

Adolescents' unique vulnerabilities to environmental hazards

Fragile Beginnings

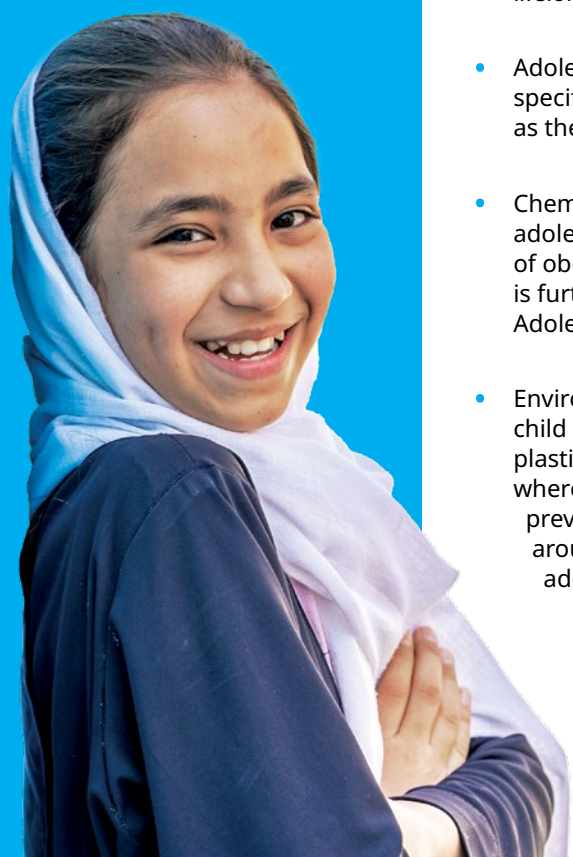
Children face unique vulnerabilities to environmental hazards at every stage of life.

Children today face a new set of challenges that were unimaginable just a generation ago. Across the world, climate change and environmental degradation are threatening child survival, health and well-being. While adolescence (10–19 years old) is often considered the healthiest stage of life, dynamic changes in adolescent bodies and brains makes them uniquely vulnerable to environmental hazards.

The Fragile Beginnings briefing note series provides a scientific stocktake of the growing body of research on the unique vulnerabilities in utero and at birth, infancy and childhood, and in adolescence. This document reviews the unique vulnerabilities of adolescents to environmental hazards. It focuses on environmental exposures that take place during adolescence. Health effects that emerge during adolescence as a result of antenatal or early childhood exposures are not reviewed.

Adolescence is a period of rapid and transformative growth and development, setting the stage for life as an adult

- Puberty causes virtually every system in the adolescent body to go through profound transformation of both physiology and function. From the brain to the lungs, bones, immune system and reproductive system, these dramatic changes are vulnerable to disruption by pollutants, disease, nutritional deficiency and extreme weather events driven by climate change.
- The brain development that occurs during adolescence is second only to infancy in terms of extent and significance. Neurological changes shape a wide range of cognitive functions, from thinking to emotional processing, memory and motivation. These changes are vulnerable to environmental risks.
- Adolescents are at high risk of developing mental health conditions. Navigating these changes is more difficult when community support and social infrastructure are disrupted by climate change-related disasters.
- Certain changes that occur in the brain during adolescence can lead to poor self-regulation and an increased tendency towards risk-seeking behaviours.
- The elevated nutritional needs of adolescents make them susceptible to harm from poor nutrition that can affect their health for the rest of their lives.
- Lung function during adolescence transforms to reach adult capacity. Environmental hazards such as air pollution can harm this transition, affecting lifelong respiratory health and increasing the future risk of respiratory diseases.
- Adolescents face unique risks of communicable diseases beyond those specific to childhood. These include an increased risk of tuberculosis, as well as the hazards posed by HIV and other sexually transmitted infections.
- Chemicals found in plastics and pesticides can increase the prevalence of adolescent obesity, which has quadrupled since 1990. Adolescents are at risk of obesity due to their increased energy and nutritional needs – risk which is further heightened by unhealthy diets and insufficient physical activity. Adolescent obesity can lead to many serious health problems in adult life.
- Environmental hazards are increased for adolescents who are involved in child labour, particularly in hazardous work in informal e-waste recycling, plastic waste recycling, artisanal and small-scale gold mining, and agriculture, where the likelihood of exposure to toxicants is high and the knowledge and prevalence of protections from these exposures is low. Informal work around the home such as cooking with polluting fuels can also expose adolescents to harmful household air pollution.



Examples of environmental hazards and how they affect adolescents



Climate-related hazards

Extreme weather

Climate change can affect the physical, social and emotional development of adolescents. Adolescents are at risk of vector-borne diseases such as malaria, which will become more prevalent in a changing climate. Extreme heat can affect sleep, learning and school attendance. It can also cause heat illness in adolescents playing outdoor sports or working in outdoor occupations. Floodwaters pose risk to adolescents, who have increased risk-taking behaviours that can lead to injuries and drowning.

Climate change also threatens most aspects of adolescent mental health. Climate-related disasters can shatter the social and community infrastructure that adolescents need as they navigate the complexities of peer relationships, self-esteem and identity development, and put them at risk for mental health disorders such as post-traumatic stress disorder, depression and anxiety.

Food insecurity

Environmental hazards such as climate change-related floods and droughts can reduce food security, affecting adolescents, who have increased caloric and nutritional needs to feed the rapid growth of their bodies and brains. Food insecurity and poor nutrition

can affect the accumulation of bone, muscle and fat and alter the maturation of biological systems as well as the timing of puberty. Appropriate levels of bone development are important, as not achieving healthy bone mass in adolescence is associated with osteoporosis (i.e., weak or brittle bones) in adults. Poor nutrition can also contribute to iron deficiency – a mineral important to growing adolescents – and related anaemia, and can affect the ongoing development of the brain and immune system.

