



Analysis

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A systematic review of conceptualizations and statistical methods in longitudinal studies of resilience

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Resilience research seeks to understand how protective factors interact with adversity to yield positive outcomes over time. However, inconsistent conceptualizations and diverse methodologies limit comparability across studies. In this systematic review (preregistered on PROSPERO CRD42019138732), we examined 193 longitudinal psychosocial resilience studies published over the past 30 years, including 805,660 participants across all age groups. We analyzed (1) conceptualizations of resilience as a trait, outcome or process; (2) statistical approaches (variable-centered, person-centered or combined); (3) types of models and their relationship to adversity (for example, protective, promotive, vulnerability, differential susceptibility); and (4) heterogeneity in adversity, outcomes and promotive or protective factors. Most studies lacked an explicit resilience definition, and only 32% explicitly defined it as a trait (6%), an outcome (19%) or a process (8%). Variable-centered approaches predominated (85%), with most studies testing moderation and identifying protective/promotive effects, while few supported differential susceptibilities. Adversities were primarily childhood- or family-based, with mental health outcomes most common. Protective factors spanned individual, family and community levels, while neurobiological factors were rarely considered. We offer recommendations from our review to improve clarity and consistency in conceptualizing, operationalizing and interpreting resilience in longitudinal research.

"Sweet are the uses of adversity, which, like the toad, ugly and venomous, wears yet a precious jewel in his head." – William Shakespeare, "As You Like It" (II.1.12–17)

Resilience in human development has been a compelling and active research topic for decades, driving multidisciplinary efforts to understand how individuals adapt positively despite adversity. Numerous reviews and meta-analyses have examined resilience definitions^{1–4}, psychometric measures^{5–7} and related interventions^{8–12}.

Recently, interest has expanded to psychobiological perspectives, with reviews synthesizing findings from genomics^{13–17} and neuroscience^{18–21}. However, a key issue across reviews is the lack of consensus on defining and operationalizing resilience, leading to considerable heterogeneity that hinders evidence integration and complicates future intervention design.

Resilience is a complex, multifaceted construct with definitions varying across disciplines and frameworks. Contemporary psychology

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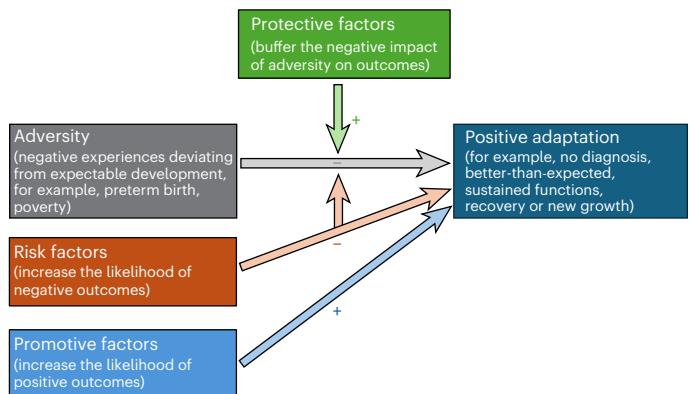


Fig. 1 | The interplay of adversity, risk factors, protective factors and promotive factors in the resilience framework. A factor may function as both protective and/or promotive depending on the context (for example, type of adversity and outcomes). For example, social support can serve a protective role by buffering against adversity and preventing mental health decline during hardship and a promotive role by enhancing well-being even in the absence of adversity.

and developmental science increasingly define resilience as the process and outcome of successfully adapting to adversity, involving mental, emotional and behavioral flexibility and adjustment to changing demands²². Capturing these adaptive pathways requires longitudinal studies²³. A systematic review of 36 longitudinal studies on resilience in aging found most studies used data-driven methods, focused on non-acute adversity (for example, cancer), defined positive adaptation as the absence of distress and rarely assessed positive mental well-being²⁴. However, the generalizability of this review was limited by the small number of studies and the aging-specific focus.

Despite extensive resilience research, a comprehensive review of how resilience has been conceptualized and operationalized in longitudinal psychosocial studies is lacking. Such a review would help both novice and experienced researchers understand prevailing definitions, methodological approaches and their respective strengths and limitations, ultimately guiding future work. To address this gap, we provide an integrative overview of longitudinal resilience studies in psychosocial fields across the lifespan. First, we present a narrative summary of resilience concepts and statistical approaches. This is followed by a systematic review of methods (definitions, statistical approaches, key findings) and content areas (adversity types, outcomes and protective factors). We then offer recommendations on terminology, conceptual clarity, methodology and interpretation for future research.

Narrative review of resilience concepts and statistical approaches

Resilience as a trait, outcome or process

Resilience has been conceptualized as a trait, an outcome or a process^{25,26}. Trait resilience, or ‘resiliency’, refers to inherent characteristics that facilitate coping and adaptation under adversity⁷. Various psychometric scales have been developed to measure trait resilience, but a meta-analysis of 61 scales over 30 years identified four common latent factors: recovery, goal-orientation persistence, adaptability and social cohesion²⁷. While these scales show high generalizability, they often lack sensitivity to temporal changes arising from person–environment interactions²⁸. Although relatively stable, trait resilience is not static and may fluctuate across the lifespan due to personal experiences, environmental influences and developmental stages²⁹. This complexity challenges the trait-oriented perspective as it tends to overlook intra-individual variation and shows limited predictive validity in longitudinal research^{26,30–32}.

Resilience as an outcome, or resilient functioning, refers to positive adaptation following adversity and can be operationalized in various ways, including the absence of psychopathology, better-than-expected functioning, recovery to baseline, sustained high functioning, new growth or combinations thereof^{26,33,34}. Two common methods for capturing resilience are (1) the residualization approach, which measures deviation from expected functioning in adversity-outcome regressions, and (2) developmental trajectories analysis, which identifies distinct adaptation patterns over time³⁵. Both have limitations. Residualization is sensitive to outliers and suffers from non-independence with outcome variables; for example, cognitive resilience often correlates strongly with cognitive ability itself^{36,37}. Trajectory approaches lack consensus on defining resilient patterns, and overlap across measures remains unclear^{38,39}. As such, the outcome perspective is more instrumental than conceptual, and it may oversimplify resilience, emphasizing positive outcomes after adversity while overlooking the underlying mechanisms and contextual influences^{35,40}.

There is growing consensus that resilience involves dynamic, multisystemic processes shaped by the interplay of internal (for example, genetics, intelligence, self-efficacy) and external (for example, social support, education) factors that protect positive adaptation in the face of adversity^{2–4,26}. This process-oriented perspective emphasizes that resilience is neither static nor uniform; it varies across time, contexts and life domains^{23,41}. For example, individuals may adapt well in professional or academic settings but struggle socially¹. Such multidimensionality is often overlooked, yet when examined, the proportion of individuals classified as resilient may drop from 60% to below 20%^{31,42,43}. This highlights the risk of overestimating resilience through single-domain assessments and the need to consider domain-specific fluctuations. Moreover, protective factors may function differently across life stages, for example, parental monitoring and protection, deemed beneficial in early childhood, may hinder independence and autonomy in young adulthood^{4,44}. Shifting from trait-based to process-oriented perspectives, longitudinal research is essential to capture how resilience unfolds over time and across contexts and to extract multisystemic insights for supporting individuals facing adversity^{24,32}.

