



Seasonal Climatic Variations and Dietary Exposures Influence on Atopic Dermatitis

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Abstract

Atopic Dermatitis, more commonly known as eczema, is a chronic inflammatory skin condition that results in dry and inflamed skin. This literature review will investigate how seasonal climatic variations and dietary exposures influence the onset and severity of atopic dermatitis flare-ups in children. This research is relevant because caretakers can struggle to identify and handle these triggers of flare-ups, and a strong understanding could help with managing their children's eczema and improve their quality of life. To conduct this review, scholarly research articles were used to gather information on the pathogenesis of atopic dermatitis, strategies for management and their effectiveness, the role of diet and seasonal climate changes on the severity of eczema flare-ups, and the impact of various management interventions on eczema. This paper aims to amalgamate information for patients, dermatologists, and caretakers to improve understanding of triggers in childhood eczema.

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Atopic dermatitis (AD) is a chronic inflammatory skin disorder characterized by xerosis (abnormal dryness of a body part or tissue), intense pruritus (a feeling or sensation of itchiness on the skin), and lesions, affecting up to 20% of all children (Cleveland Clinic, 2022; Russo et al., 2025). Its pathophysiology involves a genetic predisposition of the skin barrier to dysfunction and immune dysregulation via Th2 and Th22 immune pathways, and the release of pro-inflammatory molecules such as IL-4 and IL-13; these pathways are responsible for inflammation and repair of muscle and epithelial cells following disease (Russo et al., 2025). Thus, dysfunction of these systems create a perpetual cycle of skin breakdown and immune sensitivity (Russo et al., 2025; Silverberg et al., 2013). Despite an understanding of the underlying mechanisms behind atopic dermatitis, the environmental and dietary factors that trigger or intensify flare-ups are not well known and remain mostly undocumented (Oykhman et al., 2022; Yang et al., 2025). Nevertheless, a subset of studies has begun to document specific environmental and dietary variables associated with flare-up activity, giving a starting basis from which to examine these triggers more closely.

Environmental research has demonstrated that ambient temperature, relative humidity, UV radiation, and aeroallergen levels have significant effects on the skin barrier and immune activation response in children (Yang et al., 2025). Additionally, many seasonal variations in skin

symptoms have been observed, such as spring-onset AD associated with wet and cold climate conditions, summer and fall-onset linked to heat and humidity, and winter-onset associated with a dry climate (Yang et al., 2025). Dietary patterns have also been proposed to have a significant role in atopic dermatitis severity (Vassilopoulou et al., 2024). Western diets, which can include processed foods and fat, have been reported to dysregulate the Th1 and Th2 immune balance (Vassilopoulou et al., 2024). Interventions such as probiotic supplementation have been associated with alleviating symptoms by helping to restore microbial balance in the gut (Vassilopoulou et al., 2024). Despite increasing evidence that shows the effects of climate and diet on the onset of atopic dermatitis in children, the extent to which these factors interact and work together to influence the onset and severity of symptoms throughout the year has not been thoroughly addressed. A better understanding of these relationships is very important to the development of seasonally informed, diet-inclusive AD management strategies. The present study, therefore, investigates how seasonal climatic variations and dietary exposures independently and jointly influence AD flare-up patterns in children.

Pathogenesis of Atopic Dermatitis

Atopic dermatitis, also known as eczema, is a chronic inflammatory skin disorder caused by a mutation in the filaggrin (FLG) gene that compromises the skin barrier, allowing allergens, irritants, and bacteria to penetrate the skin and cause an exaggerated immune response mediated by Th2 and Th22 cells (Frazier & Bhardwaj, 2020). The FLG gene's role is to provide instructions to make profilaggrin, which is later broken down into filaggrin monomers that help create the skin's outer layer (Frazier & Bhardwaj, 2020). However, if there is insufficient production of filaggrin monomers, for example, due to a mutation, the skin barrier weakens, and microscopic gaps form within it (Frazier & Bhardwaj, 2020). This weakened barrier allows allergens, irritants, and bacteria to penetrate much deeper into the skin (Frazier & Bhardwaj, 2020). In response, pro-inflammatory mediators are released, prompting an immune response mediated by Th2 and Th22 cells (Russo et al., 2025). Th2 and Th22 stimulate the release of cytokines, including IL-4, IL-13, IL-22, and IL-31, which suppress terminal differentiation proteins such as filaggrin and loricrin, further weakening the skin barrier, while also promoting epidermal hyperplasia and driving the intense itching characteristic of AD flares (Gittler et al., 2012). During flares, IL-4 and IL-13, type 2 cytokines produced primarily by Th2 cells and innate lymphoid cell 2 (ILC2) populations, act on keratinocytes, mast cells, eosinophils, fibroblasts, and other target cells to drive inflammation. As these cytokines are released, they amplify the Th2-mediated immune response, intensifying itching (Tokura et al., 2024).

