple ACEs into broader categories for the cumulative effect analysis. Two studies [47,50] estimated the effect of individual ACEs with Cox regression or decision tree techniques, respectively, while accounting for the presence of other measured ACEs.

Before performing the effect analysis, all studies appeared to have investigated the amount and possible mechanisms of missing data to inform the methods used to handle the missing data. However, ten studies did not report the amount of missing data [40,42–44,48,49,53–56]. Complete case analysis was used in four studies [41,47,52,57]. Seven studies [38,43,44,46,48–51] performed multiple imputations for the missing data; five of them explicitly explained the rationale and assumption was data missing at random (see S4 Table). Three studies [38,39,45] performed full information maximum likelihood estimated regression models, which used all non-missing data to account for missing data. Six studies [40,42,53–56] reported neither the amount of missing data nor the handling method. Data availability was an eligibility criterion in all the studies, and some deletion or exclusion was applied due to insufficient data for some variables.

Findings and conclusions from the included studies

ACEs impact. The main findings reported and concluded by each study were summarised in S4 Table. The proportions of adolescents with no ACE or at least one ACE were reported in eleven studies [39,40,43–45,48,49,52–55]. These studies reported that 33.7% [48] to 52% [45,54] of adolescents did not have ACEs. Among those had ACE(s), the majority had one

ACE only (ACE score of 1, 22.1% [55] to 44.7% [44]). Two studies reported that 36.4% [51] and 56.1% [38] of adolescents experienced "low adversity", i.e. either no ACE or a small number of ACEs. Seven studies reported the mean ACE score/count, ranging from 0.7 [41] to 4.6 [42]. One study [48] reported that ACEs were highly correlated with one another, except for sexual abuse and bullying.

Fourteen studies reported the most prevalent ACE categories among their adolescent participants. Separation of parents or caregivers was most prevalent in five studies from USA (27.2–41.2%) [52–54,57] and Hungary (23.8%) [55]. Four other studies reported that household mental health problems or illnesses was the most prevalent during childhood (32–59%) [41,47,48,50]. Parental substance abuse (20–23.4%) [40,45], verbal maltreatment at age 5 (36.5%) [49] and experiencing conflicts with classmates (61.8%) [51] were other prevalent ACEs. These variations reflected the differences in study designs, including eligibility criteria, study settings, and the classification and measuring tools of ACEs. The prevalences should be interpreted within the study context and characteristics of the participants. Nevertheless, some ACEs, e.g., separation of parents or caregivers and household mental health problems, appeared more common in more than one study and country.

ACE scores were reported to be positively associated with the risk of having emotional or internalised problems (e.g., mood-related complaints) [45,46,52,55,56], mental health diagnoses [53], self-harm [48], behavioural problems throughout childhood [40], externalised problems (e.g., social and behavioural symptoms) [45,46,55,56], depression symptoms [51,54], anxiety symptoms [54], delinquency [42,44,45], police contact [43] in adolescence. Similarly, household dysfunctions and multiple adversities were positively associated with depressive symptoms [38]. The effect of individual ACEs showed that sexual abuse [73], victimisation (e.g., child maltreatment) [50], household mental illness [50,54], household alcohol problem [50], and income hardship [54] strongly increased the risk of adolescent mental health problems. Thirteen studies [38–40,42–45,47–50,52,53] interpreted their findings with respect to the timing of ACEs and outcomes according to the children's ages at measurements. A common example was inferring that the ACEs, which happened before outcomes were measured, were associated with the outcomes in adolescence.

Socioeconomic characteristics. The proportion of ACEs was found to be socially patterned and higher among children in more deprived, disadvantaged socioeconomic conditions [39,49,50]. Lowthian *et al.* [50] found that social deprivation and ACE independently increased the risk of child mental health diagnosis. Straatmann *et al.* [49] estimated that ACEs mediated the effects of socioeconomic disadvantages on adolescent behavioural problems and contributed to about one-sixth of this increased risk. Regarding ethnicity or race, the negative impact of the same number of ACEs experienced by Black adolescents was found to be stronger on delinquency than for White adolescents in Fagan and Novak [41].