Adversity, positive adaptation and protective factors

Regardless of the definitions adopted, resilience research involves three core elements: (1) adversity as the antecedent, (2) positive adaptation as the outcome and (3) multilevel resources that protect or promote positive adaptation^{6,25}. However, the terminology surrounding these elements is often inconsistent. Having addressed the diverse criteria for positive adaptation in outcome-based models, we now clarify conceptual ambiguities around adversity and protective factors (Fig. 1). For a detailed glossary, see Table 2.1 in the *Handbook of Resilience in Children*²⁶.

Adversity, risk and risk factors are often used interchangeably, yet they hold distinct meanings. Adversity refers to negative experiences that deviate from expected supportive environment and pose challenges to healthy development⁴⁵. These can range from macro-level (for example, war, disasters, pandemics) to micro-level (for example, neglect, abuse, life stress) experiences and cumulative exposures. Risk denotes the likelihood that adversity leads to negative outcomes, while a risk factor is a specific attribute that increases the likelihood⁴⁶. Adversities can function as risk factors^{16,45}. For example, preterm birth is an adversity, and organ immaturity (for example, lungs or brains) and related complications (for example, chronic lung disease or periventricular bleeds) are risk factors for cognitive impairment⁴⁷. Conversely, not all risk factors are adversities; for example, biological sex or genetic predisposition may be risk factors for mental health conditions but are not adversities themselves. The key distinction is that adversities are inherently negative experiences, while risk factors are defined by their association with negative outcomes.

Table 1 | Comparison of the variable-centered, person-centered and combined approaches

| | Variable-centered | Person-centered | Combined |
|-----------------------------------|---|---|---|
| Purpose | To examine the relationships and interactions between variables across the full sample | To identify distinct trajectories or profiles within the population | To integrate both variable- and person-centered methods |
| Strategy | Test linkages among measures of adversity, potential promotive or protective factors and positive outcome | Classify individuals into subgroups on the basis of their responses to adversity over time | Combine classification and multivariate analysis to identify factors for resilient subgroup |
| Typical analytical methods | Analysis of variance; regression analysis Structural equation modeling Latent growth curve modeling | Cluster analysis (for example, Q-sort) Latent class/profile analysis Latent transition analysis GMM | Hybrid models combining person- and variable-centered techniques (for example, GMM and multinomial regression analysis) |
| Examples | Corallo et al. ³⁷ • Data: longitudinal NLSY97 • Adversity: childhood environmental disadvantages • Moderator: parental vigilance (limit-setting, maternal knowledge) • Outcome: adult mental health symptoms • Analysis: multiple regression with interaction terms • Key finding: promotive effect of higher maternal knowledge and protective effect of parental limit-setting | Schäfer et al. ⁵³ • Data: 28 longitudinal cohorts • Adversity: COVID-19 pandemic • Outcome: mental distress • Analysis: GMM • Key findings: distinct trajectories emerged—stable-low distress (most common), recovery, chronically elevated and delayed worsening | Hiller et al. ⁹⁸ • Data: 627 UK social welfare-involved children • Adversity: out-of-home care • Outcome: internalizing and externalizing difficulties • Analysis: GMM (to identify trajectories) + multinomial logistic regression (to examine predictors of class membership) • Key findings: fewer placements and being placed with siblings showing protective effects for resilient trajectory (versus chronic problems group) |
| Pros | Relatively direct and easy-to-understand estimates | Capturing individual heterogeneity with higher ecological validity | Balances individual differences and accounts for variable effects |
| Cons | Homogeneity assumption may overlook individual differences | Requires larger sample sizes and may not generalize well to other populations | Requires large datasets and involves higher statistical complexity |

Protective factors can stem from a broad array of internal resources (for example, optimism, problem-solving skills, self-efficacy) and external supports (for example, family relationships, social connections, positive environments) that help buffer the negative impact of adversity^{3,26}. As shown in Fig. 1, the same factor may show protective or promotive effects depending on context, but the two terms, although often used interchangeably, differ statistically⁴⁸. Protective effects represent moderation, when factors specifically reduce the negative impact of adversity, with stronger or exclusive effects in high-adversity groups^{25,30}. Promotive effects reflect the main effects, where factors broadly benefit individuals regardless of adversity²⁵. For example, stimulating parenting shows promotive effects across children's cognitive and behavioral outcomes but offers a protective effect on internalizing symptoms, specifically in low-birth-weight children⁴⁹. Some researchers use 'resilience factors/resources' as an umbrella term to describe both effects without distinction. However, differentiating between protective and promotive effects is valuable for understanding developmental processes (for example, nature–nurture interplay, where individual characteristics and environmental factors shape outcomes differently) and for informing targeted interventions (for example, protective effects may warrant prioritizing support for those exposed to adversity).

Statistical approaches: variable-centered, person-centered and combined approaches

In resilience research, two primary analytical approaches are commonly used: variable-centered and person-centered⁵⁰. Variable-centered approaches examine relationships among adversity, risk, protective and promotive factors as well as outcomes across an entire population, typically using regression-based methods⁵¹. By contrast, person-centered approaches underscore heterogeneity in responses to adversity by identifying distinct subgroups (for example, resilient versus maladaptive) with similar adjustment profiles over time or across domains⁵². Each approach has limitations. Variable-centered approaches assume population homogeneity and may overlook individual differences in adaptation⁵⁰. Person-centered analysis, while useful for identifying subgroups, often yields prevalence estimates

without explaining why individuals follow different developmental trajectories^{53,54}.

To address these gaps, researchers increasingly advocate integrating the two approaches^{48,52,55}. For example, Miller-Lewis et al.⁴⁸ found that variable-centered analysis revealed the promotive effect of child–parent relationships, while person-centered analysis identified teacher-reported self-control as a protective factor associated with resilient group membership. Statistical methods such as latent class growth analysis and growth mixture modeling (GMM) offer an integrated framework for examining resilience at both group and individual levels⁵⁶. Using GMM, researchers⁵⁷ identified three math performance trajectories among late preterm children: resilient (better-than-expected); risk (declining) and reference (stable average). Regression analysis further showed that sensitive parenting and preschool attendance were protective factors for membership in the resilient group⁵⁷.

Table 1 compares and illustrates the three approaches to studying resilience. Each has strengths and limitations, and the choice should align with the research questions and available longitudinal data.

Beyond resilience: individual differences in environmental sensitivity

Interaction is a central theoretical and statistical concept in resilience research, capturing how internal and external factors shape positive adaptation to adversity⁶. Expanding beyond resilience, person–environment interaction models such as vulnerability, differential susceptibility and vantage sensitivity offer valuable insights into individual differences in response to environmental influences, both negative and positive. Although all emphasize interaction, they propose distinct mechanisms and can be tested competitively⁴⁹.

