

The Development and Scientific Basis for a Revised Adverse Childhood Experiences Pyramid Graphic

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Background

In 1998, results from a seminal study on Adverse Childhood Experiences (ACEs) were published by researchers from Kaiser Permanente (KP) and the Centers for Disease Control and Prevention (CDC). This retrospective study of approximately 17,300 adults demonstrated that ten categories of childhood abuse, neglect, and household challenges were common, with 64% of participants reporting exposure to at least one ACE. The study also identified a graded relationship between the number of ACE categories experienced and multiple health risk factors and diseases: as the number of ACEs increased, so did the risk of adverse health outcomes.^{1–3}

Since publication of this initial study, a robust body of research demonstrates that ACEs are associated with many common and serious health and life conditions.^{1,3–7} ACEs are linked to at least nine of the ten leading causes of death in the United States, including heart disease, cancer, unintentional injury, stroke, chronic lower respiratory diseases, Alzheimer’s disease, diabetes, kidney disease, and chronic liver disease and cirrhosis, as well as high-school non-completion, adult unemployment, and poverty status as an adult.^{2,5–9}

When the original KP–CDC study was first published, the authors proposed that ACEs contribute to poor health outcomes primarily through their influence on health risk behaviors, such as smoking or substance misuse, which may function as neuroregulatory coping mechanisms.² This conceptual pathway is depicted in the “ACE Pyramid” graphic (see Figure 1) currently featured on the [CDC’s ACEs website](#).

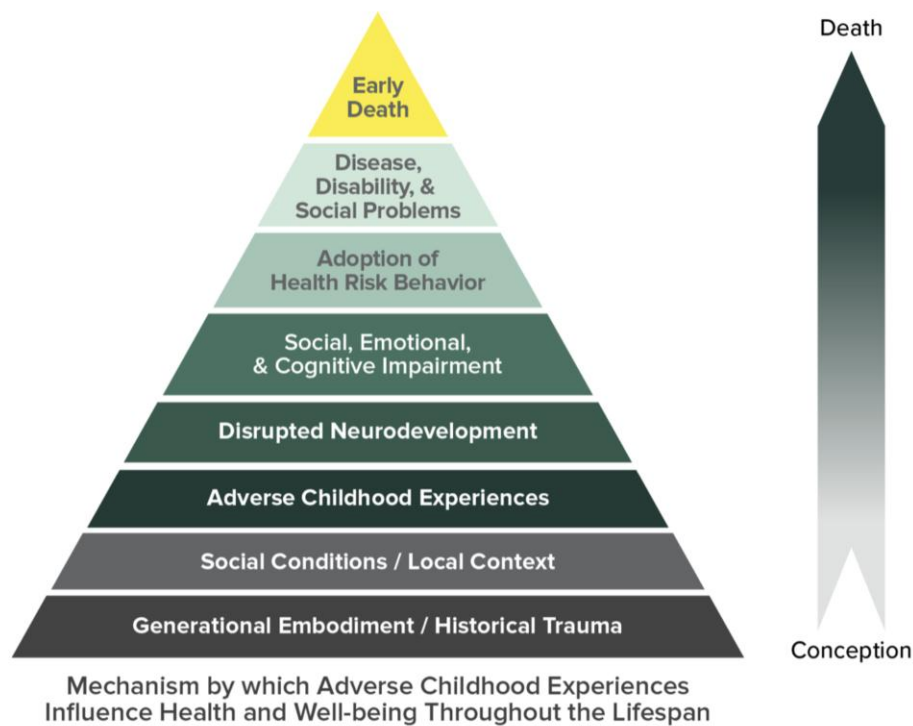


Figure 1. Outdated ACE Pyramid featured on the CDC ACEs website

While this model remains one important explanatory framework, subsequent research has substantially expanded the understanding of the mechanisms linking early adversity to health. Growing evidence highlights the physiological effects of chronic, excessive, or severe stress responses on lifelong physical, mental, and social health—especially when such stress occurs during sensitive periods of child development. A comprehensive review of this literature was published in Roadmap for Resilience: The California Surgeon General’s Report on Adverse Childhood Experiences ¹⁰

Methods

An ACE Pyramid revision team was convened, in partnership with CDC colleagues leading national ACEs-related efforts, to explore updating the existing graphic and to develop a process for getting input from leaders in the field. The revision process aimed at aligning the pyramid with contemporary evidence on the impacts of early life adversity. Although alternative visual frameworks from the scientific literature were considered, each presented limitations related to complexity, accessibility, or ease of adoption. Given the widespread familiarity and use of the existing ACE Pyramid, the decision was made to retain the pyramid format to support continuity, usability, and broad dissemination.