Genetic predisposition is a major risk factor for AD (Cordeiro et al., 2025). At least 46 genes are implicated in AD onset, including SPINK5, LAMA3, HRNR, and COL8A1 alongside FLG, with most of these affecting epidermal cell differentiation and the integrity of the skin's barrier (Cordeiro et al., 2025). It is important to note that genetic patterns also differ by

population. For example, the x.3321delA FLG gene mutation is more common in Asian populations and has caused high rates of AD in regions like China, Korea, and Japan, while R501X and 2282del4 are FLG gene mutations that are more commonly found in European populations (Cheng et al., 2021).

Environmental exposures can interact with and exacerbate the genetic vulnerability to atopic dermatitis. Epigenetic mechanisms like DNA methylation, histone modification, and microRNA regulation following exposures to factors such as smoke and air pollution change gene expression in AD (Cordeiro et al., 2025). Skin and gut health may also play an important role in symptom severity, as increased *Staphylococcus aureus* colonization and reduced microbial diversity in the gut can increase inflammation and further contribute to deteriorating the skin barrier (Cordeiro et al., 2025).

Despite progress made in related research, many aspects of AD remain unknown. Many studies report varying prevalence estimates of FLG mutations in patients with eczema, ranging from 10-40% (Cordeiro et al., 2025; Mahajan et al., 2025). This range reflects the observation that FLG and AD aren't directly linked; some patients have low filaggrin protein levels in their skin even without an FLG mutation, suggesting that other factors beyond FLG mutations can weaken the skin barrier (Cordeiro et al., 2025). Subgroup comparisons between Europeans and Asians also show no significant differences in genetic associations with atopic dermatitis. This suggests that AD-related genetic variants do not follow a uniform pattern across these groups (Cordeiro et al., 2025). This suggests that regional or local factors, such as the environment, dietary habits, and gene-environment interactions, in combination, may have contributed to these variations (Cordeiro et al., 2025).

Dietary Patterns and Nutritional Intervention

Food allergies and eczema remain closely intertwined conditions, with roughly one-third of children who have severe eczema also carrying a documented food allergy diagnosis (Idris et al., 2023). Milk and egg are identified as the allergens most often targeted in elimination diets for infants and young children with AD, with these diets primarily focusing on removing well-known allergenic foods (Vassilopoulou et al., 2024).

Early exposure to cow's milk appears to affect milk allergy onset, as infants who received cow's milk formula within their first three days of life showed a greater tendency to develop allergy to cow's milk and other foods (Idris et al., 2023). This suggests that the earliest days after birth may be a sensitive window for allergy development (Idris et al., 2023). Maternal consumption patterns may also play a role in allergy onset, as a 2023 study investigating the relationship between maternal diet during pregnancy and infant risk of eczema and food allergy found that mothers without existing allergies who consumed high amounts of milk while pregnant tended to have children with a reduced likelihood of developing cow's milk allergy; this

points toward in utero tolerance development (Idris et al., 2023). A similar protective trend was found with peanuts and tree nuts, where mothers without allergies who ate at least five servings weekly during pregnancy had children with lower rates of peanut or tree nut allergy (Idris et al., 2023).

Testing children for food and environmental allergies, however, has not proven to be a reliable way to reduce AD symptoms, potentially due to a high false-positive rate in test results that leads families to eliminate foods unnecessarily (Frazier & Bhardwaj, 2020). Existing evidence on dietary elimination as a treatment has produced divided opinions among researchers who reviewed thirteen years of clinical data (Oykhman et al., 2022). Some children with AD undergoing controlled food challenges did show delayed eczematous reactions, occurring with or without an accompanying IgE-mediated response, which supports at least a partial food-related component of AD in some cases (Oykhman et al., 2022). Yet, growing evidence of other, non-dietary drivers of AD has made the value of eliminating potential food allergens as a treatment increasingly contested (Oykhman et al., 2022).