Infectious diseases

Adolescents are at risk from many common diseases that affect children – such as gastrointestinal infections, lower respiratory tract infections and malaria – and also have increased risk of infections that emerge in adolescence. Adolescents are at higher risk of active tuberculosis (TB) than children, possibly due to changes in immunity during puberty but also due to expanded social networks and exposures in schools and transit situations. Adolescence also marks a time for risk of sexually transmitted infections (STIs), including HIV as well as syphilis, gonorrhoea, chlamydia and human papillomavirus (HPV). Many factors contribute to STIs in adolescents, including lack of access to services for reproductive and sexual health, inconsistent condom use and increased risk-taking behaviours.

Pollution

Air pollution

Air pollution, both ambient and household, affects many systems in an adolescent's body. It can disrupt developing lung function, which can lead to reduced lung function and lung disease later in life. It can also trigger flares of asthma, a chronic disease which can be challenging to manage for adolescents gaining autonomy. Air pollution has negative effects on the developing brain and is associated with disrupted sleep. Poor outdoor air quality may interfere with physical activity, which can in turn affect adolescents' physical fitness. Air pollution can also contain toxic chemicals called obesogens, which can promote obesity.

Pesticides

Adolescents who work in child labour in agriculture are at risk from pesticide exposure which can affect their developing brains and cause neurological symptoms. Pesticides can also affect other developing tissues. For example, although no longer used in

agriculture, exposure to DDT during puberty in girls has been linked to increased risk of breast cancer in adulthood.

Endocrine-disrupting chemicals

Adolescents are exposed to a wide array of chemicals in the air they breathe, the foods they eat, the water they drink and the products they use. Many chemicals have been shown to disrupt the function of hormones in the body which control vital processes such as growth, metabolism, reproductive and sexual development, and immune function. There is some research that shows certain endocrine-disrupting chemicals (EDCs) may affect timing of puberty; ongoing research is needed to define sensitive time windows for exposure. EDCs such as plasticizers, pesticides, per- and polyfluoroalkyl substances (PFAS) and polycyclic aromatic hydrocarbons (PAHs) can also promote obesity – an important consideration given the increasing rates of obesity in adolescents globally and the lifelong impacts of adolescent obesity, including future heart disease.



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The factors which make adolescents uniquely vulnerable to environmental hazards

Technical brief

Dynamic physiology

1. Puberty

The beginning of adolescence is marked by the onset of puberty, which triggers a period of rapid growth and development of the body and brain, including the attainment of sexual and reproductive maturity.¹ After 'mini-puberty' in infancy, which ends around age 6 months in boys and age 2–4 years in girls, there is a reactivation of the systems that control reproductive development, i.e., the hypothalamic-pituitary-gonad axis which connects the brain to the testicles or ovaries.² The age at which puberty starts differs amongst individuals, typically around ages 8–12 in girls and 9–14 in boys.³

There are numerous physiologic changes that happen during puberty. The growth spurt associated with puberty is the most dramatic change. This growth spurt starts earlier in girls than in boys; after menses start, girls generally grow an additional 2.5 cm. Boys continue to grow slowly after puberty ends and reach their adult height around age 18. Bone mass continues to accrue, not reaching its peak until a person reaches their early 20s. The cardiovascular, renal and immune systems are also developing. Sex hormones produced during puberty can affect the regulation of the immune system, possibly contributing to the increased risk of autoimmune disease in adolescent girls.⁴ Blood pressure and heart rate make a transition to adult values along with height and weight.⁵

The steady growth in height, the accumulation of bone, muscle and fat mass, and the maturation⁶ of various biological systems that occur during puberty can be affected by nutrition, making puberty a nutrition-sensitive window to promote healthy growth. Extended undernutrition in adolescents, as shown in patients with anorexia nervosa, can result in reduced grey matter (nerve cells) and white matter (extensions of nerve cells) in the brain, especially in networks which control higher executive functions.⁷ Inadequate intake of protein and vitamins B12, C and D can also impair most immune functions.⁸



Timing of puberty

In the past 30 years, the onset of puberty has occurred earlier than before in both boys and girls.⁹ Genetics largely determine the onset of puberty, but other factors such as nutritional status also play a role. For example, chronic energy insufficiency can delay puberty, while chronic energy surplus is related to earlier puberty start.¹⁰ Environmental factors may also be important. For instance, animal data suggests that exposure to EDCs may play a role in shifting the onset of puberty, although overall human research has been inconclusive and precise windows of exposure have not been clearly defined.¹¹ Nevertheless, a 2024 umbrella review of meta-analyses that evaluated associations between human health and exposure to major classes of plastic-associated chemicals did find that childhood exposure to some chemicals, such as the phthalate DEHP, was significantly associated with precocious puberty in girls.¹²

Timing of puberty is important beyond adolescence as it is associated with adult health outcomes. For example, early onset of puberty is associated with increased risk of type 2 diabetes, obesity, heart disease and some cancers, including breast, endometrial (i.e., the lining of the uterus) and prostate cancers.¹³

2. Developing brains

Over the past 20 years, research has shown that the extent and significance of the development of neural systems that occurs during adolescence is second only to those that occur infancy.¹⁴ During this time, there are rapid changes in the cerebral cortex, which is the outermost layer of the brain that controls key cognitive functions such as thinking, learning, memory and problem solving.

The development of the cerebral cortex includes maturation of neurotransmitter systems which help brain cells communicate, and significant increases in the sizes of certain regions of the brain, including the amygdala, an almond-shaped region of the brain that helps process emotions, and the hippocampus, which is involved in learning and memory.¹⁵ Connections between nerve cells, or synapses, continue to be pruned during this time, which facilitates brain plasticity and is a hallmark of adolescent brain development.¹⁶ There is also a surge in connectivity and communication between different lobes of the brain.¹⁷ Synapses which transmit dopamine – which is closely associated with how the brain handles reward seeking, motivation and impulsivity – are modified in the adolescent brain, and may be related to tendency to risky decision making.¹⁸

Brain development during adolescence can be affected by many environmental hazards. For example, animal studies have shown that exposure to air pollution can disrupt the pruning of synapses and the development of neural circuitry.¹⁹ Studies which evaluate the structure of human brains using MRI have shown that both fine particle pollution (i.e., PM_{2.5}) and gaseous pollutants such as ozone and nitrogen oxides have been linked to changes in brain structure and function such as cortical thickness, surface area and volume, the microstructure of grey matter (nerve cells) and white matter (extensions of nerve cells), cerebral blood flow, brain metabolites and functional connectivity.²⁰

The significant and complex development of neural circuits in adolescence raises concern that the adolescent brain is vulnerable to environmental hazards during this period. Emergence of health effects from antenatal and childhood exposures can compound health effects from exposures during adolescence, which can complicate research seeking to evaluate links between exposures and specific health effects. Exposure to mercury during adolescence, for instance, may be associated with behaviour changes, although more studies are needed²¹ as antenatal and childhood exposures are also common.