The vulnerability–stress model, also known as the diathesis–stress or dual-risk model, posits that vulnerability arises from the interplay between adversity and inherent predispositions (for example, genetic, behavioral and psychological traits) that increases the risk for negative outcomes⁵⁸. For example, individuals with extremely low birth weight (<1,000 g) experienced more internalizing problems following cumulative adversity than did their normal-birth-weight peers⁵⁹.

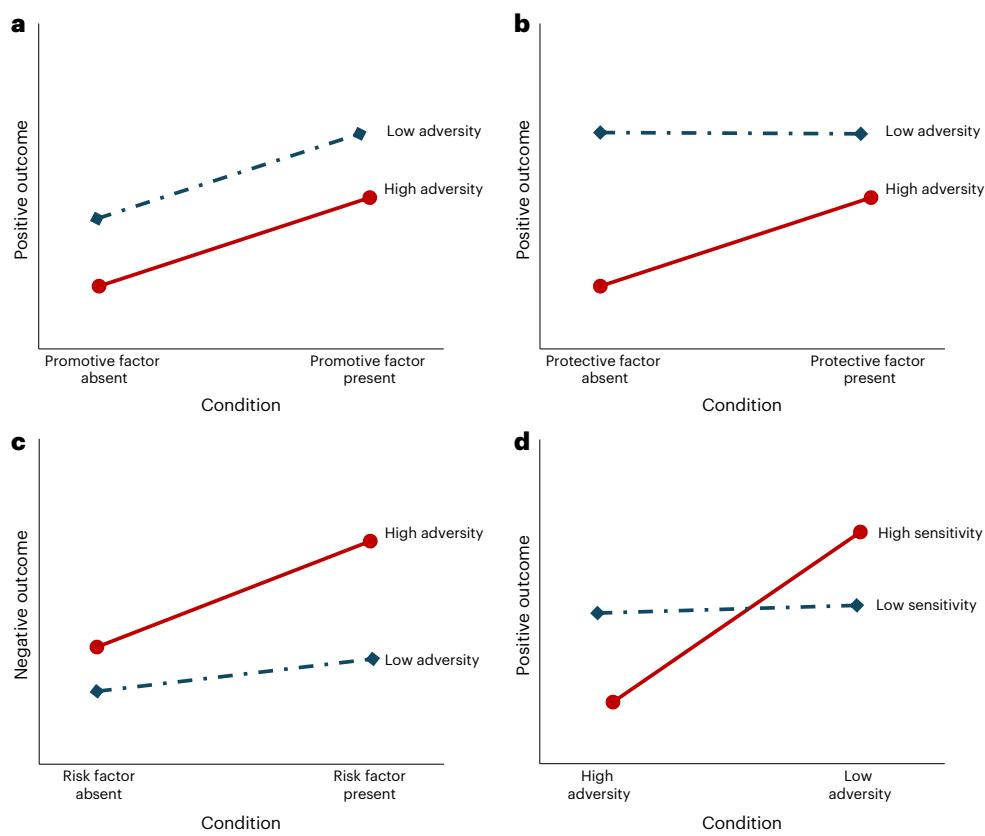


Fig. 2 | Interaction patterns of individual differences with environmental contexts. **a**, Promotive effect: the attribute shows a main effect that operates similarly under both high- and low-adversity conditions. **b**, Protective effect: the attribute buffers against negative outcomes, offering a moderation effect that benefits individuals exposed to high adversity. **c**, Vulnerability: an interaction

between adversity exposure and underlying risk factors that predispose individuals to negative outcomes (for example, diathesis–stress model).

d, Differential susceptibility: certain individuals are more sensitive to both negative and positive environments, responding ‘for better and for worse’.

Although moderation analysis is commonly used to test vulnerability hypotheses, mediation analyses have also been applied to examine how adversity is associated with negative outcomes through intermediate risk processes. For example, individuals born preterm (adversity) are more likely to experience school bullying (risk factor), which is further associated with greater psychotic symptoms in adulthood⁶⁰.

Differential susceptibility theory extends the ‘dark side’ of vulnerability by proposing that some individuals are not only more negatively affected by adversity but also benefit disproportionately from positive environments⁶¹. It emphasizes developmental plasticity, with individual differences of susceptibility shaped by biological and psychological markers. For example, individuals born small for gestational age had higher-than-expected adult wealth when raised with above-average maternal sensitivity but lower wealth when raised with below-average maternal sensitivity, whereas this pattern was not seen in peers born appropriate for gestational age⁶². Environmental sensitivity can also be assessed through questionnaires and behavioral observations⁶³. Using the Highly Sensitive Person Scale, individuals are categorized as orchids (31%—highly sensitive, flourishing in nurturing environments but struggling under adversity), tulips (40%—moderately sensitive majority) or dandelions (29%—less sensitive but more resilient to adversity)⁶⁴. This orchid–dandelion typology reflects two evolutionary bet-hedging strategies, plastic (high susceptibility, adaptable) versus fixed (low susceptibility, stable) responses to environmental unpredictability⁶³.

The ‘bright side’ of environmental sensitivity is reflected in a new concept of vantage sensitivity, which refers to an individual’s general proclivity to benefit from positive, well-being- and competence-enhancing environments⁶⁵. However, unlike resilience, vulnerability

and differential susceptibility models, vantage sensitivity considers individual differences in response to positive experiences only, without making claims about the potential response to adverse experiences⁶⁶. Moreover, although empirical support for vantage sensitivity is growing, the evidence remains relatively limited and is still in the early stages^{49,67}.

Therefore, our synthesis of findings from previous longitudinal studies on the interaction patterns of additional factors in the associations between adversity and outcomes will be categorized into four main groups: promotive effects (beneficial regardless of adversity), protective effects (particularly beneficial under adversity), vulnerability (amplifying the negative impact of adversity) and differential susceptibility (better outcomes in low-adversity but worse outcomes in higher-adversity conditions). Figure 2 summarizes and illustrates these models.

Systematic review of longitudinal resilience studies

This systematic review examines how resilience is conceptualized, operationalized and interpreted in existing longitudinal psychosocial research and identifies current trends and gaps to inform future research. Specifically, we will (1) provide an integrated overview of the methodological landscape, including resilience definitions (trait, outcome or process), statistical approaches (variable-centered, person-centered or combined), analytical processes (for example, moderation, mediation) and main interaction patterns (promotive, protective, vulnerability, differential susceptibility), and (2) conduct a content analysis to synthesize core study elements across domains of adversity exposures, outcomes and promotive/protective factors.

