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Solar medicine: Unraveling the biological and therapeutic effects of sunlight

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Abstract

Background: Sunlight has long shaped human health, functioning as both healer and hazard. Its effects span neonatal jaundice therapy, circadian regulation, cardiovascular health, dermatology, and vitamin D metabolism.

Methods: A structured narrative review was conducted with literature from inception to May 2025 using PubMed, Scopus, and Google Scholar. Keywords included "sunlight exposure," "phototherapy," "circadian rhythm," "mental health," "vitamin D," "cardiovascular effects," and "skin protection." Reference lists of key papers were hand-searched. Peer-reviewed clinical studies, mechanistic research, and consensus guidelines were included; anecdotal and non–peer-reviewed works were excluded.

Findings: Sunlight supports bilirubin clearance in neonates, stabilizes circadian rhythms, improves mood, regulates blood pressure via nitric oxide mediated and independent pathways, and enables vitamin D synthesis essential for skeletal and immune function. Risks include photoaging, cataracts, and cutaneous malignancies, particularly with unprotected or chronic exposure. Balanced strategies such as protective clothing, sunscreen, antioxidants, and individualized recommendations that consider latitude, season, and skin type can help optimize benefits while reducing harm.

Conclusion: Sunlight remains a double-edged force in medicine. When approached judiciously, it enhances physiological balance and psychological well-being; when neglected or overindulged, it endangers health. An integrative framework for "solar medicine," blending evidence-based protection with context-specific guidance, may refine public health recommendations and restore a more harmonious human relationship with the sun.

Keywords: Sunlight exposure; Phototherapy; Circadian rhythm; Vitamin D metabolism; Cardiovascular health; Mental health; Skin protection; Integrative medicine; Solar medicine; Preventive health

Key Messages

- Sunlight is a double-edged sword: While it supports mood, immunity, and cardiovascular health, excessive exposure can damage DNA (deoxyribonucleic acid) and increase cancer risk.
- Timing matters: Brief daily sun exposure (10–20 min on arms/legs) supports vitamin D synthesis—avoid peak UV hours (10 a.m.–4 p.m.).
- Protective strategies: Use of sunscreen, sunglasses, and antioxidants can mitigate harmful effects while preserving benefits.

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1. Introduction

Sunlight is not merely illumination; it is a biological signal woven into the rhythms of human physiology. Across evolutionary time, exposure to natural light has shaped metabolic pathways, neuroendocrine cycles, and skin adaptations.

In contemporary life, characterized by sedentary work, artificial lighting, and screen dependence, its influence is often neglected.

The physiological footprint of sunlight is broad: bilirubin clearance in neonates, serotonin regulation in mood disorders, circadian entrainment of sleep–wake cycles, nitric oxide–mediated vascular relaxation, and vitamin D synthesis, among others [1-4]. In dermatology, controlled phototherapy is a mainstay for certain conditions, whereas unprotected exposure contributes to premature aging and malignancy [5].

This paradox of sunlight as both healer and hazard requires careful navigation. Its biological effects depend not only on dose, but also on wavelength, timing, and individual factors such as skin pigmentation and geographic latitude. Understanding these variables is critical for clinicians, researchers, and public health practitioners.

The following sections trace the multifaceted roles of solar exposure in human health, balancing therapeutic potential with strategies to mitigate risk.

2. Method of Review

2.1. Search Strategy

Literature searches were conducted in PubMed, Scopus, and Google Scholar from inception to May 2025, consistent with established guidance on academic search systems [6]. Search terms included combinations of "sunlight exposure," "phototherapy," "circadian rhythm," "mental health," "vitamin D," "cardiovascular effects," and "skin protection." Reference lists of relevant reviews and primary studies were hand-searched for additional citations.

2.2. Inclusion and Exclusion Criteria

Included studies were peer-reviewed articles published in English, focusing on human or translational evidence, systematic reviews, and authoritative guidelines. Classical and historical studies foundational to the field were retained for context. Conference abstracts, anecdotal reports, and studies without direct relevance to human physiology or health outcomes were excluded. This approach aligns with accepted typologies of reviews [7].