Clear evidence that the developing adolescent brain may be uniquely vulnerable to toxic exposures comes from the study of the effects of tobacco and other substances such as marijuana. The timing of drug exposure can be important. For instance, exposure during adolescence to THC, the main psychoactive ingredient in the cannabis plant, can increase risk of substance abuse later in life, and exposures to nicotine during early adolescence may increase risk of dependence.²²

Healthy environments during adolescence, a critical period of brain development, are vital to healthy development. In addition, programs and strategies that help adolescents build resiliency and manage environmental challenges can promote adolescent and lifelong health.²³

3. Psychological and emotional development and mental health

Adolescence is a critical time for emotional development. The myriad of changes that occur in the brain and body of an adolescent are concurrent with social changes involving peers, schools, workplaces and communities, which adolescents need to learn to navigate.²⁴ The onset of puberty drives changes in the brain's limbic system, which regulates emotions and behaviours. Adolescents learn to identify and regulate emotions and learn how they affect thoughts and behaviours. In early adolescence,²⁵ self-esteem is often at its lowest point



and tends to improve in middle to late adolescence.²⁶ Adolescents have increased interest in engaging socially with peers and potential romantic partners.

During early adolescence, individuals are susceptible to peer pressure, have a limited focus on long-term consequences, and are unable to effectively estimate risk, all of which can lead to increased risk-taking behaviours and poor self-regulation.²⁷ Adolescents are also at high risk of developing mental health conditions such as major depression, eating disorders, substance use and anxiety disorders.²⁸ Supportive homes, schools and communities can help adolescents handle stress effectively.

Climate change threatens adolescents' emotional well-being. At a time when they are vulnerable to anxiety, adolescents feel the threat that climate change brings.²⁹ Stressors associated with climate change such as social and economic disruptors could increase harmful substance use in a vulnerable adolescent population.³⁰ Climate change-related events such as flooding and wildfires can present unique mental health challenges to adolescents, forcing them to navigate the complexities of their social and emotional development while dealing with complex stressors such as migration and displacement.³¹ For example, climate change-related disasters are associated with post-traumatic stress disorder in adolescents, mainly those exposed to disaster-related injury, death and loss while simultaneously lacking social and family support.³² Overall, while not specific to adolescents, climate change events and conditions are also related to stress, anxiety, depression and mood.³³ Further research is needed to delineate specific mental health outcomes for adolescents as the climate crisis continues.

Effects of climate change on learning

As adolescents are developing physically, cognitively and socially, schools can play an important role in promoting adolescent health.³⁴ Climate change-related weather events can result in school closures. A 2024 report from the World Bank found that in low-income countries, students on average lost 18 days of school annually, compared with 2.4 days in wealthier countries.³⁵ Furthermore, extreme heat itself negatively affects learning.³⁶

4. Developing bones

Around one half of bone mass is accrued during adolescence, making it a critical window for bone health as reduced peak bone mass is a risk factor for osteoporosis, which can have significant health impacts in older adults.³⁷ Environmental factors such as poor nutrition (particularly, reduced intake of calcium and vitamin D), lack of weight-bearing activity, and smoking can negatively affect bone mass.³⁸

5. Metabolic changes

Adolescents have increased energy and nutrient requirements to meet the needs of their rapidly growing bodies.³⁹ It can be a challenge to meet these needs while maintaining a healthy weight. Maintaining a healthy weight during adolescence is important because obesity during adolescence is associated with an array of medical problems including prediabetes, type 2 diabetes, fatty liver disease, abnormal levels of fats in the blood, polycystic ovarian syndrome, obstructive sleep apnoea and mental health disorders.⁴⁰ Obesity during adolescence is also associated with adult health problems including heart disease and death from any cause.⁴¹

Since 1990, the number of obese adolescents globally has quadrupled.⁴² Many factors contribute to obesity including unhealthy diets, low levels of physical activity and sedentary lifestyles.⁴³ Additional environmental factors can play a role, including exposure to obesogens, which are chemicals that can affect hormones that control hunger and satiety, and can disrupt functions in cells related to metabolism and inflammation.⁴⁴ These chemicals are ubiquitous and include the plasticizers bisphenol A and phthalates, as well as dioxins, the pesticide atrazine, PFAS, flame retardants and PAHs.⁴⁵

6. Cardiovascular development

The cardiovascular system continues to develop in adolescence and sets the stage for cardiovascular health in adulthood. For example, high blood pressure in adolescence is a risk factor for high blood pressure and cardiovascular disease in adults.⁴⁶ Air pollution has been shown to be associated with increased blood pressure in adolescents.⁴⁷ There is also suggestive evidence that early atherosclerosis can begin in adolescence and be affected by exposure to ambient air pollution, which in adults has been shown to be a modifiable risk factor for heart disease.⁴⁸

7. Lung development

Lung function continues to mature in adolescence, developing rapidly around ages 11–15 years in both boys and girls. Lung function growth then slows but continues in girls until the late teen years, and in boys until the early twenties. As adolescents transition to adult status, their lung function can affect the likelihood of having respiratory diseases later in life.⁴⁹

Air pollution has been shown to have significant impact on the development of lung function in adolescents. In a well-known study done in Los Angeles in the United States, improved outdoor air quality achieved over decades was associated with a decreased proportion of adolescents with low lung function at age 15 years. The finding was seen in adolescents both with and without asthma.⁵⁰