The risks associated with prolonged or unnecessary food elimination are becoming more widely acknowledged, even though reviewed trials did not report sufficient direct data on harm (Oykhman et al., 2022). This concern is particularly acute for infants, since prolonged avoidance of certain foods early in life can paradoxically encourage the development of new allergies rather than prevent them (Oykhman et al., 2022). Existing guidance broadly discourages maternal dietary restriction during pregnancy as well, with all twenty-eight reviewed clinical guidelines recommending against exclusion diets and instead favoring breastfeeding as a preferred allergy-prevention approach (Idris et al., 2023). However, it is worth noting that the body of research supporting these conclusions is itself limited, since the underlying studies in this area have tended to be small and not rigorously vetted, weakening the reliability of their findings.

Probiotic supplementation stands out in the evidence as one of the more promising dietary interventions for children with AD, including children who do not have a documented food allergy, underscoring the relevance of gut health in skin health outcomes (Vassilopoulou et al., 2024). A 2024 meta-analysis of twenty studies involving 1,387 children found that probiotic supplementation was associated with benefits in SCORAD (scoring atopic dermatitis) severity scores regardless of the ethnic background of the study population (Vassilopoulou et al., 2024). This phenomenon is thought to involve live organisms that, when given in adequate quantities, help regulate the gut microbiome and strengthen intestinal barrier integrity, which in turn supports immune function (Vassilopoulou et al., 2024).

The age at which probiotics are most effective is still debated, however (Vassilopoulou et al., 2024). One 2017 meta-analysis involving 1,070 children and adolescents concluded that

SCORAD-measured reduction in eczema severity was greater in children older than twelve months, while other researchers found the opposite, reporting that supplementation in infants under one year might be more effective at reducing eczema severity (Vassilopoulou et al., 2024). The EAACI (European Academy of Allergy and Clinical Immunology) task force's own review found generally improved SCORAD scores from probiotic use across childhood, with a stronger effect specifically observed in children older than thirty-six months (Vassilopoulou et al., 2024). Duration of probiotic treatment also appears relevant, with periods longer than twelve weeks showing possible benefit for SCORAD outcomes, though these findings were not statistically significant (Vassilopoulou et al., 2024). Postbiotics, defined as preparations of inactive microorganisms or their byproducts, have been proposed as a lower-risk alternative to live probiotic strains (Vassilopoulou et al., 2024). However, the evidence for their effectiveness remains weak, with many investigators unable to identify a significant benefit in their own analyses (Vassilopoulou et al., 2024).

Vitamin D has also attracted substantial research attention, given its proposed role in regulating skin immunity, supporting barrier function, and reducing inflammation by influencing keratinocyte growth and differentiation (Vassilopoulou et al., 2024). Across four randomized controlled trials investigating the effect of dietary interventions on atopic dermatitis skin symptoms in infants and children without food allergies, vitamin D supplementation consistently showed benefit when delivered in a fat-soluble form, reducing atopic dermatitis severity scores relative to placebo (Vassilopoulou et al., 2024). However, this benefit disappeared when it was given in a water-soluble cellulose capsule instead (Vassilopoulou et al., 2024). Alongside probiotics, vitamin D has received notable attention among the dietary interventions studied, and it shows the clearest, though still modest, promise for improving skin symptoms as measured by SCORAD (Vassilopoulou et al., 2024).

Influence of Seasonal Climate Changes

AD prevalence varies around the world and between different demographic groups, with both genetic and environmental factors proposed as factors contributing to these differences. AD prevalence has been increasing in East Asian populations, especially people living in urban areas (Cheng et al., 2021). With urbanization rates growing in China from 11.8% in 1950 to 49.2% in 2010, studies suggest that there is a strong association between industrialization and increasing disease severity and burden (Cheng et al., 2021). Children of Asian immigrants in Western countries also seem to have a higher risk of developing AD, due to epigenetic changes that are unique to their immigrant parents' population (Cheng et al., 2021).

Studies suggest that seasonal allergens have a major influence on AD flares in children, with climate change intensifying their impact by extending the pollen season and increasing the time of allergen exposure (Russo et al., 2025). During thunderstorms, quick changes in humidity can break pollen grains into smaller pieces, releasing starch granules and cytoplasmic fragments that are able to penetrate the skin barrier, while strong winds combine these particles with pollutants, disrupting the skin barrier further and enhancing immune activation (Russo et al., 2025).