2.3. Data Extraction and Synthesis

Titles and abstracts were screened for relevance, followed by full-text review. Key data elements (population, exposure type, outcomes, mechanisms, and limitations) were extracted. Evidence was consolidated thematically across six domains: neonatal health, mental health, metabolic regulation, cardiovascular physiology, dermatological effects, and vitamin D synthesis. The narrative design follows established distinctions between systematic and narrative review approaches [8].

2.4. Quality Assessment

Given the narrative design, no formal quality scoring tool was applied. Instead, emphasis was placed on identifying recurring themes, consensus findings, and areas of ongoing debate. This reflects accepted practices for narrative synthesis [9].

3. Sunlight and Neonatal Health

3.1. Neonatal Jaundice

Neonatal jaundice, caused by the accumulation of unconjugated bilirubin, remains one of the most common conditions in newborns. The immature liver of neonates is often unable to conjugate bilirubin efficiently, leading to transient hyperbilirubinemia. While usually benign, untreated jaundice may progress to kernicterus and permanent neurological injury.

Phototherapy with artificial blue-light devices is the standard of care. These devices use narrow-band wavelengths (≈460–490 nm) that photo-isomerizes bilirubin into more soluble forms, which are then excreted in bile and urine. Notably, sunlight when filtered and carefully dosed, contains sufficient blue-green light to produce a similar effect [10].

Clinical studies in sub-Saharan Africa and Asia have explored filtered or intermittent natural sunlight as a resource in regions with limited access to medical phototherapy units. Results show that sunlight can reduce serum bilirubin effectively, provided that infants are shielded from UV (ultraviolet) and IR (infrared) radiation to prevent burns, dehydration, or ocular injury [1,11]. However, safety remains a key concern as uncontrolled exposure risks thermal stress and UV-induced damage.

Thus, while sunlight has therapeutic potential in resource-constrained environments, its use should be approached with strict protocols, including shading methods, controlled timing, and close clinical monitoring. In higher-resource settings, standard phototherapy remains the safer and more reliable option.

4. Sunlight and Mental Health

4.1. Depression and Mood Disorders

Depressive disorders have become increasingly prevalent in younger generations, partly linked to urban lifestyles that reduce time outdoors. While many factors namely genetics, diet, socioeconomic stressors play a role; inadequate natural light exposure has emerged as an underappreciated contributor.

Sunlight influences mood primarily through serotonergic pathways. Bright light exposure stimulates serotonin turnover in the brain, particularly within the limbic system, a region integral to emotional regulation [2]. Higher serotonin activity has been observed on sunny days compared with overcast conditions, suggesting a direct photobiological effect.

Seasonal Affective Disorder (SAD) illustrates this relationship most clearly. SAD occurs during months of reduced daylight, especially at higher latitudes, and is associated with depressive symptoms, hypersomnia, and carbohydrate craving. Controlled light therapy, delivering 2,500 to 10,000 lux of bright white light in the early morning, has been shown to alleviate symptoms by resetting circadian rhythms and improving neurochemical balance [12,13].

However, sunlight exposure alone is insufficient as a standalone intervention. Natural light and outdoor activity has been shown to improve mood and sleep quality, but their impact varies across individuals and often requires integration with other interventions such as pharmacotherapy, psychotherapy, and structured exercise. Moreover, the antidepressant effect of light may depend on factors such as season, geographic location, and an individual's circadian phase sensitivity.

Overall, light both from the sun or carefully dosed artificial sources, should be regarded as a valuable adjunct in managing mood disorders. For populations with limited daylight, artificial light therapy remains the safer and more controlled option.

5. Sunlight and Metabolic Regulation

5.1. Circadian Rhythms and Sleep

Light is the most powerful synchronizer of the human circadian system. Specialized retinal photoreceptors, particularly melanopsin-containing intrinsically photosensitive retinal ganglion cells (ipRGCs) transmit light signals to the Suprachiasmatic Nucleus (SCN), the body's central clock. Exposure to bright light in the morning helps align circadian rhythms with the external day–night cycle, improving sleep onset, hormonal balance, and daytime alertness [14,15].

By contrast, inappropriate light exposure, especially blue-rich light from electronic devices during the evening is found to suppress melatonin secretion, delay circadian phase, and disrupt sleep quality.

Such disruption has been linked to metabolic consequences, including weight gain and insulin resistance, underscoring the intimate relationship between circadian biology and metabolic health [16,17].