8. Vulnerability to certain infectious diseases

Although globally there have been significant reductions in the burden of and death from communicable diseases among children under 5 years of age, the decline in mortality rate has been less pronounced in adolescents. Research that specifically looks at global communicable disease burden in adolescents has historically been lacking. In 2021, a major global report showed that while gastrointestinal infections, lower respiratory tract infections and malaria were major causes of communicable disease in both children and adolescents, TB and HIV emerged as important causes specifically during adolescence.⁵¹



Tuberculosis

Global attention on TB has been focused on cases in adults, with the true burden of TB in adolescents remaining uncertain. Age-related trends have, however, been observed. For example, the risk of progression from latent TB to active TB is lowest in children aged 5–9 years, then increases through adolescence, possibly due to changes in immunity during puberty. TB disease type also shifts during adolescence to a more transmissible form typically seen in adults. There are also differences in susceptibility to TB by sex: The disease affects younger girls and boys equally, but the risk for females increases around the time of menarche, resulting in a higher incidence of TB and disease progression compared to boys of the same age. Social and environmental factors that contribute to TB in adolescents include expanded social networks, overcrowded housing, greater exposure in schools and on transit, and air pollution.⁵²

HIV

Overall, new infections and HIV deaths are decreasing in adolescents as in all age groups globally.⁵³ In 2022, adolescents aged 10–19 years accounted for 4 per cent of people living with HIV but carried 10 per cent of new infections, with 71 per cent of those new infections occurring in girls. Sub-Saharan Africa carries the majority of the burden of new HIV infections in adolescents, with only 33 per cent of new cases occurring outside the region.⁵⁴

Increasing global investment in preventing TB and HIV in adolescents is needed.⁵⁵ TB services that address the needs of adolescents are required, such as integration of peer support and mental health services to address the social isolation and disruption of education that may be caused by TB and its treatment.⁵⁶



Other sexually transmitted infections

Other STIs including syphilis, chlamydia, gonorrhoea, trichomoniasis and genital herpes (related to HPV) are prevalent in adolescence. In the 2019 Global Burden of Disease analysis which evaluated the incidence of other STIs from 1990 to 2019 in people ages 10–24 years, adolescents aged 10–14 were the only age group to have an increase in the number of cases.⁵⁷ Inconsistent condom usage contributes to STIs.⁵⁸

Adolescent girls are especially vulnerable to STIs such as chlamydia and HPV due to differences in the structure of cells and mucous in the cervix, which is the lower part of the uterus that connects with the vagina.⁵⁹ Certain strains of HPV are associated with cervical cancers.⁶⁰ HPV is also associated with other cancers, including anal and penile cancer.⁶¹

Understanding complex environmental factors such as neighbourhood influences related to local structural barriers to accessing knowledge and services related to sexual and reproductive health is critical, as is reducing the access gap that exists between rural and urban areas.⁶²

9. Physical fitness

Adolescence is an important time to lay the groundwork to develop and maintain physical fitness that can affect lifelong health. There is strong evidence that higher levels of cardiorespiratory fitness and healthy body

composition in adolescence are associated with better cardiovascular health later in life.⁶³ Despite the importance of adolescence as a key time to maintain physical fitness, global data suggests that around 80 per cent of adolescents aged 11–17 years do not meet current physical activity guidelines.⁶⁴

Unhealthy and unsafe built environments, air pollution and disruptions caused by climate change-related disasters can all create barriers to adolescents being physically active, which can affect their physical fitness and cardiovascular health.

10. Changes in sleep patterns

Sleep plays an important role in physical and mental health, immune function and performance in school. In adolescents, the processes in the body that control sleep regulation undergo dramatic changes that lead to adolescents having different sleep patterns. Adolescents generally have later sleep-onset time which makes it difficult to fall asleep early in the evening and get up in the morning. Adolescents 10–12 years old are recommended to get 9–12 hours of sleep while older adolescents are recommended to get 8–10 hours of sleep.⁶⁵

Many social factors can affect sleep hygiene including school start times, homework load and job responsibilities. Although not specific to adolescents, environmental hazards, including both indoor and outdoor air pollution and extreme heat, can lead to sleep disruption.⁶⁶



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Evolving cognitive maturity

Potential for risk-taking behaviours

As adolescents develop, the first changes that occur in the brain spark greater sensitivity to rewards, threats, novelty and peers, whereas the parts of the brain related to cognitive control and self-regulation take longer to mature. This trajectory may bias adolescents' decision making and sensation seeking during the period wherein they are engaging in new and unsupervised activities.⁶⁷

Unintentional injuries such as road traffic accidents and drowning are the leading cause of death and disability among adolescents.⁶⁸ In particular, they are a major cause of disability with lifelong consequences, such as acquired brain injury. Adolescents may not recognize the hazard posed by some environmental conditions such as floodwaters or contaminated bodies of water.⁶⁹ Adolescents are more likely to engage in risky behaviour around water, including consuming alcohol, which can contribute to risk of drowning.⁷⁰

Climate change increases flooding, which increases risk of drowning, particularly in low- and middle-income countries. Heat events may also increase this risk, as adolescents may seek relief from elevated temperatures. Drowning accidents of children and adolescents aged 5–14 are more likely to occur in open waters, such as rivers, lakes, ponds, reservoirs and seas.⁷¹

Challenges in managing chronic diseases

Adolescence is a challenging period in which to manage illnesses effectively, including chronic diseases. Adolescents need to balance their developing need for autonomy and peer relationships with the constant challenge of adhering to treatment plans and/or avoiding triggers for diseases. For example, asthma management is challenging for adolescents, and smoking or exposure to air pollution can trigger flares.⁷² Type 1 diabetes is also difficult to manage in adolescence, as control and monitoring of blood sugar levels is time intensive and can impact self-esteem and body image at a time when these traits are just developing.⁷³



Special considerations for adolescent girls and young women

Menstruation

Adolescent girls need environments and services that allow them to manage menstruation safely, hygienically and without embarrassment, all of which are fundamental to their sexual and reproductive health and overall well-being.⁷⁴ Poor or inadequate water, sanitation and hygiene (WASH) facilities contribute to infections and anxiety and potential physical or sexual violence.⁷⁵ Climate change events can also reduce access to WASH and sanitary products.⁷⁶

Pregnancy during adolescence

In 2022, an estimated 13 per cent of adolescent girls and young women globally gave birth before age 18, with rates differing widely by global region. Adolescent birth rates are lowest in countries in Europe and North

America, and highest in countries in sub-Saharan Africa.⁷⁷ Pregnancy during adolescence presents unique physical, social and emotional challenges during an already dynamic period and can affect a girl's education, livelihood and health, and subject her to social stigma, rejection and violence.