Mediators and moderators. The effects of ACEs on adolescent outcomes were found to be positively mediated via self-esteem (in moderate adversity) [51] and resilience [56], but negatively via sleep problems [42], less self-control [42,44], externalising behaviour [43], and early delinquency (at age 11) [44]. Various outcome trajectories, including anxiety-depression risk, externalising behaviours, and police contact, were moderated by sex [46,54], being in late adolescence (ages 15–17 vs 12–14) [43], cognitive disability [45], race or ethnicity [43], and family function [52].

Cambridge Quality Checklist (CQC) assessments

The CQC assessment required consideration and understanding of the study design and methodology to facilitate the interpretation of study results. The assessment of each study was summarised in S5 Table.

Checklist of correlates–sampling, response rate, and sample size. Most included studies used random or stratified random sampling of a wider population of interest (score 1), except three studies which used convenience sampling (score 0) [41,42,51]. The response rate of seventeen studies was inadequate (score 0) because it was lower than 70% at the last time point of a longitudinal study, not reported, or any differential differences were not reported. Sample size was deemed adequate (score 1) in all included studies (n>400).

Checklist of correlates–measure of correlate (ACE measures). The measure of correlates, i.e. ACEs, were assessed separately for the classic-10 ACEs, bullying, and other ACEs. At least one classic-10 ACE was measured in each included study. The corresponding measures in six studies were assessed as having adequate reliability and validity: five studies [39–41,46,47] collected the ACEs data from more than one information source (score 1); one study [55] used the whole set of ACE-SQ, which has been evaluated with adolescents in the community, to show evidence of adequate internal consistency and good concurrent criterion validity [98,99].

The ACE measures of the classic-10 used in 14 studies were assessed as inadequate (score 0). Only one study [42] reported the psychometric properties of the ACE measure internal consistency (reliability), which was modest (Cronbach's $\alpha = 0.61$). Four studies selected the questions relevant to ACEs from the available data collected in two separate birth cohorts [43,44,48,49]. The questions were similar to those in the ACE-Q or ACE-IQ, respectively. Therefore, the psychometric properties of these ACE measures were judged by the available psychometric properties of these ACE measures. However, we were unable to find evidence of the psychometric properties of ACE-Q and ACE-IQ evaluated with proxies of children and of ACE-IQ evaluated with children [6]. The questionnaire of James *et al.* [45] was based on the Parent-Child Conflict Tactics Scale (CTS-PC) [100], but there was a lack of evidence about its validity and reliability [6]. The whole set of ACE measures in the four NSCH studies [52–54,57] were judged inadequate. This NSCH-ACEs module was evaluated by Bethell and colleagues [101] but they did not report the psychometric properties. No information was available to assess the Adverse Childhood Experience Questionnaire [102] developed by Lackova Rebicova *et al.* [56], or about the bespoke questionnaire based on the questionnaires of Childhood Trauma Questionnaire Short-Form (CTQ-SF) [95] and Hu *et al.* [103] used in Chen *et al.* [51]. The description of ACEs included in Lowthian *et al.* [50] was factual and concrete, but the reliability of the routine records may vary between staff's documentation practices, e.g., the timing of recording alcohol problems first emerged. Due to this uncertainty, the ACE measures in this study were assessed to be inadequate.

The measures of bullying were all rated as inadequate because of the weak or unknown psychometric properties [38,39,42,48]. Thirteen studies included and measured other adversities as ACEs. Three studies [38,41,46] collected other ACEs information from more than one informant or one time point; thus, the measures were considered adequate (score 1). The measures in the remaining ten studies were rated as inadequate (score 0) because the reported internal consistency was insufficient [42], or psychometric properties were not reported or found [42–44,49,50,52–54,56].

Checklist of correlates–measure of outcome. The measure of outcomes of ten studies [40,41,43,44,47,48,52–54,57] were assessed as inadequate (score 0) because the outcome measures were not evaluated for reliability or validity, e.g., proxy recall of events or opinions on children's emotional problem, adolescent self-reported police contact and self-harm, or scoring method was not validated [40]. The other ten studies [38,39,42,45,46,49–51,55,56] used outcome measures which are commonly regarded as validated and reliable, and they used standard scoring methods, e.g., Child Behavior Checklist and Beck Depression Inventory-II. Hence, their outcome measures were considered to be adequate (score 1).