5.2. Insulin Regulation and Energy Balance

Emerging evidence suggests that light exposure influences glucose metabolism. Animal studies indicate that circadian misalignment exacerbates insulin resistance and promotes adiposity. In humans, irregular light–dark cycles and reduced morning light exposure have been associated with impaired insulin sensitivity and higher body mass index [17,18].

The ipRGC system plays a central role in these effects, linking light perception to hypothalamic and endocrine pathways that regulate energy expenditure. Excessive screen time, with prolonged evening exposure to artificial light, has been implicated in circadian desynchrony and downstream metabolic disturbances, particularly in adolescents and shift workers [16].

5.3. Morning Light and Metabolic Activation

Morning light exposure has been shown to support weight regulation and improve metabolic outcomes. A study of adults in Chicago found that individuals receiving the majority of their daily light exposure before midday had lower body mass indices than those whose light exposure peaked later in the day, even after adjusting for sleep duration and activity levels [18]. This suggests that the timing of light may be as important as its intensity.

Red light does not stimulate melatonin production; rather, it is less disruptive to melatonin secretion than blue-enriched light, thereby minimizing circadian disruption in evening environments [12,14,16].

Thus, sunlight acts not only as a regulator of circadian rhythms but also as a modulator of energy balance and glucose metabolism. Morning light appears metabolically advantageous, while excessive evening light, whether from artificial sources or late-night exposure, can predispose individuals to sleep and metabolic disorders.

6. Cardiovascular Effects of Sunlight

6.1. Blood Pressure Regulation via Nitric Oxide Mobilization

Beyond its influence on circadian biology, sunlight has notable vascular effects. Recent studies have shown that UVA radiation can lower blood pressure independently of vitamin D. When skin is exposed to UVA, photolabile stores of Nitric Oxide (NO) and its metabolites are mobilized into the circulation. This bioactive NO promotes vasodilation, reduces vascular resistance, and thereby lowers systemic blood pressure [3].

This mechanism is distinct from classical vitamin D–dependent pathways. Indeed, experimental studies demonstrate that blood pressure reductions occur immediately following UVA exposure, without corresponding changes in serum vitamin D levels. These findings suggest that sunlight contributes to cardiovascular health through at least two independent axes: vitamin D synthesis and NO release.

6.2. Clinical Implications

The blood pressure–lowering effects of UVA may have particular relevance in populations with high cardiovascular risk. For instance, patients with chronic kidney disease or those undergoing hemodialysis often experience difficult-to-control hypertension. Pilot trials have indicated that carefully dosed UVA exposure may provide an adjunctive non-pharmacological strategy for such patients [19].

At the population level, epidemiological data support this mechanistic evidence. Blood pressure and cardiovascular mortality rates show seasonal variation, with lower values observed during summer months when sunlight exposure is higher [20-22]. While these associations are multifactorial, sunlight-driven NO mobilization may contribute.

7. Dermatological and Photoprotective Effects

7.1. Melanin Production and Skin Protection

The skin is both vulnerable to, and adapted for, solar radiation. UV light triggers melanogenesis, a protective response mediated by melanocytes in the epidermis. This process is initiated by DNA (deoxyribonucleic acid) photodamage and signaling through opsins such as OPN2 (rhodopsin-like) and OPN4 (melanopsin), rather than classical retinal rhodopsin. These signals activate melanocyte-stimulating pathways, leading to increased melanin synthesis and transfer to keratinocytes [23].

Melanin acts as a natural photo-protectant, absorbing and scattering harmful UV radiation. By doing so, it reduces the risk of photodamage, premature aging, and photo carcinogenesis. However, melanin's protective capacity is partial and variable. Darker skin types have greater innate photoprotection but remain susceptible to UV-induced damage, albeit at lower risk than lighter skin phenotypes.

7.2. Phototherapy and Light-Based Treatments

Controlled light exposure has long been used therapeutically in dermatology. Narrowband UVB phototherapy is an established treatment for psoriasis, vitiligo, and atopic dermatitis, leveraging the immunomodulatory effects of UV radiation [24,25]. Similarly, targeted UVA1 therapy has shown efficacy in scleroderma and other connective tissue diseases.