Many social and environmental factors contribute to adolescent pregnancy, including limited education and low economic status; childhood marriage; lack of access to contraceptives and/or lack of knowledge on how to use them; and sexual abuse.⁷⁸ Substance use and peer pressure can also play a role.⁷⁹ Adolescent pregnancy is associated with problems during pregnancy such as pre-eclampsia and maternal anaemia, and with adverse pregnancy outcomes such as low birthweight, prematurity and stillbirth. Adolescents who are pregnant have a higher risk of anaemia due to higher iron needs.⁸⁰



Unique and different exposures

Occupational

Adolescents who enter the workplace may encounter unique hazards in occupational settings, both in environments with adult-specific safeguards and in informal settings where safeguards are not in place.⁸¹ Adolescents may engage in hazardous work in informal e-waste recycling, plastic waste recycling, artisanal and small-scale gold mining, and agriculture. Restrictions and laws around adolescent involvement in various work settings may differ from country to country. The participation of adolescents above the minimum working age in work that does not disrupt their health and personal development or interfere with their schooling is generally regarded as something positive; this can include activities such as assisting in a family business or earning money outside school hours and during school holidays.⁸² The term 'child labour', on the other hand, refers to work that deprives children of their childhood, potential and dignity, and that is harmful to physical and mental development. Child labour also interferes with schooling.⁸³ According to the International Labour Organization, adolescent boys are more likely than girls to be engaged in child labour.⁸⁴

Adolescents can encounter many hazards in various labour situations including exposure to pesticides and other dangerous agrochemicals. Pesticides are known to affect developing nervous systems, although research on adolescent-specific exposures is lacking. A 2008 study done in Egypt evaluated males 9–18 years of age hired as seasonal workers to spray pesticides in cotton fields with backpack applicators.⁸⁵ Children and adolescents who applied pesticides had lower activity levels of an enzyme that works at the intersection of nerve cells and is blocked by certain pesticides. They also performed less well on neurobehavioural tests such as those that evaluated their memory and attention span, and reported more neurological symptoms including blurred vision, dizziness, headache and difficulty concentrating. Adolescents may also be engaged in physically strenuous tasks such as carrying heavy loads, standing, stooping and bending for long periods, and repetitive and forceful movements in awkward body positions. Additionally, they may be exposed to extreme temperatures, use dangerous cutting tools, or work around farm vehicles and heavy farm machinery.⁸⁶



Adolescent girls may have responsibilities such as cooking in the home, which can expose them to harmful household air pollution when polluting fuels and technologies are used. Assessments of household air pollution exposure in adolescent girls are limited, however, despite the fact that they are known to assist with household tasks like cooking and garbage burning.⁸⁷

Finally, in some contexts, climate change may affect adolescents' entry into the labour market. Extreme weather events may threaten family livelihoods, creating economic pressure that may cause families to pull adolescents from education to supplement income.⁸⁸

Long life expectancies

At different ages during adolescence, certain cells and tissues of various organs are rapidly dividing, making them prime targets for carcinogens that can cause mutations in replicating DNA.⁸⁹ Exposure to carcinogens is a risk factor for cancer later in life. Because young people have many expected years of life, cancers which have long latency periods can affect them more than an older person with the same carcinogenic exposure, who will not live enough years to have the cancer develop. For example, one of the sensitive periods for the human breast is during adolescence, when exposure to DDT has been shown to be associated with breast cancer in adult women.⁹⁰