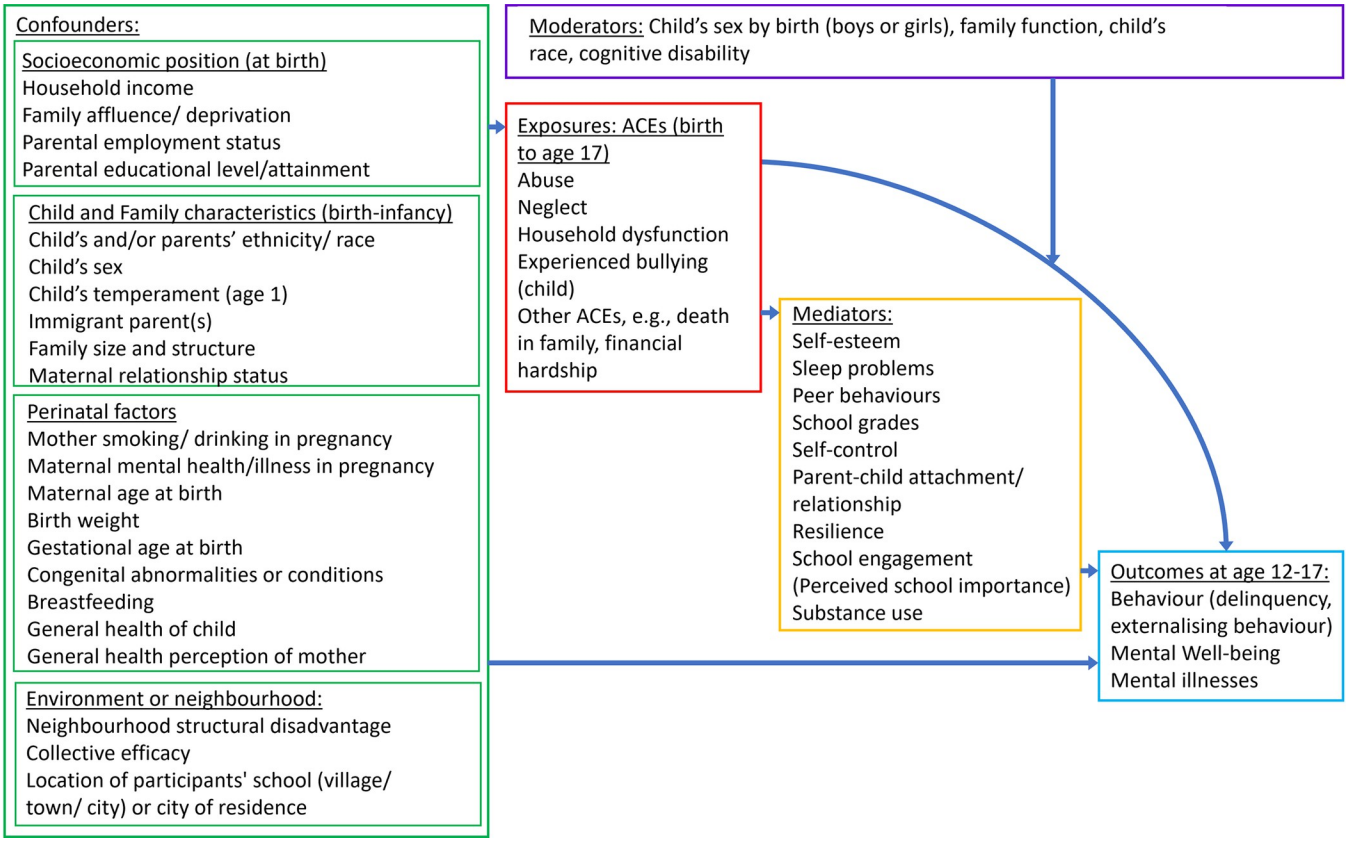

Fig 2. Causal diagram representing the correlates of children analysed in the included studies.

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Overall findings of all studies in each checklist. Only one study [55] was judged to be adequate in all areas of the correlate checklist. Fourteen studies scored the maximum in the checklist for the risk factors because they collected and used prospective data. Only one of 20 studies [46] was assessed with a high score of 7 (out of 8) on the checklist for causal risk factors because the analyses accounted for the changes in outcomes over time. This was also the only study that scored adequate scores on all three checklists, thus could be considered as providing high-quality of evidence [31,32].