Allergens like mold exposure have been associated with up to a 95% increased risk of eczema (Russo et al., 2025). Fine particulate matter (PM) can penetrate the skin due to its oily properties, causing inflammation and oxidative stress, with a large 2025 US study finding a strong correlation between PM_{2.5} (particulate matter with a diameter of 2.5 micrometers or smaller) exposure and AD, even after accounting for many demographic and clinical factors (Russo et al., 2025; United States Environmental Protection Agency, 2026). In Turkey, a 2025 study consisting of 21,407 patients found that increased ozone levels and PM₁₀ were strong environmental predictors of AD admission (Ayşin et al., 2025). In the second half of the year, PM₁₀ levels were observed to have a major impact on the number of AD patients (Ayşin et al., 2025). The study's model showed that when PM₁₀ levels were above 55,730, an increase in wind speed was associated with an 80% increase in AD patients (Ayşin et al., 2025).

Cold, dry air reduces ambient vapor pressure and can cause transepidermal water loss, weakening the skin barrier and increasing AD vulnerability in children (Yokomichi et al., 2022). The 2022 Japan Environment and Children's Study, which looked at over 100,000 children, found that those born between October and December had the highest rate of AD prevalence by the time they were 3 years old, suggesting that early exposure during the first months of life plays a big role in the AD onset (Yokomichi et al., 2022). In this study, a one-standard-deviation increase in temperature was associated with a hazard ratio of 0.87 for AD onset, suggesting that warmer environments in early life may reduce a child's risk of developing AD (Yokomichi et al., 2022). Supporting this, a 2013 US study found that children in areas of higher relative humidity, UV index, and average water temperatures had a significantly lower AD prevalence, while environments that required indoor heating were associated with higher rates of AD onset (Silverberg et al., 2013). A 2025 Taiwanese survey investigating seasonal subtypes of childhood AD and evaluating their climatic associations further elucidated potentially distinct seasonal attack subtypes in children (Yang et al., 2025). Spring attack AD was associated with cool, wet conditions; summer and fall attacks were associated with high heat, and winter attacks were linked to dry climates (Yang et al., 2025). These findings suggest that ambient temperature and humidity are associated with the timing and pattern of eczema flares in pediatric patients as well as children's skin barrier function (Yang et al., 2025).

Strategies for Managing Atopic Dermatitis

Topical corticosteroids are the first-line treatment for inflammatory responses in atopic dermatitis flares (Frazier & Bhardwaj, 2020). Usually, they are applied twice daily until the skin shows clear improvement, with continued use guided by clinical improvement (Frazier & Bhardwaj, 2020). To reduce the risk of side effects, clinical guidelines recommend using the lowest possible potency steroid for as short a period as possible (Frazier & Bhardwaj, 2020). Some possible side effects of topical corticosteroids include skin atrophy and discoloration, purpura (when small blood vessels leak blood under the skin's surface), telangiectasias (an abnormal dilation of superficial capillaries, arterioles, or venules typically localized just below the skin's surface on the face), striae (fine lines on the body that occur following rapid skin stretching), hypopigmentation, and acneiform eruptions. Most of these effects resolve after discontinuing steroid use, but resolution can take months (Cleveland Clinic, 2022; Frazier & Bhardwaj, 2020; Merriam-Webster, 2026; Zhu et al., 2024). Despite the effectiveness of steroids, side effects have contributed to "steroid phobia," affecting 83% of parents of children with eczema, often resulting in caregivers using a lower potency of medication and for shorter periods of time than what guidelines recommend (Young et al., 2021).

For patients who need long-term management or those who cannot tolerate steroids, topical calcineurin inhibitors (TCIs) like pimecrolimus and tacrolimus are alternatives for patients above the age of two (Frazier & Bhardwaj, 2020). Unlike topical steroids, calcineurin inhibitors do not cause skin atrophy and can be used in places with thinner skin, like the face, neck, and groin (Frazier & Bhardwaj, 2020). Pimecrolimus is recommended for mild to moderate AD cases, while tacrolimus is reserved for more moderate to severe cases (Frazier & Bhardwaj, 2020). However, TCIs are rarely prescribed by care providers due to unfamiliarity, cost, or concern about their black box warning for lymphoma (which has not been substantiated by long-term research) (Young et al., 2021).