References

- 1 Viner RM, Allen NB, and P. GC, *Puberty, Developmental Processes, and Health Interventions*, in *Child and Adolescent Health and Development. 3rd edition*, Bundy DAP, et al., Editors. 2017, The International Bank for Reconstruction and Development / The World Bank: Washington, DC.
- 2 Rohayem, Julia, et al., 'Mini-Puberty, Physiological and Disordered: Consequences, and potential for therapeutic replacement', *Endocrine Reviews*, vol. 45, no. 4, August 2024, pp. 460–492.
- 3 Abreu, Ana Paula, and Ursula B. Kaiser, 'Pubertal Development and Regulation', *Lancet Diabetes & Endocrinology*, vol. 4, no. 3, March 2016, pp. 254–264.
- 4 Yang, Qianfan, et al., 'Sex Hormone Influence on Female-Biased Autoimmune Diseases Hints at Puberty as an Important Factor in Pathogenesis', *Frontiers in Pediatrics*, vol. 11, art. 1051624, 2023.
- 5 Viner, Allen and Patton, 'Puberty, Developmental Processes, and Health Interventions'.
- 6 Norris, Shane A., et al., 'Nutrition in Adolescent Growth and Development', *Lancet*, vol. 399, no. 10320, 8–14 January 2022, pp. 172–184.
- 7 Ibid.
- 8 Ibid.
- 9 Lopez-Rodriguez, David, et al., 'Endocrine-Disrupting Chemicals and Their Effects on Puberty', *Best Practice & Research Clinical Endocrinology & Metabolism*, vol. 35, no. 5, art. 101579, September 2021.
- 10 Anderson, Greg M., et al., 'Metabolic Control of Puberty: 60 years in the footsteps of Kennedy and Mitra's seminal work', *Nature Reviews Endocrinology*, vol. 20, no. 2, February 2024, pp. 111–123.
- 11 Lopez-Rodriguez et al., 'Endocrine-Disrupting Chemicals and Their Effects on Puberty'; Ulbjerg, C. S., et al., 'Prenatal and Postnatal Exposures to Endocrine Disrupting Chemicals and Timing of Pubertal Onset in Girls and Boys: A systematic review and meta-analysis', *Human Reproduction Update*, vol. 28, no. 5, September–October 2022, pp. 687–716.
- 12 Symeonides, Christos, et al., 'An Umbrella Review of Meta-analyses Evaluating Associations between Human Health and Exposure to Major Classes of Plastic-Associated Chemicals', *Annals of Global Health*, vol. 90, no. 1, art. 52, 2024.
- 13 Anderson et al., 'Metabolic Control of Puberty'.
- 14 Patton, George C., et al., 'Our Future: A Lancet commission on adolescent health and wellbeing', *Lancet*, vol. 387, no. 10036, 11 June 2016, pp. 2423–2478.
- 15 Kendrick, Dalisa R., Steven R. Boomhower and M. Christopher Newland, 'Adolescence as a Sensitive Period for Neurotoxicity: Lifespan developmental effects of methylmercury', *Pharmacology Biochemistry and Behavior*, vol. 217, art. 173389, June 2022.
- 16 Spear, Linda Patia, 'Adolescent Neurodevelopment', *Journal of Adolescent Health*, vol. 52, no. 2, suppl. 2, February 2013, pp. S7–S13.
- 17 Kendrick, Boomhower and Newland, 'Adolescence as a Sensitive Period for Neurotoxicity'.
- 18 Ibid.
- 19 Herting, Megan M., Katherine L. Bottenhorn and Devyn L. Cotter, 'Outdoor Air Pollution and Brain Development in Childhood and Adolescence', *Trends in Neurosciences*, vol. 47, no. 8, August 2024, pp. 593–607.
- 20 Ibid.
- 21 Kendrick, Boomhower and Newland, 'Adolescence as a Sensitive Period for Neurotoxicity'.
- 22 Kwan, Leslie Y., et al., 'This is Your Teen Brain on Drugs: In search of biological factors unique to dependence toxicity in adolescence', *Neurotoxicology and Teratology*, vol. 81, art. 106916, September–October 2020.
- 23 UNICEF Innocenti – Global Office of Research and Foresight, *The Adolescent Brain: A second window of opportunity – A compendium*, United Nations Children's Fund, Florence, Italy, 2017.
- 24 Viner, Allen and Patton, 'Puberty, Developmental Processes, and Health Interventions'.
- 25 National Academies of Sciences, Engineering, and Medicine, et al., 'Normative Adolescent Development', ch. 2 in *Promoting Positive Adolescent Health Behaviors and Outcomes: Thriving in the 21st century*, edited by Robert Graham and Nicole F. Kahn, National Academies Press, Washington, D.C., 2020.
- 26 *The Adolescent Brain*.
- 27 Patton et al., 'Our Future: A Lancet commission'.
- 28 'Normative Adolescent Development'.