Causal diagram representing the correlates analysed

Fig 2 summarises the conceptual relationships between ACEs, outcomes, and the confounding factors analysed in the included studies, and the mediating and moderating factors found to be influential. It should be noted that if confounding factors were included in the included studies' analyses, they were measured before or inferred to precede ACEs, commonly at the baseline of the included longitudinal studies.

Discussion

This review identified 20 studies that measured ACEs during childhood and estimated the association between ACEs and adolescent mental health and social behaviour. Each study included a selection of the classic-10 ACEs, with 16 studies also included bullying and/or other adversities, such that there were 27 unique adversity categories across the 20 studies. The variation in choices of questionnaires for ACE data collection, and that most studies included

adversities other than the classic-10, demonstrated heterogeneity in the definitions and concepts of "adverse childhood experiences" between studies.

The ACE questionnaires most commonly used in the included studies, e.g., ACE-Q and ACE-IQ, were designed for use with adults, and there was insufficient evidence of adequate reliability and validity for using them with children or their parents/caregivers [7,98,99,104,105]. All self- or proxy-reported ACE measures ask people to recall information from the past, e.g., recalling occurrences of the previous year. Collecting ACE information from routine records of agencies dedicated to monitoring and actioning on child maltreatment, e.g., USA Child Protective Services, and healthcare services, e.g., UK NHS, appeared to be feasible. However, the practices of recording the ACEs in routine records might vary over time, and ACEs might be under-recorded or under-reported [100,106,107]. Collecting outcome data in adolescence also appeared viable by using self-reported or proxy-report questionnaires and routine records, although the reliability and accuracy might vary.

The quantitative analysis methods also varied between studies. Regression modelling was the most applied statistical technique. Over half of the studies only analysed the effect of ACEs with the cumulative effects of ACE count, i.e. ACE score. The temporality of ACE nor the temporal effects of ACEs were specifically analysed. Despite the variation in analysis methods, each included study found that ACEs harmed adolescents' mental health and social behaviour. These findings resonated with the existing understanding and cumulating evidence of ACE effects on these outcomes during the whole childhood [1,2,11]. There were common factors, e.g., children's sex or gender, family's socioeconomic characteristics, included in the long list of confounding, moderating, and mediating factors in the analyses and shown to be statistically significant in the included studies. They reflected that the presence and effects of ACEs are influenced by an extensive network of familial and social factors surrounding children. Socioeconomic disadvantage or deprivation was the most common characteristic that increased the risk of ACEs and exacerbated the ACE impacts on adolescents.

From the findings of methodologies, three causes of concern were identified: 1) a lack of consensus on ACE definition, inconsistent categories measured in the ACE measurement tools; 2) possible bias due to missing data and collecting ACE data with measurement tools of inadequate psychometric properties; and 3) a lack of use of outcome change or specification of timing of ACEs. These led to uncertainties about the interpretation of findings and suitability of comparing the strength of causal association between ACE scores and the suggested outcomes.

Strengths and limitations

The detailed extracted data and narrative synthesis of each study's methodology of measuring ACEs and the analysis techniques were the main strengths of this review. These details are usually summarised briefly but rarely provided in reviews of ACE studies. Nevertheless, these would be useful to researchers and readers who are starting to study and understand the ACE literature and evidence. We compared each question and meaning of an "ACE" used to indicate ACE occurrence between the included studies. In the CQC assessments, we identified relevant evidence of the psychometric properties of the ACE measures for collecting ACE information about children. The CQC is particularly useful in prompting reviewers to consider the quality of the measurement tools, and the timing of data collection for explanatory factors and outcomes for inferring causal relationships. However, there were limitations in the CQC and our assessments. For example, the tool does not focus on assessing other contextual evidence for causal conclusions [32], e.g., analysis methodology and plausibility of the reported findings of the study. Another example is a lack of guidance on incorporating the assessments

of more than one correlate and measurement tool. Therefore, we did not assess the analysis methods and confidence in the findings of the included studies.