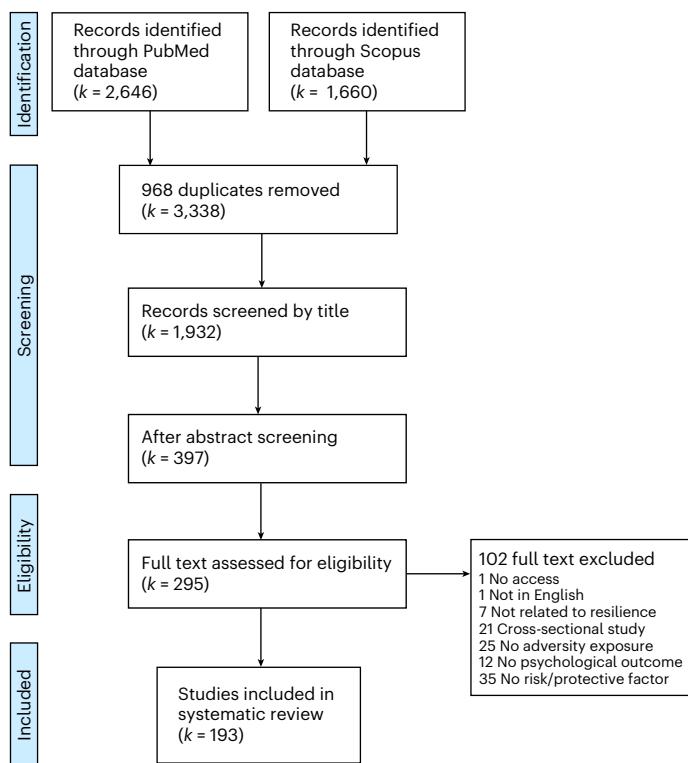


Fig. 3 | PRISMA flow chart of the screening and study selection process. PRISMA flow diagram illustrating the identification, screening and selection of studies (k = number of studies). Studies were published up to December 2023; reference lists of included studies are provided in the Supplementary Information.

Results

Study selection and characteristics

We identified 193 articles meeting eligibility criteria after title, abstract and full-text screening (Fig. 3). Published between 1992 and 2023, studies increased notably from 2006, peaking in 2023 (Supplementary Fig. 1). The rise from 2020 to 2023 may reflect COVID-19 impacts, with 18 studies addressing pandemic exposure. Nearly half were conducted in the United States (49%). Sample sizes ranged from 24 to 111,229, assessment waves from 2 to 72 and follow-up periods from 1 month to 75 years. Participant ages spanned the lifespan: 1.04% focused on infants, 10.36% on children, 38.86% on youth/adolescents, 35.23% on adults, 12.44% on older adults and 2.07% on mother-child dyads. Detailed study characteristics are available in Supplementary Table 1.

The included studies had an average quality score of $M = 5.95$ ($s.d. = 1.31$). Of these, 62 (32%) were rated as 'good', 129 (67%) as 'fair' and 2 (1%) as 'poor'. Interrater reliability for the total scores was acceptable ($\kappa = 0.68$, 95% confidence interval (CI) = 0.57, 0.76), indicating adequate agreement between raters. Full quality ratings are provided in Supplementary Table 2.

Integrated synthesis of definition, statistical methods and findings

Originally developed to visualize energy and materials flow⁶⁸, Sankey diagrams have become useful in bibliographical analyses and systematic reviews for illustrating article-level connections and heterogeneity⁶⁹. These diagrams depict categories as nodes linked by edges, with their widths representing proportional data flows. To visualize the frequencies and flows between resilience definitions, statistical methods and findings, we created a Sankey diagram (Fig. 4) using detailed data from included studies (Supplementary Table 1) via the networkD3 package in R. The diagram highlights considerable

heterogeneity in how resilience is defined, the analytic approaches used and the reported findings.

Resilience definitions. Only 32% of studies explicitly defined resilience, with 19% (number of studies, $k = 36$) that defined resilience as an outcome, 8% ($k = 15$) as a process and 6% ($k = 11$) as a trait. The remaining 68% ($k = 131$) lacked a clear definition or omitted the term 'resilience' entirely, instead using related terms such as 'protect/protective/protection' (most frequent), 'promotive', 'resources', 'recovery', 'risk', 'buffer' and 'vulnerability'. Term frequencies are shown in Supplementary Fig. 2.

Statistical approaches. Variable-centered approaches, primarily regression-based methods, were used in 85% of studies ($k = 165$), regardless of resilience definition. Person-centered or combined approaches were more common in studies defining resilience as an outcome (28%, $k = 10$). Conversely, combined approaches were less common in studies defining resilience as a process (20%, $k = 3$) or a trait (18%, $k = 2$). Among studies without a clear definition, 4% ($k = 5$) used the person-centered approach, and 6% ($k = 8$) used combined approaches.

Statistical processes and interaction patterns. Most studies (86%, $k = 166$) tested moderation effects, either alone or combined with main or mediation effects. Of these, 43% ($k = 72$) reported protective effects, 19% ($k = 31$) promotive effects, 11% ($k = 19$) vulnerability and 3% ($k = 5$) differential susceptibility, and 2 studies reported no significant findings. An additional 22% ($k = 37$) examined multiple additional factors, showing different patterns for each variable. Mediation-only analyses appeared in 4% ($k = 8$), identifying mechanisms of vulnerability. Solely main effects were examined in 9% ($k = 17$), with 14 reporting promotive effects and 3 indicating vulnerability.

Heterogeneity of adversity exposures, outcomes and promotive or protective factors

To illustrate the diversity and connections between adversity and outcomes, we created another Sankey diagram using categorized data from the included studies (Supplementary Table 1). As shown in Fig. 5, childhood adversity was the most frequently studied ($k = 49$), followed by family adversity ($k = 37$), personal or psychological challenges ($k = 25$), environmental or community adversity ($k = 20$), COVID-19 ($k = 18$), health-related adversity ($k = 14$), developmental challenges ($k = 13$), cumulative adversity ($k = 9$) and life-work transitions ($k = 8$).

In terms of outcomes, 61% ($k = 118$) of studies focused on mental health, followed by multiple domains (16%, $k = 31$), cognitive function (11%, $k = 22$), behavioral problems (4%, $k = 8$), educational achievement (3%, $k = 5$), personality (3%, $k = 5$) and social relationships (2%, $k = 4$). Protective or promotive factors by outcome domain are summarized in Supplementary Table 3. All outcome domains were associated with factors at both internal (individual) and external (family and community) levels. A word cloud analysis (Fig. 6), based on frequency data from Supplementary Table 4, highlights the factors most commonly targeted for examination by researchers, irrespective of statistical significance. Family- and community-level factors appeared most frequently examined, while individual-level factors spanned a broader range, including demographics, psychological capacities, physical health and biological variables.

Discussion

This systematic review quantified the heterogeneity in both methodological approaches (conceptualizations, statistical approaches, interaction patterns) and research content (adversity exposures, outcomes, promotive/protective factors) in longitudinal psychosocial resilience studies. Notably, 68% of studies did not explicitly define resilience as a trait, outcome or process, and 85% used variable-centered approaches.