Beyond UV wavelengths, visible and near-infrared (NIR) light have gained prominence in both clinical and cosmetic practice. Blue light demonstrates antimicrobial effects against *Propionibacterium acnes* and has been incorporated into acne management protocols [26]. Red and NIR light penetrate more deeply, stimulating fibroblast activity, collagen production, and wound healing. Collectively, these modalities—often delivered through Light-Emitting Diode (LED) devices—offer non-invasive options for skin rejuvenation, infection control, and inflammatory modulation.

Sunlight and artificial light both exert profound dermatological effects. While melanin provides a degree of natural defense, deliberate therapeutic applications of light, whether UV or visible, can be harnessed to treat a wide range of skin diseases. The challenge remains in balancing therapeutic benefit against the long-term risks of uncontrolled exposure.

8. Vitamin D Synthesis and Systemic Health

8.1. Mechanism of Vitamin D Production

Vitamin D is unique among vitamins in that humans can synthesize it directly from sunlight. When skin is exposed to UVB radiation (290–315 nm), 7-dehydrocholesterol in the epidermis undergoes photoconversion to pre-vitamin D_3. This unstable compound then undergoes thermal isomerization to vitamin D_3 (cholecalciferol). Further hydroxylation in the liver and kidneys produces the active hormone, calcitriol (1,25-dihydroxyvitamin D) [27].

Importantly, this reaction does not occur behind ordinary glass, as UVB is filtered, contributing to widespread deficiency among populations spending most of their time indoors. Factors such as skin pigmentation, latitude, season, age, and use of sunscreen significantly modify cutaneous vitamin D synthesis.

8.2. Health Implications

Vitamin D plays a central role in calcium and phosphorus metabolism, skeletal development, and bone integrity. Beyond musculoskeletal health, accumulating evidence links vitamin D status to immune function, cancer risk, cardiovascular disease, and neurodegenerative conditions [28]. However, the strength of these associations varies, and randomized trial evidence remains mixed.

Vitamin D deficiency is highly prevalent worldwide. For example, during winter months in northern latitudes such as Boston or Edmonton, solar zenith angles prevent sufficient UVB from reaching the surface, making cutaneous synthesis virtually impossible [4].

8.3. Geographic and Demographic Considerations

Skin pigmentation is a critical determinant of vitamin D synthesis. Melanin competes with 7-dehydrocholesterol for UVB photons, reducing vitamin D production in darker skin types. Consequently, individuals of African or South Asian descent often require longer sun exposure to achieve equivalent serum vitamin D concentrations compared to lighter-skinned individuals living at the same latitude [29].

Latitude and season exert equally strong influences. Populations living above ~35° latitude experience several months each year when solar UVB is insufficient for vitamin D synthesis. In such settings, reliance on diet (e.g., fatty fish, fortified foods) or supplementation becomes necessary.

Recommendations

Current consensus suggests that brief daily sun exposure (10–20 min on arms/legs) supports vitamin D synthesis while avoiding peak UV hours (10 a.m.–4 p.m.). Darker skin types may require longer exposure, whereas fair-skinned individuals should exercise caution to avoid erythema and long-term damage [30].

For individuals at high risk of deficiency, such as the elderly, those with dark skin at northern latitudes, or populations with limited outdoor activity; oral supplementation is recommended. Importantly, while modest sun exposure supports vitamin D sufficiency, excessive UV exposure increases skin cancer risk, underscoring the need for individualized guidance.

Vitamin D synthesis represents one of the most well-studied benefits of sunlight, yet it exemplifies the delicate balance between benefit and harm. Adequate sun exposure can support systemic health, but supplementation and dietary intake remain essential safeguards in populations where environmental or biological factors limit cutaneous production.

9. Discussion

Collectively, evidence from neonatal health, mental health, metabolic regulation, cardiovascular physiology, dermatology, and vitamin D biology converges on a unified photobiological framework, supporting the concept of 'solar medicine,' in which wavelength, timing, dose, and individual susceptibility together determine health outcomes.

9.1. Risks and Protective Strategies

9.1.1. Hazards of sunlight Exposure

Although sunlight is essential for health, excessive or unprotected exposure carries well-documented risks. UV radiation, particularly UVA (320–400 nm) and UVB (280–320 nm), induces direct DNA damage, oxidative stress, and immune suppression. These processes accelerate photoaging and increase the risk of actinic keratoses, squamous cell carcinoma, basal cell carcinoma, and melanoma [31].