For moderate to severe cases of AD that do not respond to topical treatments, narrowband ultraviolet B phototherapy offers another treatment option (Frazier & Bhardwaj, 2020). Additionally, among the newer systemic treatments, dupilumab, a monoclonal antibody, received FDA approval in 2017 for patients 12 and older with moderate to severe cases of AD (Frazier & Bhardwaj, 2020). Intended for patients with no response to any form of standard therapy, this medication blocks the interleukin-4 receptor, reducing the overproduction of inflammatory cytokines (Kawamoto et al., 2025). JAK inhibitors like abrocitinib and upadacitinib have also demonstrated a notable effect in children by blocking JAK-mediated inflammatory signaling, with higher doses associated with rapid reductions in symptom severity, cost, and limited availability; this treatment option is restricted in many places, however (Kawamoto et al., 2025; Mahajan et al., 2025). Crisaborole, a topical phosphodiesterase-4 inhibitor, was approved

by the FDA in 2016 for mild to moderate AD in patients above the age of 2, but, once again, its high cost limits many people from using it (Frazier & Bhardwaj, 2020).

Home remedies

Maintenance therapy for atopic dermatitis relies on consistent daily skin care (Frazier & Bhardwaj, 2020). Regular emollient use is a critical preventative and long-term care tactic, keeping the skin moisturized, thereby decreasing symptom severity (Frazier & Bhardwaj, 2020). Emollients with a high oil-to-water ratio, in particular, are highly recommended. Guidelines recommend that preference be given to ointments with high lipid content, followed by creams, then lotions, for application once or twice a day (Frazier & Bhardwaj, 2020). Another aspect of recommended daily skin care maintenance includes showering, as once daily 5-10 minute showers at lukewarm temperature help to hydrate and clean the skin by removing scales, bacteria, allergens, and irritants. While doing this, soap-free cleansers should be used throughout. Bleach bathing may also help moderate to severe cases due to its antiseptic and antistaphylococcal properties (Frazier & Bhardwaj, 2020).

Conclusion

The evidence reviewed in this paper indicates that seasonal climatic variation and dietary exposure may contribute to atopic dermatitis onset and severity, though the strength of that contribution differs between the two. Climatic data from Japan, Taiwan, and Turkey converge on a fairly consistent pattern: cold, dry conditions with low vapor pressure are associated with increased AD incidence, while environmental factors such as elevated ozone and particulate matter are associated with higher rates of clinical presentation. Dietary evidence is less unified. Probiotics and fat-soluble vitamin D show modest, recurring benefits, while food elimination diets lack strong support and carry documented risk in infants

However, inconsistencies do still exist among the climatic findings. One study noted that prior ecological work found no clear humidity-AD association, contrasting with its own finding that vapor pressure was significant. Likewise, a Turkish study found that increased PM10 was associated with a lower likelihood of AD admission, an outcome that runs counter to the general assumption that greater particulate pollution worsens skin disease. These contrasts indicate that the field has not settled on which specific climatic or pollutant variable most reliably contributes to AD severity, and this ambiguity should not be understated.

In response to the question of how seasonal climatic variations and dietary exposures influence the onset and severity of atopic dermatitis flare-ups in children, the claim that seasonal

allergens and dietary exposure create a large difference in eczema development and severity is not well supported by the sources reviewed. Genetic predisposition and baseline immune dysregulation remain the dominant associated factors across nearly every source consulted. Instead, seasonal and dietary factors appear to function as modifiers acting upon an already predisposed skin barrier rather than as an independent cause of disease. Characterizing them as major drivers of AD development would overstate existing evidence; a more defensible claim is that they influence the timing, frequency, and severity of flares in children who are already susceptible to the condition.

These findings nonetheless carry clinical relevance. Seasonal-subtype data from Taiwan suggest that AD management could reasonably be adapted according to season. The evidence against unsupervised elimination diets is also relevant, given that non-evidence-based restriction is common among families with children diagnosed with AD.

Several limitations should temper confidence in these conclusions. The dietary elimination review and the systemic therapy meta-analysis both identified small, poorly vetted study samples as a constraint. The study that observed that children born between October and December had the highest rate of AD prevalence by age 3, despite its large sample size, relied on caregiver-reported diagnoses subject to recall bias and excluded short-term seasonal factors such as pollen exposure. Given these gaps, the directional trends identified across the reviewed literature are worth taking seriously, but the underlying evidence base is not yet strong enough to support firm, generalizable conclusions.

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