This review was restricted to English journal publications from three databases. Thus, some of the relevant studies might not have been included. The main rationale for restricting to peer-reviewed publications was to focus on formal studies of causal mechanisms, which are unlikely to be studied in grey literature. Noticeably, no included studies were published between 1998 and 2015 and none of the included studies measured educational outcomes. This trend of studying ACE impacts on children in more recent years may be relevant to the trend of ACE studies focusing on adults in earlier ACE studies [5]. The sharp increase in the number of ACE studies published in journals yearly from 2016 [3] may explain that the foci of ACE studies also expanded. It should be noted that many studies investigated a single ACE category only or classified the experiences with other terms, including "childhood adversity" and "child maltreatment". Hence, none of them were included in this review despite the conceptual and methodological similarities.

Implications for future research

Quantitative analysis methods in ACE literature. A transparent and clear description of the study methodology is essential for the reproducibility and comparability of ACE studies. In the included studies, the meaning or definition of each included ACE, the measurement items, and methods dealing with missing data were heterogeneous or not reported. Consequently, the meaning and range of "ACE score" varied between studies, leading to incomparable prevalence of ACE and potentially inaccurate estimates of the effect of ACEs.

Another methodological consideration is the approach to quantify the impacts of ACEs for the estimation. There are several options for analysing the association between ACEs and outcomes. Lacey and Minnis [108] discussed in depth the strengths and limitations of four common approaches to analysing adversities: ACE score, single adversities, empirically driven methods (e.g., latent class analysis (LCA)), and theoretically driven adversity models.

This review found that in the 11 studies which reported the proportion of children with each cumulative ACE score, the biggest proportion of children had no ACE (ACE score of 0), and the second biggest proportion experienced one ACE (ACE score of 1). The same was true in the findings of the CDC-Kaiser ACE Study [94]. Certain ACEs, e.g., sexual abuse, have been recognised as associated with a higher risk of disabilities or death [92]. These warrant the idea of analysing the independent effect of each single ACE and comparison between them. However, the coexisting ACEs are usually unaccounted for in this analysis approach of single adversities.

The ACE score method was used in 16 included studies, by analysing the summed ACE counts as integer numbers of ACE categories (i.e. the original method used in the CDC-Kaiser ACE Study [92]), or continuous numbers (e.g., to overcome problems in fitting categorical data into the regression model [48]). Despite the limitations to the ACE score approach, e.g., the effect of each ACE should not be assumed to be equal or substitutable, it is commonly used, either with the main justification being its simplicity and popularity in ACE research, or rarely being questioned [108]. LCA can also be used to group a range of ACEs into broader categories according to the correlation between ACEs and the prevalence of different combinations [108]. The classification is data-driven depending on the amount of data and characteristics of participants in the dataset; moreover, it requires careful interpretation and classification, e.g., when deciding the number and names of categories. Both ACE score and LCA of the "cumulative adversity level" do not necessarily reflect the severity, e.g., whether the ACEs happened concurrently or separately in childhood, for how long, or whether one or

another ACE is more impactful [108–110]. The ACE scores and latent classes in the existing literature are heterogeneous between studies.

In this review, we also identified decision tree classification and time-to-event modelling that were used by two included studies [47,50] to estimate the association of individual ACEs with outcomes. Decision tree analysis can be beneficial in providing a clear prediction of the outcomes according to the more complex and multiple interactions and the probability of each ACE leading to the outcome. However, this technique requires a large dataset [111]. A time-to-event model with time-varying exposures was only used in one included study, which accounted for the timing of the first occurrence of any included ACE and the sequent outcomes of interest [50]. However, this method requires detailed and accurate data about the timing of ACEs and the emergence of outcomes, and it does not appear to evaluate the duration or severity of ACEs.

It would be challenging or unfeasible to estimate the impact of each ACE combination, and the combined effect is unlikely to be described by simple additive or multiplicative interactions. Therefore, using both single ACEs and cumulative ACEs can be beneficial for estimating the effect of each ACE. It may also facilitate understanding of the impact of a combination of ACEs, e.g., which ACE is the driver of risk effect in a combination [108].

