

The Impact of Regular Use of Sunscreen on Vitamin D Synthesis and Diabetes Risk Alongside Related Contributions of AI – A Narrative Review

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Abstract

The daily topical application of sunscreen is widely recommended to shield the skin against harmful ultraviolet radiation exposure and prevent skin cancer, particularly in diabetic patients, who are more prone to the dangers of skin complications such as skin hypersensitivity, sunburns, slow wound healing, and xerosis (dry skin). Due to sunscreen's role in blocking ultraviolet radiation, there is a potential rise in concerns about its impact on lowering vitamin D levels by interfering with its biosynthesis pathway. Vitamin D plays a crucial role in balancing glycemic levels in blood by promoting insulin production, cellular receptor sensitivity, and metabolism. Low vitamin D status has been closely linked to impairment of the islets of Langerhans, pancreatic beta cells, which is further attributed to lessened insulin secretions, amplifying the risk of developing diabetes; sparking controversy over whether daily usage of sunscreen is a potential causative factor of the metabolic imbalance. Meanwhile, artificial intelligence (AI) is emerging as a powerful health research tool with advanced methods for analyzing sophisticated datasets and identifying patterns in health status parameters such as vitamin D levels, regular sunscreen use, and diabetes risk. This review article thoroughly explores the connection between excessive ultraviolet B (UVB) sun radiation protection, vitamin D biosynthesis, and associated diabetes risk. Additionally, it also offers recommendations, insights on the progress of AI technology, and promising novel approaches as solutions to achieve healthy UVB radiation exposure without disrupting the vitamin D synthesis pathway, which is further related to heightened diabetes risk.

Keywords: diabetes, vitamin D, sunscreen, ultraviolet B radiation, artificial intelligence

Abbreviations: DM: diabetes mellitus; UVB: ultraviolet B; T1DM: type 1 diabetes mellitus; T2DM: type 2 diabetes mellitus; GDM: gestational diabetes mellitus; AI: artificial intelligence; ML: machine learning; VDR: vitamin D

receptor; RXRs: retinoid X receptors; VDREs: vitamin D response elements; ROS: reactive oxygen species; IL-6: interleukin-6; IL-17: interleukin-17; TNF- α : tumor necrosis factor-alpha; RAS: renin angiotensin system; IRS-1: insulin receptor substrate-1; GLUT4: glucose transporter 4; AVP: arginine vasopressin; SPF: sun protection factor; BMI: body mass index; ADAM: adaptive moment estimation; SVMs: support vector machines; GLM: generalized linear model

Introduction

Diabetes is a group of chronic disorders characterized by the body's inability to regulate essential physiological processes, resulting in hormonal dysfunction and metabolic imbalance, with diabetes mellitus (DM) being the most prominent irreversible long-term metabolic disorder suffered for a lifetime marked by abnormalities in insulin production or insulin function. In some cases, patients experience both [1]. Insulin is responsible for the cellular uptake and conversion of glucose from ingested materials into energy [2]. A growing body of research highlights that vitamin D deficiency plays a role in onset or progression of different subtypes of diabetes [3] such as autoimmune destruction of insulin synthesizing pancreatic islets of Langerhans beta cells referred to as type 1 diabetes mellitus (T1DM) [4], the cellular inability to utilize produced insulin also known as type 2 diabetes mellitus (T2DM), and gestational diabetes mellitus (GDM) which is inability of the body to use insulin during pregnancy due to placental produced hormones [5]. Vitamin D (calciferol) has gained attention due to its critical involvement in insulin biosynthesis, glucose utilization, and inflammation regulation [6, 7]. Low levels of vitamin D in the body can also be caused by insufficient vitamin D intake, decreased gastrointestinal absorption, and disrupted cutaneous production [8]. Vitamin D is primarily synthesized in the skin, particularly under exposure to ultraviolet B (UVB) radiation from sunlight. However, the widespread of topical sunscreen products [9] applied to protect the skin from sunburn, prevent premature aging, and skin cancer [10, 11], the literature points out some of the widely used ingredients to formulate sunscreens such as octocrylene, titanium dioxide (TiO₂), and octinoxate association with blocking UVB penetration, which further contributes to a deliberate decrease in vitamin D synthesis. As a result, excessive application of these agents, especially in tropical regions of the world where daily sunscreen use is a necessity, has been speculated to potentially influence the onset or progression of diabetes [12]. Despite these concerns, the line connecting the relationship between sunscreen usage, vitamin D levels, and susceptibility to diabetes remains blurred with multiple contradictions. While a number of published studies show a significant correlation, other literature indicates that dietary sources, vitamin D supplementation, and incidental sun exposure may compensate for this effect [13]. The interdependence of distinct aspects such as genetic predisposition [14], skin pigmentation, aging, geographic location, and lifestyle habits [15] adds further complexity to conclude the actual impact of sunscreen on metabolic health [16]. At the same time, there is a rapid advancement in healthcare that involves the correlation of multiple risk factors for early diagnosis and detection of diseases, followed by the prediction of personalized intervention plans with the aid of artificial intelligence (AI) [17, 18]. With prevalence of DM new cases, aggravating diabetes complications, and heavy economic burden [19], AI-powered predictive tools and machine learning (ML) are progressive means under development with expectations of high precision and accuracy in analyzing a wide range of datasets in investigation of the influence of sunblock on vitamin D and identification of individuals at higher risks of developing vitamin D deficiency-related diabetes while simultaneously establishing proactive approaches against the global epidemic of DM [20]. These technologies hold significant importance in the development of personalized sun protection products and devices that could balance the necessity of skin protection and the availability of adequate vitamin D levels [21]. Given the conflicting evidence on sunscreen usage in relation to vitamin D synthesis and associated diabetes risk, it is crucial to develop effective sun protection solutions, especially for persons with high susceptibility to diabetes or already managing the condition [22]. Currently, AI-driven approaches are under development of platforms that offers tailored implications to be integrated in endocrinology, cosmetic dermatology, and public health [23], for regulation of optimal sun exposure, sunscreen use, and vitamin D balance by taking into account multiple factors such as an individual's skin type, lifestyle, geographical location, and health status [24]. This will aid healthcare professionals to make conscious decisions based on data-driven research findings regarding sun protection without compromising patients' vitamin D status, especially for individuals at higher risk of the onset of diabetes or its complications [25, 26]. This