The eyes are equally vulnerable. Chronic UV exposure contributes to photokeratitis, pterygium, cataracts, and age-related macular degeneration [32].

9.1.2. Protective Clothing and Sunscreen

Physical barriers remain the first line of defense. Tightly woven fabrics, synthetic fibers (nylon, polyester), and dark colors offer superior protection compared to loosely woven cotton. Clothing with a certified UV Protection Factor (UPF) of 30–50 provides robust defense, whereas a standard cotton T-shirt offers an SPF (Sun Protection Factor) near to seven [33].

Broad-spectrum sunscreens (SPF ≥ 30), applied liberally and reapplied every 2 hours, are proven to reduce photoaging and skin cancer risk. Long-term follow-up from randomized trials shows regular sunscreen use reduces melanoma incidence [34].

9.1.3. Ocular Protection and Antioxidants

Conventional sunglasses may not block UV rays entering from the sides or oblique angles. Wrap-around designs or UV-blocking contact lenses offer more comprehensive coverage. Nutritional antioxidants further augment ocular protection. Vitamins C and E, zinc, and carotenoids such as lutein and zeaxanthin reduce oxidative stress within the retina, protecting against light-induced injury and age-related degeneration [35].

9.1.4. Natural and Pharmacological Enhancements

Novel approaches to photoprotection are emerging. Dietary polyphenols (e.g., green tea catechins, resveratrol) demonstrate anti-inflammatory and antioxidant properties in preclinical studies. Plant-derived agents such as forskolin have shown the ability to stimulate melanogenesis and reduce UVB-induced apoptosis in experimental models [36]. However, these interventions remain experimental and require validation in clinical trials.

9.2. Practical Recommendations for safe sunlight exposure

Sunlight is both a healer and a hazard. The challenge for clinicians and the public alike lies in striking the right balance—optimizing benefits while minimizing risks. Evidence-based guidance can help individuals integrate safe sun exposure into daily life.

9.2.1. Duration and Timing

Brief daily sun exposure (10–20 min on arms/legs) supports vitamin D synthesis while avoiding peak UV hours (10 a.m.–4 p.m.).

For most fair-skinned individuals, 10–30 minutes of sun exposure to face, arms, and legs, two to three times per week, is sufficient.

Individuals with darker skin may require longer exposure, while those with very light skin should reduce duration to avoid erythema [30].

9.2.2. Geographic and Seasonal Adjustments

People living above 35° latitude (e.g., Canada, Scandinavia) cannot synthesize adequate vitamin D during winter months due to solar zenith angle. In these cases, dietary intake or supplementation becomes necessary [4].

Residents in equatorial regions should avoid prolonged midday exposure and prioritize protective strategies, as year-round UV radiation is intense.

9.2.3. Protective Practices

Sunscreen should be applied after initial exposure (10–30 minutes) to balance vitamin D synthesis with skin protection. Broad-spectrum formulations with SPF ≥ 30 are preferred [22].

Protective clothing, wide-brimmed hats, and UV-blocking sunglasses reduce cumulative damage [21,23].

Children and infants require special caution, as their skin is more sensitive and vulnerable to long-term damage.

9.2.4. Lifestyle and Supplementation

Diets rich in vitamin D (e.g., fatty fish, cod liver oil, fortified dairy, egg yolk) help bridge seasonal gaps.

Supplements may be necessary for the elderly, indoor workers, or individuals with malabsorption syndromes. Clinical guidelines recommend tailoring dose to maintain serum 25(OH)D levels ≥ 50 nmol/L, with some experts suggesting 75 nmol/L as optimal [30].

Incorporating outdoor physical activity not only ensures sun exposure but also counters sedentary lifestyle risks [37].

Safe sunlight exposure is not a one-size-fits-all prescription. Recommendations must account for skin type, geography, season, and lifestyle. A balanced approach, brief, regular sun exposure supports vitamin D synthesis (while avoiding peak UV hours) supplemented by protective measures and dietary strategies, allows individuals to harness the benefits of sunlight without incurring its long-term harms.

Figure 1 compiles beneficial and harmful effects of sun exposure at a glance with key message. Table 1 summarizes how sunlight influences various human physiological systems through specific biochemical mediators. It outlines the effects, health impact, and recommended exposure strategies to balance benefits and minimize risks. Table 2 presents Safe Sun Exposure guidance and recommendations by different organizations worldwide.