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The revision process began by articulating a clear project goal: to develop an updated ACE Pyramid graphic that illustrates the mechanisms by which ACEs influence health across the lifespan (see Figure 2). To support this goal, the team developed a process grounded in the latest scientific evidence and incorporated broad partner input. Subject matter experts were invited to review and provide feedback on both the conceptual content and its visual representation through multiple iterative review cycles. In total, 53 partners (including authors) from 16 organizations spanning government, academia, healthcare, professional associations, and community-based and nonprofit sectors at the local, state, and national level contributed content expertise at least once during the process (see list of contributors).

Results: Description of the Revised ACE Pyramid

A detailed description of the elements of the revised ACE Pyramid graphic is provided, along with the scientific evidence supporting each component. An interactive version of the graphic that features the descriptions below is available at [mockup currently at: <https://staging--aces-pyramid.netlify.app>].

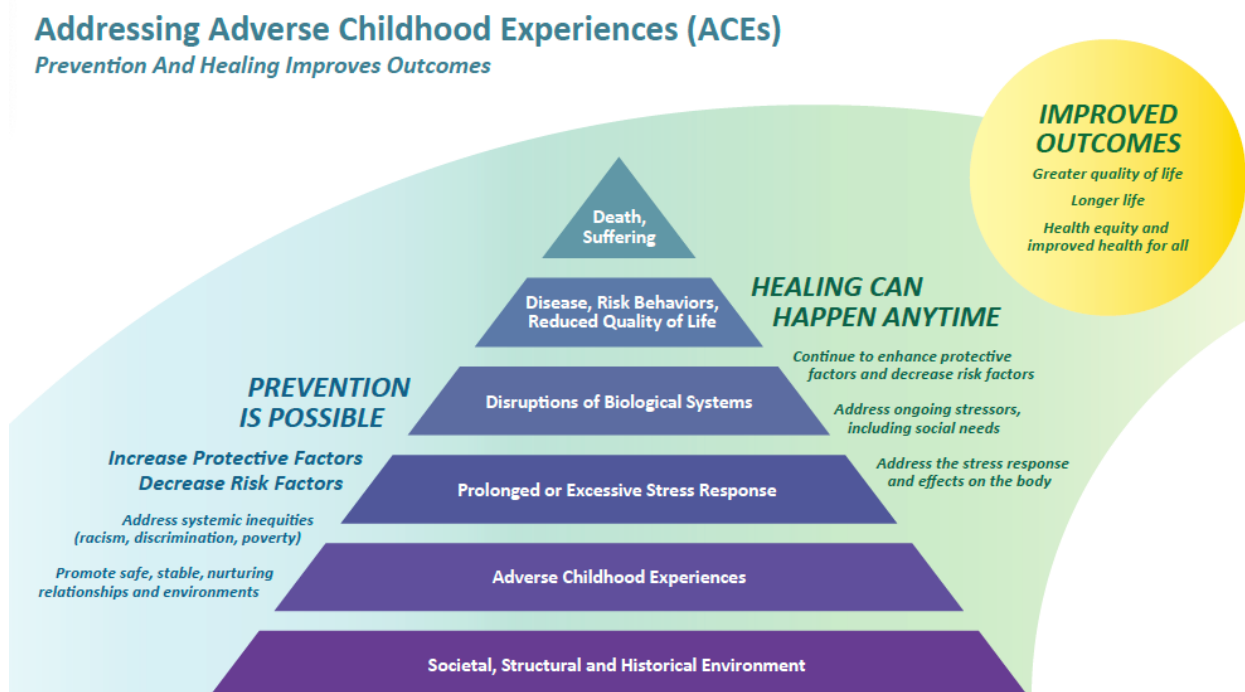


Figure 2. Revised ACE Pyramid

Adverse Childhood Experiences are associated with a wide range of poor mental, social, and physical health outcomes.^{1,2,5-7} The ACE Pyramid shows a main mechanism by which this happens: When children experience adversity that leads to a prolonged or excessive stress response, the development of biological systems is disrupted. This can impact health throughout the life course.¹⁰

Societal, Structural and Historical Environment

Childhood development is influenced by the societal, structural, and historical environment.^{4,11-14}

Each child will be exposed to a unique mix of factors that either protect or pose a risk to health and well-being. Risk factors can include injustices such as **historical trauma, structural racism, and economic inequities.**

Protective and risk factors can include **governmental policies**, as well as **interpersonal, systemic or institutional structures** that support or undermine safe, stable, nurturing relationships and environments.