review explores the intricate relationship between the influence of topical sunscreen use on vitamin D biosynthesis and the associated diabetes risk of different subtypes. Additionally, it also provides insights into interventions on the basis of holistic recommendations, product development approaches, and current technology advancements.

Materials and Methods

This article is based on its perspective from comprehensive literature reviews drawn from peer-reviewed scientific journals with academic papers in English with no time constraints across a wide range of knowledge sourced from reputable databases such as Medline (via PubMed), Scopus, and EMBASE. The publications were screened thoroughly based on their title, abstract, and conclusion, followed by full text analysis. The literature search conducted focused on keywords such as “Vitamin D”, “Diabetes”, “Sunscreen”, and “Artificial intelligence”. Articles highlighting the association between sunscreen use, vitamin D deficiency, matched diabetes risk, alongside contradicting views and contributions of AI to put an end to the controversy regarding the topic were also addressed.

Vitamin D Deficiency, a Contributing Factor in Different Forms of Diabetes

Vitamin D is a pro-hormone that undergoes 2 different successive enzymatic hydroxylation to form calcidiol in the liver and the biologically active form calcitriol in the kidneys, respectively. The originating dietary plant source of vitamin D is vitamin D₂ (ergocalciferol), mostly found in mushrooms. When our skins are exposed to UVB radiation of the sun, vitamin D₃ (cholecalciferol) is synthesized at the cutaneous level of our skin after its precursor 7-dehydrocholesterol has been converted into pre-vitamin D₃ alongside 7-dehydrocholesterol as inactive by-products. Cholecalciferol moves through systemic circulation to the liver, where it is converted into calcidiol (25-hydroxyvitamin D (25(OH)D)) by enzyme 25-hydroxylase (CYP2R1), re-enters the bloodstream to the kidneys. Subsequently, under the influence of enzyme 1- α -hydroxylase (CYP27B1), calcidiol becomes the active form calcitriol (1,25 dihydroxyvitamin D (1,25(OH)₂ D) [27]. Then, the active form binds the vitamin D receptor (VDR) to form a complex VDR-calcitriol complex that interacts with retinoid X receptors (RXRs) to form a transcription factor that regulates different metabolic pathways. After that, the complex is translocated to the nucleus in the insulin gene promoter, where it binds to vitamin D response elements (VDREs), enhancing insulin gene transcription. Particularly, supporting pancreatic beta cells' function but also decreasing hepatic insulin resistance, onset of glucose uptake by adipose tissue and skeletal muscles, while establishing a balanced, healthy glycemic level in the blood. The pancreatic beta cells' VDRs activation leads to depolarization of membranes due to cellular calcium ions. This results in insulin-containing vesicles being fused with plasma, followed by exocytosis that promotes the release of the insulin hormone [28]. Beyond insulin hormone synthesis, VDRs signaling supports cellular glucose uptake and improves insulin cellular responsiveness in the liver, adipose tissue, and the muscular system. Hence, any factor that disturbs the pathway involving insulin secretion or usage by the cells can increase the risk of developing diabetes [29]. In T1DM, an autoimmune disorder characterized by immune-mediated destruction of pancreatic insulin-producing beta cells, VDRs in immune cells are activated to regulate immune response; thus, reducing autoimmunity and inflammation [30]. According to the Endocrine Society, 25-hydroxyvitamin D (25(OH)D) below 20 ng/ml is an indicator of vitamin D deficiency [31], a determinant in lowered insulin output [32]. This deficiency is also closely associated with oxidative stress that plays a pivotal role in the pathogenesis of onset and progressive T1DM by impairing insulin signaling and pancreatic β -cells function [33]. Conversely, the availability of vitamin D support homeostasis