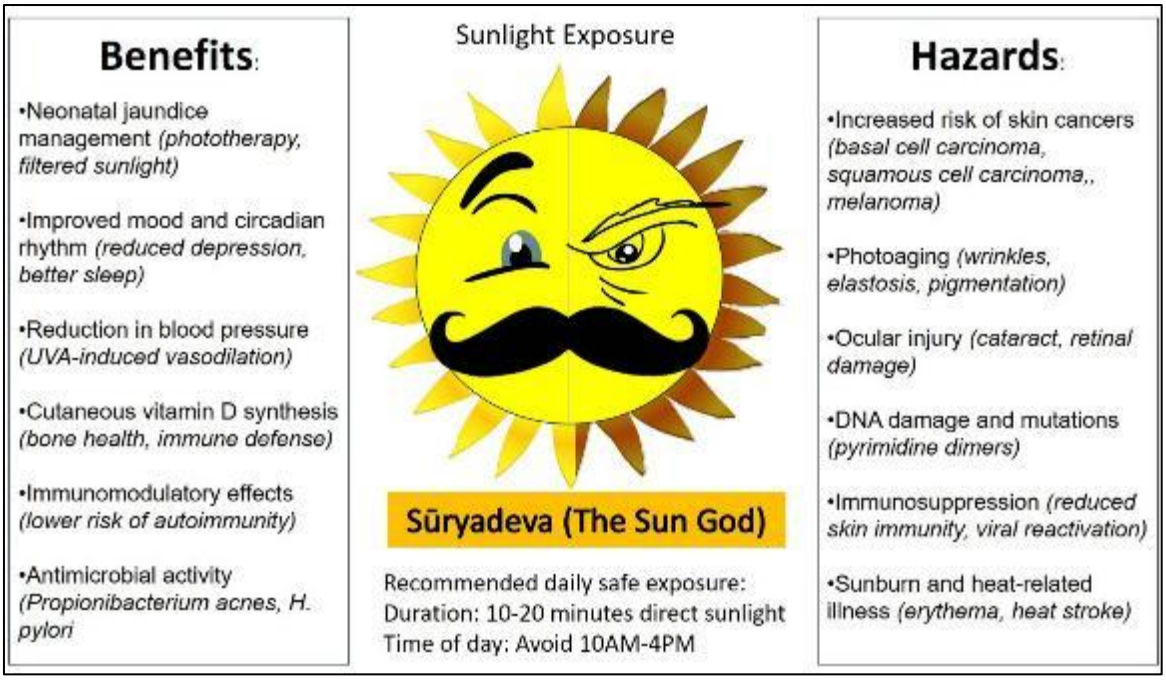

Figure 1 Benefits and Harms of Sun exposure

Table 1 How Sun Alters the Physics and Chemistry of the Human Body

Physiological System	Key Mediators	Physiological Effect	Health Impact	Exposure Guidance
Skin (Vitamin D synthesis)	7-dehydrocholesterol* → Vitamin D3† → Calcitriol ($1,25(OH)_2D$) ‡	Bone health, immune modulation	✅ Beneficial (if balanced)	Moderate sun exposure or supplementation when limited
Skin–Vascular	Nitric oxide (NO)• release via UVA	Vasodilation, blood pressure reduction	✅ Beneficial	Safe UVA exposure, avoid overexposure
Brain (Serotonin, Dopamine)	Serotonin, Dopamine, Limbic system receptors	Improved mood, cognition, reduced depression risk	✅ Beneficial	Morning light exposure for mood regulation
Brain (Melatonin–Pineal gland)	Melatonin (pineal gland), SCN ‖ regulation	Circadian rhythm regulation, improved sleep	✅ Beneficial	Daytime light exposure, avoid blue light at night
Immune System	Cytokines (IL-2, IL-10)⁇, T-cell modulation, antimicrobial peptides	Enhanced immune defense, tolerance	✅ Beneficial	Balanced exposure; avoid immunosuppression with chronic overexposure
Cardiovascular System	NO•, Renin-angiotensin system, seasonal variation	Lower blood pressure, reduced CVD risk	✅ Beneficial	Regular safe sun exposure; integrate with exercise