Risk factors in the environment can compound the cumulative dose of adversity, as well as reduce caregivers' ability to provide safe, stable, nurturing relationships and environments. This increases risk for Adverse Childhood Experiences.

Adverse Childhood Experiences

The term "ACEs" specifically refers to the 10 categories of adversities in three domains experienced by age 18 that were evaluated in the landmark KP-CDC study:¹⁻³

- **Abuse:** Physical, emotional, or sexual
- **Neglect:** Physical or emotional
- **Household Challenges:** Incarceration, mental illness, substance misuse or dependence, parental separation or divorce, or intimate partner violence

Children may also be exposed to other early life adversities not captured in the original ACEs study, such as poverty, racism, or war, which can also have negative long term effects.^{4,11,12}

Prolonged Excessive Stress Response

In response to ACEs and other early life adversity, some children will experience prolonged or excessive activation of their stress response system. This might include the release of stress hormones (e.g., adrenaline, cortisol) and altered immune reactivity.^{10,11,15}

While the stress response is vital to health and survival, it's a spectrum:¹⁶

- **Positive stress:** Mild or moderate and short-lived stress response necessary for healthy development.
- **Tolerable stress:** More severe stress response, but limited in duration or intensity, which allows for recovery.
- **Toxic Stress:** Extreme, frequent, or extended activation of the body's stress response, resulting in changes in neurologic, endocrine, and immune system development.

Safe, stable, nurturing relationships and environments and other positive childhood experiences can help buffer the stress response.^{13,17}

Disruptions of Biological Systems

Prolonged or excessive activation of the stress response, particularly during critical and sensitive periods, can disrupt the development of biological systems, including:^{10,15,16}

- **Neurologic system:** This could include brain volume changes in some regions, alterations in neural connectivity patterns, and disruptions of neurotransmitter function, which can increase risk for chronic pain, sleep issues, addictions, blood pressure issues, anxiety, depression, and impaired executive functioning, learning and memory.
- **Endocrine system:** This could include changes in the function of hormones, such as cortisol, growth hormone, thyroid hormone, and hormones associated with puberty increasing risk for growth issues, pubertal issues, weight changes, insulin resistance, and diabetes.
- **Immune function:** This could lead to chronic inflammation, reduced immune function, or auto-immune disease.
- **Genetic regulatory:** Telomere erosion and epigenetic changes can increase risk for cancer, early mortality, and intergenerational transmission.
- **Attachment and relational:** Lack of safety and co-regulation from safe, stable, nurturing caregiver and environment can erode trust, self-esteem, and future relationships.

Disease, Risk Behaviors, Reduced Quality of Life

Disease:

Without intervention, the disruptions in biological systems (i.e., neurologic, endocrine, immune, genetic regulatory, and attachment and relational) can result in a wide range of physical and mental health problems in childhood and throughout adult life (for more detail on mechanistic pathways and disease implications, see Table 1).

ACEs are associated with increased risk of over forty health conditions.^{4–7,15,18} Some common and serious ACE-associated health conditions include cardiovascular disease, cancer, diabetes, and depression.^{1,2,5–7}

Risk Behaviors:

Disruptions in biological systems due to toxic stress can lead some people to adopt health risk behaviors, such as **smoking, alcohol and other drug use, or overeating**. This can happen in a couple of ways:^{4,19}

- Health risk behaviors are often adopted as coping strategies to feel better in the short term.
- Toxic stress also alters reward pathways in the brain, which can result in adoption of health risk behaviors.

The adoption of health risk behaviors is one pathway leading to disease. However, many of those who experience ACEs or other early life adversities do not adopt health risk behaviors yet still develop disease.^{20,21}

Quality of Life:

Disruptions in biological systems, such as executive functioning, mental health, or attachment systems (emotional bonding), can also lead to reduced quality of life—for example, **reduced employment opportunities or income potential**,⁹ as well as social thinning, loneliness, **divorce or separation**.^{22,23}

In addition to the pathway leading from excessive stress to biological disruptions to reduced quality of life, ACEs can directly interfere with opportunities for **educational experiences, healthy nutrition**, and learning **healthy relationship styles**, which also can impact an individual's quality of life.^{9,24,25}

Table 1. Stress Phenotyping Framework: Mechanistic pathways and health implications.