of glucose [34], reactive oxygen species (ROS), and lipid metabolism by diminishing insulin resistance, and eliciting anti-inflammatory activity against pro-inflammatory cytokines such as interleukin-6 (IL-6), interleukin-17 (IL-17), and tumor necrosis factor- α (TNF- α), which are known to impair insulin signaling pathways and damage insulin beta cells production and distribution process [35], posing as a potential risk factor for developing either of the both types of DM. Vitamin D also activates autoreactive T cells that suppress autoimmune responses, whereas deficiency provokes unchecked immune attacks on beta cells. Low vitamin D levels due to regular sunscreen use have been associated with increased renin production, causing elevated blood pressure and an overactive renin angiotensin system (RAS) responsible for damaging pancreatic beta cells due to vasoconstriction, which can heighten the risk of the onset of T1DM or the manifestation of progressive complications [36]. T2DM is primarily characterized

by insulin resistance. In existing literature, vitamin D homeostatic control of calcium often overshadows the exploration of its connection with chronic metabolic disorders; however, it was found that insufficient vitamin D may predispose individuals to insulin resistance, which can further progress into obesity and T2DM [37]. In muscular cells, vitamin D enhances insulin receptor substrate-1 (IRS-1), followed by translocation of glucose transporter 4 (GLUT4), ensuring uninterrupted insulin signaling, regulating intracellular calcium homeostasis. Vitamin D also protects beta cells from apoptosis with its antioxidant properties [38]. However, regular use of sunscreen can alter the amount of cutaneous vitamin D to a minimum, raising T2DM risk. Diabetes insipidus is a metabolic disorder that involves the kidneys' inability to retain water, marked by excessive thirst and urination, primarily resulting from inadequate release or cellular responsiveness to arginine vasopressin (AVP), which is known as antidiuretic hormone. Vitamin D deficiency amplified by limited UVB exposure due to sunscreen use contributes to the elevated risk of susceptibility to diabetes insipidus due to its role in supporting the expression of aquaporin channels in the kidneys that modulate local inflammatory responses; thus, altering urine concentration. On other hand, elevated vitamin D levels are also associated with increased calcium absorption from the gut leading to hypercalcemia, which directly impairs the kidney's ability to respond to AVP making the collecting ducts become less permeable to water and diluting urine production (polyuria) which serve as symptomatic marker of diabetes insipidus [39]. Apart from regular use of sunscreens, pregnant women are advised to limit sun exposure to prevent hyperpigmentation (melasma) and overheating, which further escalates the risk of vitamin D deficiency. Placental hormone fluctuations are responsible for increased insulin resistance in GDM. Vitamin D deficiency is involved in reduced insulin cellular responsiveness, elevated susceptibility to inflammation, and impaired glucose intolerance, which often progress into GDM or its associated manifestations such as fetal macrosomia, preeclampsia, and preterm birth. During pregnancy, pancreatic beta cells of the mother supported by availability of vitamin D suppress pro-inflammatory cytokines from attacking the fetus as a usual body's defence mechanism against foreign bodies and support workload adjustments due to fetus implantation by producing necessary amounts of insulin required to accommodate and balance the glycemic levels of the mother and her child [40]. Moreover, in vitamin D-deficient mothers, pregnancy naturally activates the RAS, and research shows an increased risk of insulin resistance in their infants. However, the availability of vitamin D counteracts this effect by suppressing renin production, regulating blood pressure, and eliciting anti-inflammatory activity, thus reducing the risk of GDM and postpartum GDM [41].