Conceptualising "ACEs" and the relationships with other factors. The conceptualisation of ACEs closely corresponds to the analysis approaches and methods and the measurement of ACE, e.g., whether a certain adverse condition is ACE or a correlate of ACEs. Many researchers called for standardisation in ACE definition and the use of appropriately evaluated measurements for more homogeneous and precise ACE estimations, e.g., measuring the timing and frequency of ACEs vs dichotomised life-time ACEs [112]. There are at least three approaches observed from ACE studies to conceptualise what constitutes an ACE. First, it could be according to what prompts physiological responses, e.g., an event that causes the "fight-or-flight" stress response [28]. Second, the probabilistic effects on one's later life and health, e.g., an event leading to a long-term traumatic response [113–115], have been considered. Third, it could be the nature of the event, e.g., an event in which the child was injured [27,116]. Furthermore, a combination of any of these can be included to conceptualise ACEs, evidenced by the wide range of "ACEs" found in the included studies.

The CDC-Kaiser ACE Study coined the term "ACE" and aimed to evaluate adverse experiences in the home during childhood as exposures [92]. The ten chosen childhood experiences of abuse, neglect, and household dysfunction were measured, because they were the common observations disclosed to the researchers by the people suffering from ill health or being overweight in adulthood [117]. However, the term "ACE" was not clearly defined in this study, and its outcome of interest was broad, namely "*risk factors for the leading causes of death in adult life*" (p.1, [117]). Conceptually, if considering the probabilistic negative effects of ACEs on life and health, many environmental and/or social explanatory factors in childhood could be regarded as ACE, if they are associated with ill health later in life.

Another difficulty in unifying the definition of ACEs is that the definition of each ACE category varies between studies and safeguarding policies. For example, in the CDC-Kaiser ACE Study, witnessing domestic violence solely referred to "*having had a battered mother*"[30,94]; whilst, nowadays, it is commonly referred to as domestic abuse, which encompasses physical, emotional, economic controlling or coercive behaviours from anyone to another within a household [118,119]. This evolving and refining conceptualisation is beneficial, yet may further complicate the effort required to define ACEs. Nevertheless, each ACE study should have a focused aim and reasons for measuring and analysing certain adverse experiences which are included [108].

Directions for further evaluations and interventions

Most of the included studies focused on the narrative of ACEs being the primary predictor variables of negative outcomes in adolescence. Instead, three studies considered ACEs as mediators between household socioeconomic factors [49,50] or neighbourhood disadvantage [39] and adolescent outcomes. Therefore, shifting the roles of ACEs and other explanatory factors when conceptualising their relationships for analysis is viable and essential to identifying the protective factors for ACEs. Shifting the narrative to seeking effective prevention and intervention could facilitate breaking the pathways between factors contributing to ACEs and ACEs, and between ACEs and negative outcomes [3].

Notwithstanding the variations in methodology in measuring and analysing ACEs in research studies, they also indicate an opportunity for triangulation in the research of ACEs. These methodologies together offer ideas of combining multiple methods, theories or propositions, and ACE data sources to further address the effects of ACEs on adolescents and relevant interventions.

Conclusion

Among the longitudinal and cross-sectional studies included in this review, ACEs before or during adolescence were found to be associated with an increased risk of negative mental health and well-being and social behaviour in adolescence. Measuring ACEs in childhood and the associated impacts appeared feasible. However, the heterogeneous study methodologies, especially the ACE classification and measurement tools, limits the comparability of findings. Future studies of ACEs should use measurement tools that have been shown to have adequate psychometric properties, including reliability and validity, appropriate to their samples, and clearly report all the questions used to collect ACE data. They should also specify the aim of measuring and analysing the selected ACEs and avoid using the ACE score approach solely in analysis. Furthermore, more studies should address the factors which lead to ACEs or can mitigate their detrimental impacts on adolescent psychosocial development, and could use triangulation in the research of ACEs.

Supporting information

S1 Appendix. Protocol (last version, dated July 2023).
(DOCX)

S2 Appendix. Literature search strategies.
(DOCX)

S3 Appendix. Details of extracted data items.
(DOCX)

S1 Table. Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist (Tricco et al., 2018) [37].
(DOCX)

S2 Table. Adverse childhood experiences measures used in the included studies.
(DOCX)

S3 Table. Studies excluded at full-text assessment.
(DOCX)

S4 Table. Analysis methods and findings in the included studies.
(DOCX)

S5 Table. Cambridge quality checklist assessments.
(DOCX)

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