- 29 Romanello M, Di Napoli C, Drummond P, Green C, Kennard H, Lampard P, Scamman D, Arnell N, Ayeb-Karlsson S, Ford LB, Belesova K, Bowen K, Cai W, Callaghan M, Campbell-Lendrum D, Chambers J, van Daalen KR, Dalin C, Dasandi N, Dasgupta S, Davies M, Dominguez-Salas P, Dubrow R, Ebi KL, Eckelman M, Ekins P, Escobar LE, Georgeson L, Graham H, Gunther SH, Hamilton I, Hang Y, Hänninen R, Hartinger S, He K, Hess JJ, Hsu SC, Jankin S, Jamart L, Jay O, Kelman I, Kiesewetter G, Kinney P, Kjellstrom T, Kniveton D, Lee JKW, Lemke B, Liu Y, Liu Z, Lott M, Batista ML, Lowe R, MacGuire F, Sewe MO, Martinez-Urtaza J, Maslin M, McAllister L, McGushin A, McMichael C, Mi Z, Milner J, Minor K, Minx JC, Mohajeri N, Moradi-Lakeh M, Morrissey K, Munzert S, Murray KA, Neville T, Nilsson M, Obradovich N, O'Hare MB, Oreszczyn T, Otto M, Owfi F, Pearman O, Rabbaniha M, Robinson EJZ, Rocklöv J, Salas RN, Semenza JC, Sherman JD, Shi L, Shumake-Guillemot J, Silbert G, Sofiev M, Springmann M, Stowell J, Tabatabaei M, Taylor J, Triñanes J, Wagner F, Wilkinson P, Winning M, Yglesias-González M, Zhang S, Gong P, Montgomery H, Costello A. The 2022 report of the Lancet Countdown on health and climate change: health at the mercy of fossil fuels. *Lancet*. 2022 Nov 5;400(10363): 1619-1654.
- 30 Vergunst, Francis, et al., 'Climate Change and Substance-Use Behaviors: A risk-pathways framework', *Perspectives on Psychological Science*, vol. 18, no. 4, July 2023, pp. 936–954.
- 31 Scamman D, Arnell N, Ayeb-Karlsson S, Ford LB, Belesova K, Bowen K, Cai W, Callaghan M, Campbell-Lendrum D, Chambers J, van Daalen KR, Dalin C, Dasandi N, Dasgupta S, Davies M, Dominguez-Salas P, Dubrow R, Ebi KL, Eckelman M, Ekins P, Escobar LE, Georgeson L, Graham H, Gunther SH, Hamilton I, Hang Y, Hänninen R, Hartinger S, He K, Hess JJ, Hsu SC, Jankin S, Jamart L, Jay O, Kelman I, Kiesewetter G, Kinney P, Kjellstrom T, Kniveton D, Lee JKW, Lemke B, Liu Y, Liu Z, Lott M, Batista ML, Lowe R, MacGuire F, Sewe MO, Martinez-Urtaza J, Maslin M, McAllister L, McGushin A, McMichael C, Mi Z, Milner J, Minor K, Minx JC, Mohajeri N, Moradi-Lakeh M, Morrissey K, Munzert S, Murray KA, Neville T, Nilsson M, Obradovich N, O'Hare MB, Oreszczyn T, Otto M, Owfi F, Pearman O, Rabbaniha M, Robinson EJZ, Rocklöv J, Salas RN, Semenza JC, Sherman JD, Shi L, Shumake-Guillemot J, Silbert G, Sofiev M, Springmann M, Stowell J, Tabatabaei M, Taylor J, Triñanes J, Wagner F, Wilkinson P, Winning M, Yglesias-González M, Zhang S, Gong P, Montgomery H, Costello A. The 2022 report of the Lancet Countdown on health and climate change: health at the mercy of fossil fuels. *Lancet*. 2022 Nov 5;400(10363): 1619-1654.
- 32 Proulx, Kerrie, et al., 'Climate Change Impacts on Child and Adolescent Health and Well-Being: A narrative review', *Journal of Global Health*, vol. 14, art. 04061, 24 May 2024.
- 33 Cianconi, Paolo, Sophia Betrò and Luigi Janiri, 'The Impact of Climate Change on Mental Health: A systematic descriptive review', *Frontiers in Psychiatry*, vol. 11, art. 74, 2020.
- 34 United States Centers for Disease Control and Prevention, 'Schools are the RIght Place for a Healthy Start for Adolescents', CDC, 21 September 2020, <www.cdc.gov/healthyyouth/about/why_schools.htm>, accessed December 12 2024.
- 35 Sabarwal, Shwetlena, et al., *Choosing Our Future: Education for climate action*, World Bank, Washington, D.C. 2024.
- 36 Park, R. Jisung, A. Patrick Behrer and Joshua Goodman, 'Learning is Inhibited by Heat Exposure, both Internationally and within the United States', *Nature Human Behaviour*, vol. 5, no. 1, January 2021, pp. 19–27.
- 37 GBD 2019 Adolescent Mortality Collaborators, 'Global, Regional, and National Mortality among Young People Aged 10–24 Years, 1950–2019: A systematic analysis for the Global Burden of Disease Study 2019', *Lancet*, vol. 398, no. 10311, 30 October 2021, pp. 1593–1618.
- 38 Gordon, Rebecca J., and Catherine M. Gordon, 'Adolescents and Bone Health', *Clinical Obstetrics and Gynecology*, vol. 63, no. 3, September 2020, pp. 504–511.
- 39 Soliman, Ashraf T., et al., 'Nutritional Interventions during Adolescence and Their Possible Effects', *Acta Biomedica*, vol. 93, no. 1, art. e2022087, February 2022.
- 40 Hannon, Tamara S., and Silva A. Arslanian, 'Obesity in Adolescents', *New England Journal of Medicine*, vol. 389, no. 3, 20 July 2023, pp. 251–261.
- 41 Ibid.