Topical Sunscreens Role in Vitamin D Deficiency and the Promising Progress of AI-Driven Technologies Application

Globally, there are concerns regarding elevated ultraviolet rays' transmission due to ozone layer depletion. This layer manages to absorb a minimum amount of UVA, 90% of UVB, and 100% of UVC. A sunscreen is a topically applied formulation that protects the skin from premature aging, sunburn, and skin cancer by reflecting, absorbing, or scattering harmful ultraviolet radiation from the sun. Daily sunscreen application is mandatory, especially in tropical parts of the world. They are commercially sold on the market in different forms such as gels, sprays, creams, wipes, sticks, powders, oils, or creams; based on users' preference, skin types, or method of application [42]. Chemical sunscreens mainly contain UV filters that absorb UV radiation and later convert it into heat, such as oxybenzone, octocrylene, and avobenzone. On the other hand, mineral (physical) sunscreen contains UV filtering agents that reflect and scatter UV radiation from the skin, for instance: titanium dioxide, zinc oxide, and talc [43, 44]. The sun protection factor (SPF) is a measuring ratio of sunscreen's efficiency that correlates with how long it takes after applying the sunscreen to develop redness relative to unprotected skin. Therefore, modern broad-spectrum sunscreens are designed by combining different agents to cover a wide range of UVA and UVB radiations [45]. Despite their effectiveness in protecting against sunburn, dryness, and skin cancer, they also block, reflect, or scatter UVB radiation, which is essential in the vitamin D biosynthesis pathway as discussed previously. Amongst the common highlighted sunscreen ingredients that have been reported to interrupt the vitamin D synthesis pathway and are closely associated with toxicity include octocrylene, titanium dioxide, cinnamates, and benzophenone derivatives [46]. As a scenario, based on the in-silico technique including molecular mechanics Poisson-Boltzmann Surface Area (MM-PBSA) calculations, molecular dynamics, and molecular docking, it was found that octocrylene competitively binds stronger than calcitriol

(active form of vitamin D) to key proteins such as vitamin D receptor (1DB1), vitamin D binding protein (1KXP), and CYP2R1 enzyme. It was further confirmed by stability assessment methods that this binding produces a stable complex that interferes with the normal vitamin D metabolism [47], which can serve as a factor in the development of diabetes. Besides that, due to safety concerns, the Marshall Islands, Hawaii, and Palau have already banned octocrylene-containing sunscreens. Considering around 1 billion people across the globe who are diagnosed vitamin D deficient and the fact that octocrylene possesses high gut absorption, ability to inhibit multiple cytochrome P450 enzymes, and to cross blood brain barrier [48], concerns have been raised against its systematic effects in association with DM risk, metabolic disruption, and bone health related issues. With diurnal monitoring of vitamin D levels, necessary adaptation can be done by considering dietary consumption of vitamin D-rich food and regulated unprotected sun exposure (10–30 mins, especially in early morning) [49]. Vitamin D supplements are prescribed in deficiency marked individuals, especially DM patients, while supplementation in pregnant women is effective in improving glycemic control in the prognosis of GDM and reducing the occurrence of adverse pregnancy outcomes [50]. Sunscreen users are recommended to choose formulations with high UVA protection and selective UVB filtering, as they allow better UVB transmission and possess no interference in the vitamin D production process. Moving ahead, sunscreen formulation development should be vitamin D-friendly, for instance, using selective UVB filtering and allowing UVB penetration or vitamin D-enriched sunscreens containing precursors that can be absorbed through the skin, complementing the Vitamin D synthesis process [51]. The integration of AI in healthcare poses an incremental improvement in risk assessment to identify, analyze, and evaluate potential factors responsible for causing diseases with a high degree of accuracy and scalability in comparison with traditional methods. Therefore, it serves as an effective promising tool to spotlight the pattern in the dynamicity of sunscreen use, vitamin D deficiency, and diabetes risk prediction. Additionally, AI supports the provision of elaborate early prevention plans, management, and treatment approaches for the diseases. AI models are computational systems and techniques developed to simulate, extend, and expand human intelligence in machines to process and analyze large amounts of data by assisting in tasks such as decision making, risk prediction, classification, and pattern recognition. ML models have been integrated with limited success at various stages of diabetes care, including identification of diabetes risk factors alongside early prediction of diabetes, accurate classification of diabetes subtypes, and real-time glucose monitoring with predictive algorithms [52]. However, they are still under improvement. Using XGBoost ML-based prediction model with input factors such as age (years), body mass index (BMI) (kg/m^2), smoking status, income level, and diabetes history to assess an individual's risk with provision of community accessible online web-based calculator, high vitamin D-risk deficiency groups were identified, enabling implementation of early intervention and preventive measures [53]. In another case study, a ML shallow neural network on the basis of clinical data such as gender (coded numerically: 1= male and 2= female), weight (kg), and triglycerides level (mg/dl) drawn from NHANES, MIMIC-III, and MIMIC-IV achieved 86.2% of predictive performance in predicting T2DM but the input factors were found to be less influential while the adaptive moment estimation (ADAM) optimizer model yielded the best result increasing its probability with prediction reliability in DM care [54]. Researchers believe that the combination of AI models (decision trees and deep learning) and digital biosensor technologies is a revolutionary path in screening, diagnosis, and management of T2DM, particularly by detecting early signs of diabetes and predicting its associated complications. However, it was concluded that despite the rapid advancement, these tools were not yet ready to replace traditional clinical methods [55]. Supervised learning algorithms, specifically support vector machines (SVMs), can handle complex high-dimensional data in the identification of subtle patterns with a substantially varying accuracy depending on the population [56]. In addition, when conflicted with right approach in selecting appropriate and timely vitamin D replenishment strategies for population at high-risk, clinicians are advised to utilize online calculator which use AI regression model (generalized linear model (GLM)) to predict how quick the patient will reach sufficient vitamin D levels on a specific supplementation regimen on the basis of their individual clinical characteristics such as initial vitamin D status, endocrine therapy status, and adopted vitamin D replacement regimen [57]. In non-overweight subjects, it was found that vitamin D supplementation not only reduces the diabetes risk but also supports the reversal rate of subclinical diabetes to euglycemia [58]. These tools emerge as compelling innovative solutions to improve by surpassing their limitations with better optimisation for the clinical intervention in terms of diabetes screening, therapeutic approaches, and prophylactic strategies [59], along with predicting the most effective patient's tailored plan for vitamin D