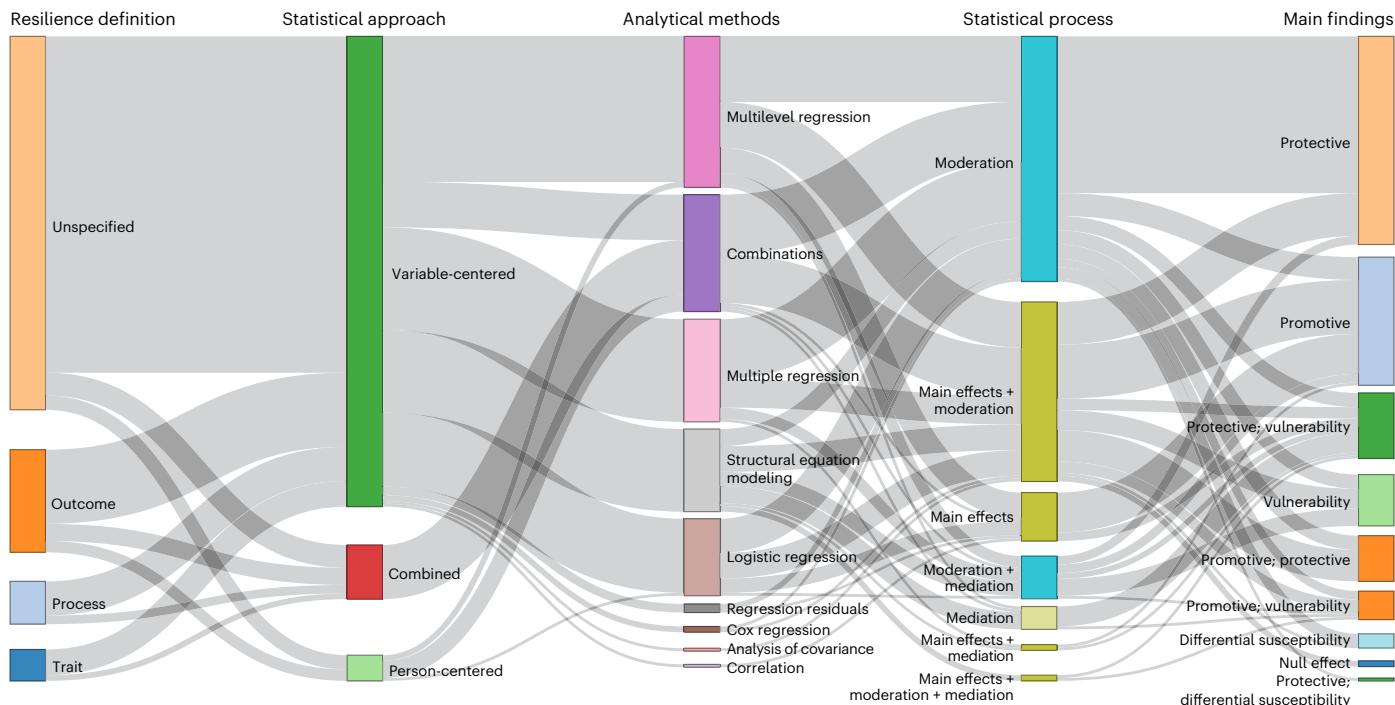


Fig. 4 | Sankey diagram illustrating the integration of resilience definitions, statistical methods and interaction patterns across the reviewed articles ($k = 193$). In the 'Analytical methods' column, 'Combinations' refers to studies using both classification and regression analysis methods. In the 'Main findings'

column, multiple patterns indicate studies that examined multiple additional factors and reported distinct patterns for each. Flow-line thickness reflects the frequency of the studied connections between categories across different components of resilience research.

Moderation effects were most commonly reported, typically indicating either resilience (that is, protective effects) or vulnerability, while only 3% identified differential susceptibility. Childhood and family adversity were the most frequently examined exposures, with mental health outcomes receiving the most attention. Protective and promotive factors were related primarily to parenting, family and community contexts, while biological markers such as genetic and neurobiological factors remained largely underexplored.

Although most reviewed studies did not explicitly define resilience, all statistically examined interactions between adversity and protective factors in relation to psychosocial outcomes, reflecting the three core elements of a process-oriented conceptualization: adversity, positive outcomes and protective factors. Common operationalizations of resilient outcomes include stable functioning^{39,53}, recovery to baseline⁷⁰ and exceeding expectations⁷¹. These approaches underscore the value of longitudinal designs in capturing how protective factors and adversity interact over time to shape developmental outcomes^{24,72}. However, the lack of clear definitions highlights a critical gap in how resilience is conceptualized and operationalized in literature. Moving forward, adopting a clear, process-oriented definition is recommended for longitudinal research to more effectively capture the evolving interplay of risk, protective and promotive factors, individual differences and contextual influences over time.

The study of psychological resilience began with early observations of heterogeneity in child psychopathology following trauma^{30,58}. While person-centered approaches are not new, they remain underused compared with variable-centered approaches. This may be due to the relative ease of identifying protective factors through variable-centered analyses and the familiarity of traditional statistical methods such as regression in developmental research^{50,51}. Among the few studies using person-centered approaches, inconsistency in defining 'resilient' subgroups or trajectories is common. Some define resilience as recovery to baseline³⁸, while others view it as stable, healthy functioning despite adversity³⁹. Criteria for defining resilience also vary

by population. For example, studies involving clinical samples often frame resilience as symptom recovery⁷³, while studies of non-clinical populations emphasize psychological stability with minimal impact from adversity⁵³. These varying thresholds can lead to conflicting conclusions and limit generalizability. Future research should clearly define study populations, clarify conceptual frameworks and specify operational definitions within each group to improve precision and applicability.

We categorized previous findings of interaction patterns into four types: protective effects, promotive effects, vulnerability and differential susceptibility, with protective effects being most frequently reported. While these categories summarize common interactions among adversity, additional factors and outcomes, they are not mutually exclusive. Vulnerability and resilience are often viewed as opposite poles on a continuum of adaptation, where the direction and magnitude of a factor influence whether it amplifies or buffers the impact of adversity^{26,58,74}. For example, for children exposed to adversity, higher maternal sensitivity may be protective whereas lower sensitivity may increase vulnerability⁷⁵. However, the assumption of symmetry does not always hold as relationships can be asymmetrical or nonlinear—protective effects may emerge only above certain thresholds, and low levels of a factor do not necessarily indicate increased vulnerability. Future research should statistically test these different interaction patterns separately, consider nonlinear models to assess threshold effects and determine whether factors operate symmetrically or asymmetrically in moderating adversity⁴⁹. In addition, interaction patterns may vary depending on study design, analytic approach and data characteristics, which should be carefully considered to support valid and meaningful interpretations.