Stress-related system	Mechanistic pathways	Potential health implications
Sensorimotor	Altered pain processing through endogenous opioid and cannabinoid system (Kozłowska et al., 2015; Lanius et al., 2018) Gut-brain axis dysregulation and gut microbiome dysbiosis (Molina-Torres et al., 2019; O'Mahony et al., 2015) Dysregulation of the vestibular system (Kearney & Lanius, 2022)	Increased risk for chronic pain syndromes, fibromyalgia, headaches, stomach aches, dissociation, numbness, self-harming, and thrill-seeking behaviors (Kearney & Lanius, 2022; Nelson et al., 2020) Gastrointestinal issues such as constipation, diarrhea, encopresis (Hughes et al., 2017; Nelson et al., 2020) Altered felt sense of physical and emotional balance, safety and groundedness (Kearney & Lanius, 2022)
Arousal & energy	Alterations in homeostatic sleep drive and circadian rhythm (Koch et al., 2017), mitochondrial energy production (Picard & McEwen, 2018), connectivity with DMN, SN, and RAS (Thome et al., 2019), and neuronal electrical activity (Jokić-begić & Begić, 2003) Changes in reactivity and size of the amygdala (Teicher & Samson, 2016)	Hyper- or hypo-arousal, hyperactivity or fatigue, increased risk for chronic fatigue syndrome, sleep problems, depression, anxiety, and bipolar disorder (Heim et al., 2019; Kajeepeeta et al., 2015; MacKinnon, 2008) Increased fear responses (fight, flight, freeze), impulsivity, aggression, reactivity to facial expressions (Shonkoff et al., 2012; Teicher & Samson, 2016)
Reward processing	Dysregulation of the ventral tegmental area and reward processing pathways (Hanson et al., 2021)	Increased health-risk behaviors and addictions (Hanson et al., 2021; Leza et al., 2021; Wiss et al., 2020)
Autonomic nervous system	Altered SNS and PNS activity (Teicher & Samson, 2016; Young-Southward et al., 2020)	Alterations in heart rate, heart rate variability, blood pressure, dysautonomia, fainting (Elbers et al., 2018)
HPA axis & endocrine	Alterations in cortisol, leptin, ghrelin, lipid and glucose metabolism, and sex steroids (Raspopow et al., 2014; Sapolsky et al., 2000)	Overweight, obesity, cardiometabolic disorders, insulin resistance, failure to thrive, poor growth, early sexual debut, teenage pregnancy (Nelson et al., 2020; Tomiyama, 2019)
Immune	Increased inflammatory markers, especially Th2-biased immune response (Elwenspoek et al., 2017; Slavich, 2015)	Asthma, allergies, increased infections, arthritis, cancers (Nelson et al., 2020)
Cognitive	Inhibition of the prefrontal cortex, shifting resources from CEN to SN, hippocampal neurotoxicity (Hermans et al., 2014; McEwen, 2007) Overactivation of the PFC and overmodulation of fear processing (Lanius et al., 2015, 2018)	Impairments in executive functioning, planning, organizational skills, learning, and memory, rumination, panic, anxiety (Burke et al., 2011; Nelson et al., 2020) Dissociation and dissociative subtype of PTSD (Lanius et al., 2015, 2018)
Attachment & relational health	Lack of safety and co-regulation from safe, supportive, nurturing caregiver (Cooke et al., 2019); alterations in oxytocin (Heinrichs et al., 2009) and neural networks for mentalization, empathy, and protective hypervigilance (Feldman, 2015)	Insecure attachment, poor self-regulation skills, trouble feeling safe in relationships (Cooke et al., 2019; Perry, 2001)
Epigenetic & genetic	Epigenetic modifications and changes in gene expression (Slavich et al., 2023; Slavich & Cole, 2013)	Chronic diseases, cancer, and early mortality (Brown et al., 2009; Nelson et al., 2020)

DMN, default mode network; SN, salience network; RAS, reticular activating system; SNS, sympathetic nervous system; PNS, parasympathetic nervous system; CEN, central executive network; PFC, prefrontal cortex.

Adapted and expanded from Bhushan et al., 2020.