replenishment. Subsequently, the breakthrough of embedding AI in wearable device to track sun exposure frequency, vitamin D levels fluctuations, and monitoring blood glycemic levels, while recording significant trends of individual's health status parameters as input data for complex AI powered algorithmic health platforms is forecasted to recommend tailored remedy based on required needs to achieve optimum metabolic balance such as customized sun exposure duration, dietary intake adjustments, and preferred vitamin D supplement (Table 1).

Publication	AI model	Advantage	Limitation
1. Artificial intelligence-aided low cost and flexible graphene oxide-based paper sensor for ultraviolet and sunlight monitoring [60].	An artificial neural network that relates color intensity variations of graphene oxide-based paper sensor due to sunlight exposure and classifies ultraviolet radiation exposure level on the basis of grayscale.	Offline compatible mobile integrated for sun exposure tracking app, supported data storage, accurate quantification of exposure dose with both visual and AI-driven digital monitoring.	Inability to exclude interference of temperature variation due to other factors, other than sunlight exposure, which can be a source of biased outcomes influencing the method's overall reliability.
2. Machine learning approach for the detection of vitamin D level: a comparative study [61].	Random forest, support vector machine, elastic net ordinal regression, and ordinal logistic regression.	With the aid of recorded clinical data and AI models comparison, the random forest model was the most accurate, resistant to multicollinearity, and non-invasive method in the determination of vitamin D concentrations.	It is dependent on high-quality data, expensive, time-consuming, and clinicians still face challenges in interpreting some of the model's clinical predictions, and it is only applicable with a small sample size.
3. A scoping review of artificial intelligence-based methods for diabetes risk prediction [62].	Unimodal ML models (such as Hidden Markov models and decision trees), deep learning (probabilistic and convolutional neural networks), alongside a multimodal approach.	Multimodal AI models integrated with e-health records, imaging, and genomic data demonstrated high performance in T2DM diabetes risk prediction and pattern recognition.	There was limited use of multimodal studies due to dependence on unimodal applications, data imbalance, alongside demographic bias, and reduced performance with the rise in prediction horizon.
4. Toward transparent diabetes prediction: combining AutoML and explainable AI for improved clinical insights [63].	Stacked ensemble automated ML (LightGBM, CatBoost, and neural networks) with an explainable AI integrated approach like integrated gradients (IG).	Took into consideration the diabetes genetic risk score and the model provided clear predictions up to the patient level about the risk of developing diabetes; thus, supporting early interventions.	It was effective as a risk assessment predictive model for diabetes rather than a clinically significant diagnostic tool. Its application also demonstrated misclassification errors.
5. Machine learning-driven prediction of vitamin D deficiency severity with hybrid optimization [64].	Combination of improved Whale Optimization Algorithm and stacking classifier (including gradient boosting machine, k-nearest neighbors, and logistic regression).	Blood sample collection was not required, supporting the determination of vitamin D deficiency, severity, and compatibility between multiple models, enhancing prediction validity.	Complex integration trial into clinical practice, alongside bias due to its specific region-oriented basis (India), self-reported data, and inaccuracy in data inputs that can alter prediction outcomes.