A substantial body of research linked childhood and family adversity (for example, maltreatment, neglect, parental psychopathology, socioeconomic disadvantages) to mental health conditions, including depression, anxiety, post-traumatic stress disorder and behavioral disorders. Social support and family factors are the most frequently examined promotive or protective influences on

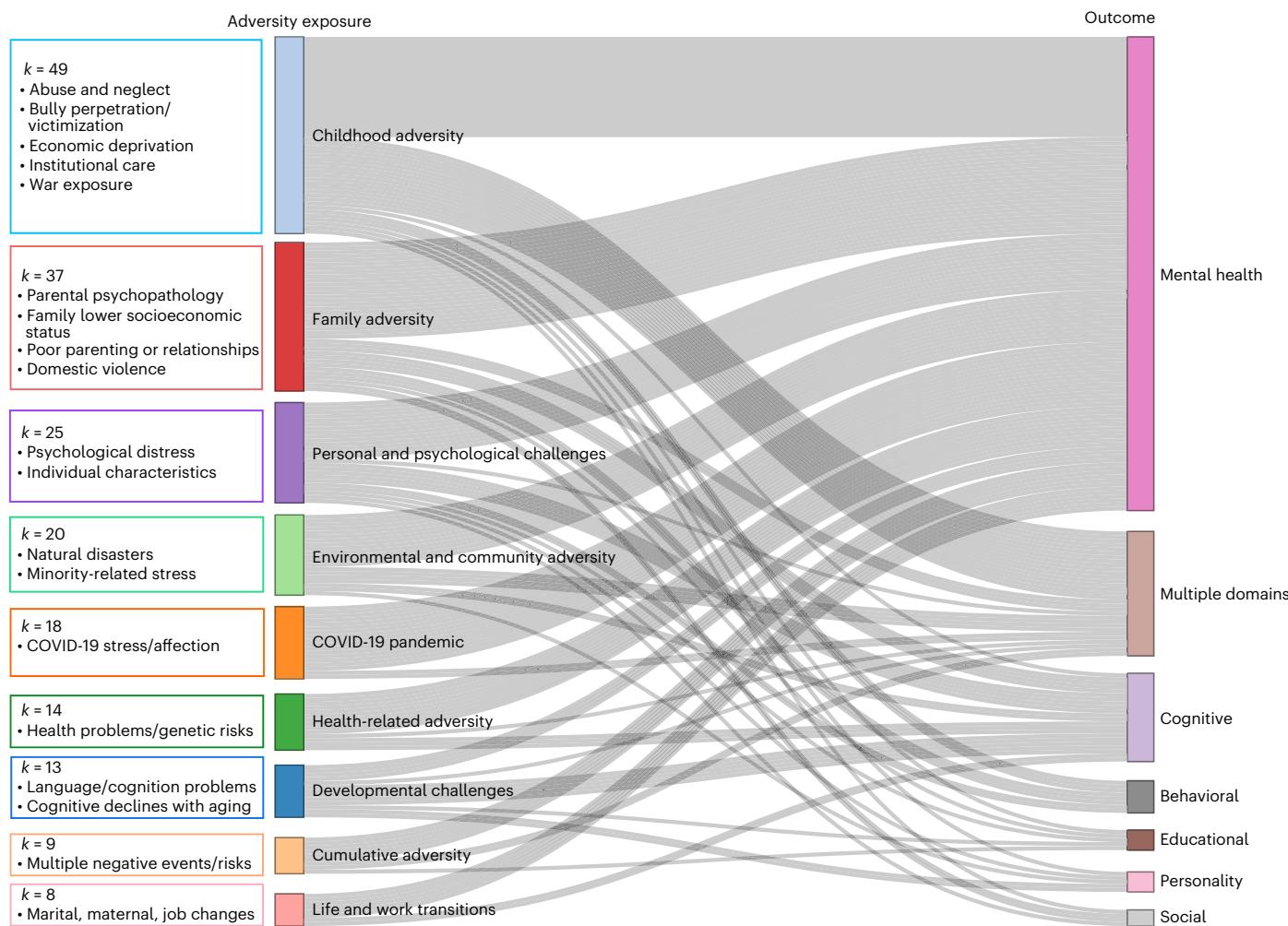


Fig. 5 | Sankey diagram illustrating the frequency of examined adversity–outcome relationships across the reviewed studies ($k = 193$). Flow-line thickness indicates how often specific adversity–outcome relationships were studied, with thicker lines representing more frequently examined topics.

psychosocial outcomes. This aligns with Luthar's synthesis of five decades of resilience research⁷⁶, which underscores the foundational role of strong relationships in supporting psychological, cognitive and social development. Meanwhile, individual-level factors, encompassing biological, demographic, physical, emotional, behavioral and cognitive characteristics, also play important roles. The wide array of examined factors reflects the complex, multidimensional nature of resilience, shaped by genes, neurobiology, brain development, behavior and contextual influences^{2,4}. Bridging biological and psychosocial perspectives remains essential for a more comprehensive, multilevel understanding of resilience.

Limitations

While this systematic review represents the largest compilation of longitudinal psychosocial resilience studies from the past three decades, offering an integrative overview of resilience conceptualization and methodologies, several limitations should be acknowledged. First, substantial heterogeneity across studies (for example, in samples, types of adversity, protective factors, outcomes and statistical methods) restricted our ability to conduct a meta-analysis on specific adversity–outcome relationships, such as the impact of child abuse on mental health, or to compare effect sizes across protective factors. Given that protective effects may vary across individuals, future meta-analyses should consider random-effects models or subgroup analyses to better account for individual differences. Second, our search strategy (Appendix I), limited to two databases and specific terminology, may

have missed relevant studies using alternative terms (for example, 'hardiness' or 'resistance') or indexed in other databases. Third, categorizing interaction patterns into four types might have oversimplified the complexity of these relationships and may not fully capture their diversity. Last, restricting the review to English-language publications may have introduced language bias, potentially overlooking relevant studies in other languages.

Recommendations for future studies

On the basis of our narrative and systematic review, we recommend that future research clarify resilience definitions, leverage large-scale longitudinal studies to examine multisystemic processes, optimize statistical methodologies and promote transparent and cautious interpretation of findings (Table 2). These efforts will help strengthen the evidence base and support the translation of resilience research into effective prevention and intervention strategies.

Conceptualization and operationalizations. While there is increasing consensus that resilience is best understood as a dynamic process, trait- and outcome-oriented definitions continue to offer valuable insights^{25,26}. Rather than prescribing a single framework, we advocate conceptual transparency: researchers should clearly define and justify their approach, whether process-, trait- or outcome-oriented, and acknowledge where these perspectives intersect. For example, trait-like characteristics (for example, grit) may function as protective factors within a broader resilience process⁷⁷. To address terminological



Fig. 6 | Word cloud of protective and promotive factors that researchers aimed to examine in the reviewed studies. Blue indicates individual-level factors, yellow is for family-level factors and red is for community-level factors. Term size indicates the frequency with which each factor was targeted for examination in study designs, irrespective of statistical significance.

inconsistencies, some scholars have proposed distinguishing related constructs by using 'resiliency' for trait-based dispositions, 'resilient' to describe positive adaptation outcomes and 'resilience' for the dynamic process²⁵.