- 42 World Health Organization, 'Obesity and Overweight', 1 March 2024, <www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>, accessed 14 December 2024.
- 43 Ibid.
- 44 Nicolaou, Marina, et al., 'Obesogens in Adolescence: Challenging aspects and prevention strategies', *Children*, vol. 11, no. 5, art. 602, May 2024.
- 45 Ibid.
- 46 Huang, Miao, et al., 'Effects of Ambient Air Pollution on Blood Pressure among Children and Adolescents: A systematic review and meta-analysis', *Journal of the American Heart Association*, vol. 10, no. 10, art. e017734, 18 May 2021.
- 47 Ibid.
- 48 Zhang, Kai, et al., 'Air Pollution, Built Environment, and Early Cardiovascular Disease', *Circulation Research*, vol. 132, no. 12, 9 June 2023, pp. 1707–1724.
- 49 Gauderman, W. James, et al., 'The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age', *New England Journal of Medicine*, vol. 351, no. 11, 9 September 2004, pp. 1057–1067.
- 50 Gauderman, W. James, et al., 'Association of Improved Air Quality with Lung Development in Children', *New England Journal of Medicine*, vol. 372, no. 10, 5 March 2015, pp. 905–913.
- 51 GBD 2019 Child and Adolescent Communicable Disease Collaborators, 'The Unfinished Agenda of Communicable Diseases among Children and Adolescents before the COVID-19 Pandemic, 1990-2019: A systematic analysis of the Global Burden of Disease Study 2019', *Lancet*, vol. 402, no. 10398, 22 July 2023, pp. 313–335.
- 52 Laycock, Katherine M., Leslie A. Enane and Andrew P. Steenhoff, 'Tuberculosis in Adolescents and Young Adults: Emerging data on TB transmission and prevention among vulnerable young people', *Tropical Medicine and Infectious Disease*, vol. 6, no. 3, art. 148, September 2021.
- 53 Beckwith, Sam, Venkatraman Chandra-Mouli and Robert Wm. Blum, 'Trends in Adolescent Health: Successes and challenges from 2010 to the present', *Journal of Adolescent Health*, vol. 75, no. 4, suppl., October 2024, pp. S9–S19.
- 54 United Nations Children's Fund, *2023 Global Snapshot on HIV and AIDS: Progress and priorities for children, adolescents and pregnant women*, UNICEF, New York, 2023.
- 55 Ferrand, Rashida Abbas, 'Communicable Diseases across the Entire Developmental Window of Childhood and Adolescence: An outstanding agenda', *Lancet*, vol. 402, no. 10398, 22 July 2023, pp. 269–271.
- 56 Laycock, Enane and Steenhoff, 'Tuberculosis in Adolescents and Young Adults'.
- 57 Zhang, Jing, et al., 'Global, Regional, and National Burdens of HIV and Other Sexually Transmitted Infections in Adolescents and Young Adults Aged 10–24 Years from 1990 to 2019: A trend analysis based on the Global Burden of Disease Study 2019', *Lancet Child & Adolescent Health*, vol. 6, no. 11, November 2022, pp. 763–776.
- 58 Tremblay, Frédérique, et al., 'A Systematic Review of the Association between History of Sexually Transmitted Infections and Subsequent Condom Use in Adolescents', *BMC Public Health*, vol. 24, art. 1000, 10 April 2024.
- 59 Shannon, Chelsea L., and Jeffrey D. Klausner, 'The Growing Epidemic of Sexually Transmitted Infections in Adolescents: A neglected population', *Current Opinion in Pediatrics*, vol. 30, no. 1, February 2018, pp. 137–143.
- 60 World Health Organization, 'Cervical Cancer', 5 March 2024, <www.who.int/news-room/fact-sheets/detail/cervical-cancer>, accessed 14 December 2024.
- 61 United States Centers for Disease Control and Prevention, 'Basic Information about HPV and Cancer', 17 September 2024, <www.cdc.gov/cancer/hpv/basic-information.html>, accessed 14 December 2024.
- 62 Wiafe, Stephanie, Ariana Mihan and Colleen M. Davison, 'Neighborhood-Level Influences and Adolescent Health Risk Behaviors in Rural and Urban sub-Saharan Africa: A systematic review', *International Journal of Environmental Research and Public Health*, vol. 18, no. 14, art. 7637, July 2021.
- 63 Patton et al., 'Our Future: A Lancet commission'; Ruiz, J. R., et al., 'Predictive Validity of Health-Related Fitness in Youth: A systematic review', *British Journal of Sports Medicine*, vol. 43, no. 12, November 2009, pp. 909–923.
- 64 Guthold, Regina, et al., 'Global Trends in Insufficient Physical Activity among Adolescents: A pooled analysis of 298 population-based surveys with 1.6 million participants', *Lancet Child & Adolescent Health*, vol. 4, no. 1, January 2020, pp. 23–35.
- 65 Agostini, Alex, and Stephanie Centofanti, 'Normal Sleep in Children and Adolescence', *Child and Adolescent Psychiatric Clinics of North America*, vol. 30, no. 1, January 2021, pp. 1–14.
- 66 Rony, Moustaq Karim Khan, and Hasnat M. Alamgir, 'High Temperatures on Mental Health: Recognizing the association and the need for proactive strategies – A perspective', *Health Science Reports*, vol. 6, no. 12, art. e1729, December 2023; Liu, Jianghong, et al., 'Air Pollution Exposure and Adverse Sleep Health across the Life Course: A systematic review', *Environmental Pollution*, vol. 262, art. 114263, July 2020.
- 67 'Normative Adolescent Development'.
- 68 World Health Organization, 'Adolescent and Young Adult Health', 26 November 2024, <www.who.int/news-room/fact-sheets/detail/adolescents-health-risks-and-solutions>, accessed 14 December 2024.
- 69 Weirich, Chelsea A., and Todd R. Miller, 'Freshwater Harmful Algal Blooms: Toxins and children's health', *Current Problems in Pediatric and Adolescent Health Care*, vol. 44, no. 1, January 2014, pp. 2–24.
- 70 World Health Organization, *Global Report on Drowning: Preventing a leading killer*, WHO, Geneva, 2014.
- 71 Luo, Shi, et al., 'The Influence of Water Safety Knowledge on Adolescents' Drowning Risk Behaviors: A framework of risk-protect integrated and KAP theory', *Frontiers in Public Health*, vol. 12, art. 1354231, 2024.
- 72 Bitsko, Matthew J., Robin S. Everhart and Bruce K. Rubin, 'The Adolescent with Asthma', *Paediatric Respiratory Reviews*, vol. 15, no. 2, June 2014, pp. 146–153.
- 73 Corbett, Tracy, and Joanne Smith, 'Exploring the Effects of Being Diagnosed with Type 1 Diabetes in Adolescence', *Nursing Standard*, vol. 35, no. 7, 8 July 2020, pp. 77–82.
- 74 World Health Organization, *Sanitation and Hygiene: Training for health care providers*, 3rd ed., WHO, Geneva, 2023.
- 75 Ibid.
- 76 Alugnoa, Desmond N., Trevor Cousins and Mayumi Sato, 'Period Poverty and Menstrual Belonging: A matter of climate justice', *Lancet Planetary Health*, vol. 6, no. 7, July 2022, pp. e551–e552.
- 77 United Nations Children's Fund, 'Early Childbearing', November 2024, <<https://data.unicef.org/topic/child-health/adolescent-health/>>, accessed 18 November 2024.
- 78 World Health Organization, 'Adolescent Pregnancy', 10 April 2024, <www.who.int/news-room/fact-sheets/detail/adolescent-pregnancy>, accessed 18 November 2024.
- 79 Maheshwari, Marvi V., et al., 'Maternal and Neonatal Outcomes of Adolescent Pregnancy: A narrative review', *Cureus*, vol. 14, no. 6, art. e25921, 14 June 2022.
- 80 Ibid.
- 81 Golub, M. S., 'Adolescent Health and the Environment', *Environmental Health Perspectives*, vol. 108, no. 4, April 2000, pp. 355–362.
- 82 International Labour Organization, 'What is Child Labour', <www.ilo.org/international-programme-elimination-child-labour-ipecc/what-child-labour>, accessed 13 November 2024.
- 83 Ibid.
- 84 International Labour Office and United Nations Children's Fund, *Child Labour: Global estimates 2020. trends and the road forward*, ILO and UNICEF, New York, 2021.
- 85 Abdel Rasoul, Gaafar M., et al., 'Effects of Occupational Pesticide Exposure on Children Applying Pesticides', *NeuroToxicology*, vol. 29, no. 5, September 2008, pp. 833–838.
- 86 *Child Labour: Global estimates 2020*.
- 87 Kearns, Katherine A., et al., 'Estimating Personal Exposures to Household Air Pollution and Plastic Garbage Burning among Adolescent Girls in Jalapa, Guatemala', *Chemosphere*, vol. 348, art. 140705, January 2024.
- 88 Eskenazi, Brenda, et al., 'The International Society for Children's Health and the Environment Commits to Reduce Its Carbon Footprint to Safeguard Children's Health', *Environmental Health Perspectives*, vol. 128, no. 1, art. 014501, January 2020.
- 89 Carpenter, David O., and Sheila Bushkin-Bedient, 'Exposure to Chemicals and Radiation During Childhood and Risk for Cancer Later in Life', *Journal of Adolescent Health*, vol. 52, no. 5, suppl., May 2013, pp. S21–S29.
- 90 Cohn, Barbara A., et al., 'DDT and Breast Cancer in Young Women: New data on the significance of age at exposure', *Environmental Health Perspectives*, vol. 115, no. 10, October 2007, pp. 1406–1414.



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