Reprinted from: Gilgoff R, Mengelkoch S, Elbers J, et al. The Stress Phenotyping Framework: A multidisciplinary biobehavioral approach for assessing and therapeutically targeting maladaptive stress physiology. *Stress*. 2024;27(1):2327333²⁶

Death, Suffering

Without buffering support or intervention, disease, adoption of health risk behaviors and reduced quality of life can lead to suffering and early death.^{27,28} In fact, **people with six or more ACEs have been shown to die nearly 20 years earlier than those without ACEs (61 years vs. 79 years).**²⁹

Prevention and Healing Improve Outcomes

Importantly, preventing and healing from ACEs are possible and can happen at any age. ACE exposure alone does not determine or foretell an individual's future health or life outcomes. The balance of risk factors (e.g. societal, structural, and historical inequities and individual adversities) and protective factors (e.g. safe, stable, nurturing relationships,

environments, and healing interventions) can influence whether an individual will have positive or negative health outcomes. Together, through multidisciplinary and collaborative approaches, we can prevent ACEs, treat toxic stress, and improve health equity and health outcomes for all.

Prevention is possible.

Preventing early life adversity and toxic stress requires a comprehensive public health approach that strengthens the conditions in which families live, work, and raise children—particularly by addressing poverty, racism, and discrimination. By **increasing protective factors** and **decreasing risk factors**, we can tip the scales toward prevention of ACEs and toxic stress.⁴

Policy and systems changes, community-level efforts, and concrete strategies help dismantle structural barriers that disproportionately impact marginalized families and further build protective factors such as:^{4,30–32}

- Expanding economic supports like paid family leave, flexible workplace policies, and tax credits like the Earned Income Tax Credit to reduce financial stress,
- Investing in evidence-based home visiting programs like Healthy Families America, Nurse-Family Partnership and Parents as Teachers,
- Increasing access to parenting supports such as Triple P, Child-Parent Psychotherapy (PCC), Parent-Child Interaction Therapy (PCIT), and SafeCare,
- Access to mental health and substance abuse treatment
- Strengthening childcare standards and ensuring high quality childcare centers,
- Promoting positive community norms around healthy child development and parenting such as eliminating corporal punishment,
- Ensuring equitable access to culturally responsive services,
- Fostering community support for children and families,
- Providing mentoring and after-school programs,
- Career training and educational opportunities to support economic security,
- Disseminating public education campaigns that shift social norms around violence and help-seeking.³³

Prevention is possible when we invest early in families, partner with communities, and ensure every family has the stability, support, and opportunity to thrive.

Healing can happen anytime.

By addressing the **external stressors** and the **internal stress biology** we can help people heal from early life adversity.

Addressing **stressors** involves continued support in enhancing individual, systemic and structural protective factors and decreasing risk factors. This includes addressing individual basic needs such as housing and food insecurity and providing resources and crisis support if there are current, on-going ACEs or other adversities throughout the life course:

Addressing the **internal stress response** involves the use of healing strategies and interventions to address the neurologic, endocrine, immune, metabolic, and genetic regulatory effects that prolonged or excessive activation of the stress response can have on the body.¹⁷ This includes evidence-based strategies such as safe, stable, nurturing relationships, physical activity, nutritional approaches and supplements, quality sleep, mindfulness practices, experiencing nature, and trauma-specific mental health interventions which have all been shown to regulate neuroendocrine, immune, and metabolic function.^{17,26,34}

Through multidisciplinary and collaborative approaches, and ecosystems of support, we can prevent ACEs and heal from toxic stress, thus improving quality of life, length of life, health equity, and health outcomes for all.

Conclusion

The revised ACE Pyramid translates decades of advancing science into a practical, accessible framework that can guide both clinical care and public health action. By explicitly illustrating the biological mechanisms linking early adversity to lifelong health, the model supports a shift from viewing ACEs solely as risk indicators to understanding and addressing toxic stress physiology as a treatable condition. In pediatric clinical practice, this framework can inform trauma-informed care, screening and assessment, anticipatory guidance, and the integration of evidence-based interventions that regulate

stress biology and strengthen protective factors. At the systems level, it can support alignment across healthcare, public health, and community sectors to build coordinated, prevention-oriented ecosystems that address both external stressors and internal stress responses.

Importantly, the revised ACE Pyramid highlights that these pathways unfold across the life course and across generations, underscoring the need for intergenerational approaches to care and prevention. Supporting the health and well-being of caregivers is foundational to improving outcomes for children, while early investment in children can alter trajectories for future generations. By integrating clinical, community, and policy strategies that strengthen safe, stable, nurturing relationships and environments, this updated framework can help advance health equity and improve outcomes for children and families. Together, it offers a shared scientific and practical foundation for treating toxic stress in pediatric practice and beyond, reinforcing that prevention and healing are possible at any stage of life.

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