For longitudinal resilience research (for example, with multiple time points, temporal ordering or developmental trajectories), we recommend adopting a process-oriented definition. Specifically, we conceptualize resilience as a dynamic process wherein exposure to adversity serves as the antecedent, positive adaptation as the outcome, and protective factors across internal and external levels function as mechanisms that mitigate adverse effects. Future studies should systematically address these three core components. First, clearly operationalize adversity by specifying the type and severity of adverse experiences (individual versus cumulative), developmental timing, duration (for example, early life versus chronic) and the measurement approach (for example, baseline versus repeated assessments) as these factors substantially influence observed resilience prevalence^{23,45,78}. Second, specify how positive adaptation is operationalized, indicating whether it reflects the absence of psychological problems, recovery from dysfunction, better-than-expected functioning, resistance to dysfunction or growth in competence. It is also important to specify whether outcomes are assessed in a single domain or multiple domains. Third, identify and test protective mechanisms that may buffer or modify the impact of adversity over time. Researchers should distinguish between promotive effects (main effects) and protective effects (interactions with adversity). Importantly, not all moderation indicates resilience; patterns of vulnerability or differential susceptibility may also be present and should be conceptually distinguished from resilience, which by definition involves both adversity and positive adaptation.

Large-scale longitudinal studies for examining multisystemic processes. Although interest in the genetic and neurobiological mechanisms of resilience is growing, traditional studies have focused on disorders or deficits using cross-sectional designs rather than strength-based outcomes over time^{15,17,19}. Gene–environment interaction and genome-wide association studies have identified candidate genes related to resilience, but findings have shown limited generalizability and replicability^{13,14,16,79}. Similarly, neurobiological studies have reported inconsistent results, with no common brain regions or neural

circuits reliably associated with resilience^{19,80}. To integrate neurobiological factors within resilience frameworks, future research should clearly distinguish their roles as traits, outcomes or processes. First, stable neurobiological characteristics (for example, genetic profiles, baseline neural connectivity) may serve as predisposing traits toward resilience. Second, neurobiological changes following adversity (for example, epigenetic modifications, brain network reorganization) may reflect adaptive outcomes and biological plasticity. Third, dynamic neurobiological processes (for example, neural modulation, neurotransmitter or neuroendocrine regulation) may represent the underlying mechanisms that support adaptation over time²⁰.

Advancing this line of research requires longitudinal studies with dense phenotyping and multimodal neurobiological data to examine links between candidate genes, polygenic scores, plastic neural circuits and individual–environment interactions^{2,4,26,81}. Large-scale longitudinal cohorts (for example, UK cohort studies, the US ABCD cohort study) offer unique opportunities to examine resilience as a multisystemic process involving biological, neural, family and sociocultural systems⁸². However, causal inference in these studies remains a major challenge. Innovative approaches—including quasi-experimental methods⁸³ (for example, regression discontinuity, instrumental variables, matching and propensity scores, interrupted time series), natural experiments³¹ (for example, global crisis such as the COVID-19 pandemic, economic downturns, conflict and disasters) and hybrid observational–interventional designs⁸⁴—can improve causal inference. Incorporating machine-learning tools for causal modeling⁸⁵ may further enhance our ability to detect complex resilience mechanisms. Moving forward, interdisciplinary collaboration across psychology, genetics, neuroscience, epidemiology and computational sciences will be essential for advancing resilience research and informing data-driven, targeted interventions.

Options and implications of statistical approaches. Integration of person-centered and variable-centered approaches offers a more comprehensive understanding of resilience at both the group and individual levels, enhancing the potential for targeted interventions. Researchers may also consider person-specific approaches that treat individuals as unique, dynamic systems and generate individualized models to explore idiosyncratic effects⁵¹. This approach is particularly suited for examining context-sensitive, nonlinear, dynamic processes and has been applied to neurobiological resilience through analyses of individual brain networks, genetic profiles and neural markers^{86,87}. Analytical techniques include P-technique factor analysis, state-space modeling, dynamic factor analysis⁵¹ and machine learning for large-scale data³⁸. While these methods offer high specificity and analytical rigor, they tend to be less parsimonious and demand advanced statistical expertise and computational resources. To support broader use, future efforts on developing user-friendly tools and training resources are needed. Ultimately, statistical approaches should be aligned with research questions and designed to balance complexity, rigor, robustness and parsimony.

Interpretation transparency and cautionary note. Resilience, vulnerability and differential susceptibility all involve exposure to adversity and represent distinct yet interrelated patterns of person–environment interaction. These patterns can be both theoretically framed and empirically tested within the same study.^{49,67,89,90} When reporting factors associated with positive outcomes, it is important to distinguish between promotive effects (enhancing outcomes regardless of adversity) and protective effects (buffering the negative impact of adversity). Similarly, when identifying vulnerability effects, researchers should clarify whether the absence or low level of a risk factor implies a corresponding protective effect, recognizing that these relationships are not always linear or symmetrical. In addition, environmental sensitivity is just one of many factors contributing to individual differences in responses to adversity. Other pathways—biological (for example, genetic variation,

Table 2 | Recommendation for future resilience studies

| Conceptualization | Datasets | Methodology | Interpretation |
|---|---|---|--|
| <p>Consensus terms</p> <ul style="list-style-type: none"> • Trait—resiliency • Outcome—resilient • Process—‘resilience’ <p>Conceptual components</p> <ul style="list-style-type: none"> • Adversity (single/multiple/time) • Protective factors • Positive adaptation (uni-/multidimensional) | <p>Large-scale longitudinal studies</p> <ul style="list-style-type: none"> • Childhood to adulthood • Multisystemic factors • Biological aspects | <p>Statistical approaches</p> <ul style="list-style-type: none"> • Variable-centered • Person-centered • Person-specific • Combined | <p>Length of follow-up matters</p> <p>Interaction patterns</p> <ul style="list-style-type: none"> • Promotive (main effect) • Protective • Vulnerability • Differential susceptibility |

epigenetic modifications, hypothalamic–pituitary–adrenal axis function), psychological (for example, personality traits, life experiences, cognitive appraisals) and contextual (for example, family functioning, socioeconomic status, cultural context)—may operate independently or interactively to shape adaptive or maladaptive outcomes.

While the notion of resilience as ‘ordinary magic’⁹¹ and the potential for growth through adversity is compelling, caution is warranted. Enduring, multidimensional resilience is less common than often assumed, especially when considering multiple adversities and outcomes over the lifespan^{42,92}. For example, children once seen as resilient may later experience poor adult outcomes, with 75% in one study meeting criteria for psychiatric disorders or subthreshold symptoms by age 16 (ref. 41). Resilience may thus be domain-specific or time-limited, or come at a cost to other areas of functioning⁹³. Future studies should carefully consider the nature of adversity exposure (single versus multiple), the dimensionality of outcomes (uni-/multidomain) and the length of follow-up when interpreting findings, given the complex and evolving nature of resilience over time.

Conclusion

Adversity is an inevitable part of life, and decades of psychosocial resilience research have provided valuable insights into protective factors that buffer its negative effects and support positive adaptation. This growing body of work holds a continued promise for guiding future research and informing practice. Our review underscores the need for clear definitions of resilience, consensus on its three core elements (adversity, positive outcomes and protective factors), the use of large-scale longitudinal studies with multilevel biological, psychological and contextual data, the application of statistical approaches aligned with conceptual frameworks and cautious interpretation of findings. Attending to these elements, from conceptualization to operationalization, is essential for capturing the dynamic interplay between individual and environmental factors, enhancing cross-study comparability and advancing the field toward more effective prevention and intervention strategies.