Table 1: Additional recent relevant literature on the application of AI models in diabetes risk assessment, ultraviolet radiation monitoring, and vitamin D deficiency, along with the AI upper hand and limitations [60–64].

Discussion

Although research progress in the existing studies remains minimal regarding the connection between the impact of regular sunscreen use on vitamin D deficiency and associated diabetes risk. Most researchers took into consideration a single or two aspects of the issue, hence leaving room for further research. Therefore, it is challenging to draw a conclusion on whether sunscreen's mechanism of UVB radiation absorption, scattering, or reflection poses a threat by blocking UV wavelengths essential in vitamin D synthesis and its anticipated contribution to elevated diabetes risk. On the other hand, there is a substantial body of research that considers vitamin D as a novel therapeutic target for the treatment of T2DM [65–67]. Controversial, evidence from specific studies suggests that factors such as incomplete sunscreen coverage, dietary intake, and brief outdoor activities are enough to sustain the daily required vitamin D levels despite the use of sunscreens. Therefore, dismissing the necessity of precautions while concluding the risk to be low or negligible [68]. With the help of observational studies and randomized control trials, it was found that there is a connection between vitamin D deficiency and GDM. It was highlighted that vitamin D (combined with probiotics, calcium, magnesium, and omega-3s) supplementation can improve glucose metabolism and lower the risk or severity of GDM [69]. Despite the previously discussed tremendous benefits of AI, it still faces challenges such as AI black box, which is the generation of predictions, forecasts, and conclusions with unclear origin and failure to disclose the reasons behind them. This hinders its acceptance in medical care due to unreliability and lack of transparency; to be fully trusted by healthcare professionals with its recommendations, especially in chronic conditions like diabetes, where a single misdirection can cost a human life. Furthermore, AI methods' hyper-dependence on clinical data poses a challenge in obtaining complete, faultless, and standardized datasets, but also highlights the need for privacy, confidentiality, and data security. Besides, human understanding is crucial in using AI to its maximum potential with creativity to establish conclusions on multifaceted concerns with multifactorial risk. Therefore, there is a need for progress in research that involves the improvement of AI-driven advanced models with the capability to accommodate diverse and high-quality data sources while simultaneously adapting to emerging new insights with minimum biases [70]. Despite the addressed constraints and limitations, AI remains a powerful, promising, transformative mode in need of growth to allow us to foresee the onset or progressive diabetes risks by taking into consideration factors such as the effect of sunscreen use on a regular basis and vitamin D deficiency.

Conclusion

Taking into account the highlighted numerous active sunscreen ingredients banned in different countries for safety reasons; given conflicting evidences and the promising breakthrough in research, there is a hope that with swift progress in AI technology; the upcoming research will reach to the final argument regarding the role of regular use of sunscreen in vitamin D deficiency and associated metabolic imbalances that manifest as different types of diabetes or their complications. This study also provided some insights as a contribution to the better understanding of vitamin D's role in glucose homeostasis, which is underexplored currently in existing clinical research. Furthermore, there is a need for the development of novel topical products or devices that possess no interference in the vitamin D synthesis pathway with maximum sun protection effect. In addition, leveraging AI and further research is a path forward that will support healthcare professionals to make more conscious decisions that are data-driven regarding sunscreen use, vitamin D balance, and diabetes risk prediction in the future.

Ethics Statement

This study did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Authors Contributions

Akimana C (Principal author): preparation, conceptualization, and designing of the manuscript framework, whereas Wikantyasning ER (Corresponding author): proofread and reviewed the manuscript. Finally, all authors had approved the manuscript for publication.

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Conflicts of Interest

The author(s) do not have any conflict of interest.

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