Eye (Retina, Ocular lens)	Rhodopsin, Melanopsin, retinal ganglion cells, lutein/zeaxanthin	Circadian entrainment, visual health, cataract/AMD risk	⚠️ Mixed (protection + harm from chronic exposure)	Use sunglasses, dietary antioxidants (lutein/zeaxanthin)
Skin (Melanin, tanning)	MC1R**, α-MSH††, melanin pigments	Skin tanning, UV protection	✅ Beneficial (adaptive)	Moderate tanning response protects but avoid sunburn
Skin (DNA, ROS damage)	DNA dimers, ROS, p53‡‡, tumor suppressor pathways	Photoaging, mutagenesis, skin cancers	❌ Harmful (if excessive/unprotected)	Use sunscreen, protective clothing, limit peak UV exposure

Footnotes: * 7-dehydrocholesterol is a skin-derived precursor that initiates vitamin D synthesis upon exposure to UVB radiation. † Vitamin D3 (cholecalciferol) is the inactive form of vitamin D produced in the skin, which is later converted into ‡ calcitriol ($1,25(OH)_2D$), the active hormone responsible for regulating calcium levels and immune function. • Nitric oxide (NO) is a vasodilator gas released from dermal stores via UVA exposure, contributing to blood pressure reduction. || SCN (Suprachiasmatic Nucleus) is the brain's master circadian clock, responsible for synchronizing sleep-wake cycles with light exposure. ⁷ IL-2 and IL-10 are immune cytokines; IL-2 promotes immune activation, while IL-10 facilitates immune tolerance. ** MC1R (Melanocortin-1 receptor) regulates melanin production and determines pigmentation response to UV exposure. †† α-MSH (Alpha-Melanocyte Stimulating Hormone) is a peptide hormone that stimulates melanin synthesis in skin cells. ‡‡ p53 is a tumor suppressor protein that plays a critical role in DNA repair and protection against UV-induced genetic damage.

Table 2 Safe sunlight Exposure Guidance

Source	**Recommendation**	**Applicable Region**	**Remarks**
US Environmental Protection Agency (EPA) – UV Index Scale [38]	Avoid direct sunlight between 10 a.m.–4 p.m. when UV index is moderate–high; seek shade.	USA, but UV Index is universal.	Clear governmental advice; widely adopted internationally.
Canadian Dermatology Association (CDA) [39]	Limit sun exposure between 11 a.m.–3 p.m.; use shade, clothing, sunscreen if outdoors.	Canada; applicable to temperate latitudes.	Consistent with WHO and other dermatology groups.
StatPearls (NCBI Bookshelf – Sunburn review) [40]	Avoid direct exposure during peak UV hours 10 a.m.–4 p.m. to prevent sunburn.	General/global.	Evidence-based clinical summary, used by physicians.
Harvard Health / American Academy of Dermatology [41]	"Short bursts" (about 10–20 min daily exposure on arms/legs) can help with vitamin D without much skin damage.	General/global.	Short frequent exposure better than long occasional.
Healthline (summarizing Endocrine/NIH data) [42]	Lighter skin: 10–15 min; darker skin: 25–40 min exposure for vitamin D synthesis.	Global, skin-type specific.	Popular but sourced from NIH & dermatology experts.
Indian Council of Medical Research (ICMR) / Indian studies [43,44]	For vitamin D synthesis, 11 a.m.–2 p.m. sunlight is most effective in Indian latitude.	India (tropics).	Maximizes vitamin D, but safety concerns (UV damage) remain.
British Skin Foundation [45]	Avoid overexposure; 5–30 min may be enough depending on skin and location.	UK/Europe.	Balanced view, but more conservative due to fairer-skinned populations.

10. Conclusion

Sunlight is more than illumination; it is a biological signal with far-reaching effects on human physiology. Its influence spans neonatal care, circadian regulation, mood, metabolism, cardiovascular health, dermatology, and vitamin D synthesis.

Yet, these benefits coexist with well-documented risks. Excessive or unprotected exposure accelerates photoaging, raises cancer risk, and contributes to ocular damage. At the same time, modern lifestyles and seasonal or geographic barriers leave many populations underexposed and deficient.

The path forward is balance. Modest, regular sun exposure, supported by protective measures and supplementation when required, allows us to harness its therapeutic value while avoiding long-term harm. To live well with the sun is to follow the middle path—embracing its benefits while respecting its risks.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest related to this work.

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