Methods

The review was conducted in accordance with the PRISMA 2020 guidelines⁹⁴ and followed the protocol registered on PROSPERO (no. CRD42019138732) in July 2019. The most recent update, made in January 2024, marked the review as completed (not yet published) and reflected changes in authorship. Amendments to the protocol included additional analyses on types of adversity, outcome domains and protective or promotive factors to provide a more comprehensive overview of previous studies.

Search strategy and eligibility criteria

We conducted advanced searches in PubMed and Scopus using a combination of four core components in the title or abstract: (1) ‘resilien*’/‘promot*’/‘protect*’ to capture the resilience framework, (2) ‘adversity/risk/stress’ for exposure, (3) terms representing various psychosocial domains (for example, ‘mental health/psychopathology/depression/anxiety/conduct disorder/IQ/cognition/employment/income/education’) and (4) the term ‘longitudinal’ to identify relevant study designs

(see Appendix I for the full search strategy). Searches were conducted in June 2019 and December 2022 and updated in December 2023 to include studies published through 31 December 2023.

Two authors independently screened the studies. After removing duplicates, titles and abstracts were screened, followed by full-text reviews of eligible articles. Given our focus on longitudinal studies, no age restrictions were applied, allowing inclusion of studies across the lifespan. Six eligibility criteria were used: (1) publication in English; (2) longitudinal design with at least two waves of quantitative data (excluding qualitative or intervention studies), with no restrictions on follow-up intervals; (3) explicit measurement of adversity, as either a binary or continuous variable; (4) psychosocial outcomes in mental health, cognition, employment or education (excluding purely medical outcomes); and (5) inclusion of additional factors distinct from adversity and outcomes to assess risk, promotive or protective effects. Disagreements or ambiguities were resolved through discussion and consensus.

Data extraction and synthesis

We extracted study characteristics, including country, sample size, age range, number of data waves and length of follow-up (in months). For resilience conceptualization, we coded the type of adversity exposure, psychosocial outcomes, promotive/protective factors examined and resilience definitions (that is, trait, outcome, process). Methodological information (see Appendix II for coding guide) included statistical approach (that is, variable-centered, person-centered or combined), specific analytical methods (for example, regression, classification), statistical processes (for example, main effect, moderation, mediation) and interaction patterns categorized as promotive effect, protective effect, vulnerability and differential susceptibility (Table 2). Detailed findings of each study and their alignment with interaction patterns are presented in the Explanation column of Supplementary Table 1.

Quality assessment

Study quality and risk of bias were evaluated using the Newcastle–Ottawa Quality Assessment Form for Cohort Studies⁹⁵, which assesses three domains: selection of groups (four items, 0–4 points), group comparability (one item, 0–2 points) and outcome ascertainment (three items, 0–3 points), with a maximum score of 9. On the basis of established thresholds, studies were categorized as poor (0–3 points), fair (4–6 points) or good (7–9 points) quality⁹⁶. Two investigators independently conducted quality assessments, with discrepancies resolved through discussion.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

This study is based on a systematic review of previously published literature, and no new data were generated. The search strategy, inclusion and exclusion criteria and data extraction methods are detailed in Methods. All data supporting the findings of this study are available in the main analysis and Supplementary Information.

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Author contributions

D.W. and Y.Z. were involved in all stages of the project, including conceptualizing, conducting the systematic review, writing and editing; they contributed equally to this work and share co-first authorship. Y.L. and R.E. contributed to database searches, literature screening, systematic review and draft editing. M.M. and E.S.T. provided paper revisions and editorial feedback. All authors reviewed and approved the final paper.

Competing interests

The authors declare no conflict of interest.

Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s44220-025-00479-3>.

Correspondence and requests for materials should be addressed to Dieter Wolke.

Peer review information *Nature Mental Health* thanks Way Lau, Michael Pluess and the other, anonymous, reviewer(s) for their contribution to the peer review of this work.

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Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection The data collection followed PRISMA guidelines, and the extraction process was based on predefined inclusion/exclusion criteria.

Data analysis Data analysis was conducted using Microsoft Excel. No custom code or advanced statistical software was used.

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- Accession codes, unique identifiers, or web links for publicly available datasets
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This study is based on a systematic review of previously published literature, and no new data were generated. The search strategy, inclusion and exclusion criteria, and data extraction methods are detailed in the Methods section. All data supporting the findings of this study are available in the main Analysis and Supplementary Information.

Human research participants

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| | |
|-----------------------------|---|
| Reporting on sex and gender | Sex and gender were not independently extracted or analyzed in this review. However, when sex or gender was identified in the included studies as a promotive, protective, or risk factor for resilience, it was noted accordingly. The review did not analyze sex- or gender-based differences beyond what was reported in the original studies. |
| Population characteristics | Age group was extracted from the included studies as part of the data charting process. Other population characteristics, including sex and gender, socioeconomic status, were not systematically extracted or analyzed unless specifically identified in the original studies as resilience-related factors. |
| Recruitment | Not applicable. This is a systematic review based on published literature. No participants were recruited. |
| Ethics oversight | Not applicable. This review used only data from previously published studies and involved no direct interaction with human participants. Ethics approval was not required. |

Note that full information on the approval of the study protocol must also be provided in the manuscript.

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Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

| | |
|-------------------|--|
| Study description | This is a systematic review of 193 longitudinal psychosocial resilience studies published over the past 30 years. The review includes only quantitative observational studies, with a primary focus on how resilience has been conceptualized and statistically analyzed (e.g., as a trait, outcome, or process; using variable- or person-centered statistical methods). No original data were collected. |
| Research sample | The sample consists of previously published longitudinal studies involving a combined total of 805,660 participants across all age groups. Demographic details such as age, sex, gender, or ethnicity were not independently extracted unless relevant to the findings of resilience within the original studies. |
| Sampling strategy | Study selection was based on predefined eligibility criteria applied to a comprehensive database search. No sample-size calculation or data saturation procedure was applicable to this review. |
| Data collection | Data were collected through systematic searches and manual extraction of relevant variables from eligible studies. Extracted variables included conceptualizations of resilience, statistical methods, types of models reported, and the nature of adversity, outcomes, and promotive/protective factors. No instruments or devices were used, and no interaction with participants occurred. |
| Timing | Data collection for the review occurred between July 2019 and January 2024. The included studies were published over the past 30 years. |
| Data exclusions | Studies were excluded only if they did not meet the inclusion criteria as specified in the preregistered protocol (PROSPERO: CRD42019138732). |
| Non-participation | Not applicable. No participants were recruited for this review, and no data on non-participation or dropout were collected. |
| Randomization | Not applicable. This review did not involve allocation of participants into groups nor include intervention studies. |

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