21 The Paleolithic Nutrition Model in Relation to Ultraviolet Light and Vitamin D

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Abstract

The biology of every species has been optimized for life in the environment in which that species evolved. Humans originated in the tropics, and while some natural selection took place in response to behaviors and environments that decreased exposure to ultraviolet light, there has never been a species-wide biological accommodation. Paleolithic nutrition advocates argue that risk of disease is higher because modern diets differ from what was consumed by early humans. Early humans were the naked ape living in the tropics, exposed to high levels of ultraviolet light and vitamin D nutrition (serum 25-hydroxyvitamin D; 25(OH)D) averaging 115 nmol/L, as compared to today's population averages that are well below 70 nmol/L. Natural selection from an available gene pool cannot compensate fully to an environmental change away from the one within which the species originally evolved. Vitamin D nutrition remains a contentious area. The epidemiological evidence consistently relates lower 25 (OH)D to higher disease risk. However, evidence from double-blind clinical trials looking at preventing new disease in healthy volunteers has been disappointing. But such negative trials have been the case for all nutrients except for folic acid which lowers risk of spina bifida. The Paleolithic nutrition model is based on fundamental biological concepts, but it has overlooked the environmental effects of ultraviolet light and vitamin D nutrition. This paper presents evolutionary and Paleolithic aspects of ultraviolet light and vitamin D with the aim to support pertinent research and, ultimately, public policy regarding nutrition and light exposure.

Keywords

Ultraviolet light · UVB · Vitamin D · 25-Hydroxyvitamin D · Paleolithic nutrition · Evolution · Natural selection · Skin color · Disease risk · Health policy · Sun protection · Anthropology

Introduction

Recent years have seen multiple debates as to what dietary policy should target in terms of circulating levels of 25-hydroxyvitamin D (25 (OH)D) [5, 46]. Dietary guidelines follow risk-benefit profiles, but they mainly focus on risk. The starting point for nutrition policy makers are intakes and levels of nutrient that are typical of people who are regarded as generally healthy. Any upward change to nutrition or sun protection

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policy requires the highest level of evidence, and that is defined as double-blind, placebo-controlled clinical trials [5, 7, 25]. However, "evidence-based medicine" does not mean that the only meaningful evidence is the pharmaceutical-licensing model of double-blind, placebo-controlled clinical trials [38]. Evidence encompasses a breadth of sources, from the bottom of the evidence pyramid upward.

The purpose of this article is to present a biologically based perspective. In the present analysis, the starting point is not what levels of vitamin D nutrition or sun exposure activity is typical among healthy members of modern societies. Instead, my contention here is that the thinking about the optimal ranges for serum 25 (OH)D and for sun exposure should start from what these were for the first humans.

The evolutionary perspective is rarely presented in medical curricula, yet it offers significant insights into understanding health and disease [19]. There have been perspectives published about the Paleolithic diet [13, 26, 50]. Recent epidemiological investigations show that Paleolithic or Mediterranean diet patterns are indeed associated beneficially with all-cause and cause-specific mortality in the United States [50]. However, I am not aware of any mention in the literature on Paleolithic nutrition, about the role of vitamin D or of ultraviolet light exposure. This would appear to be a major oversight, since biologically modern *Homo sapiens* first appeared in the horn of Africa, where exposure of skin ultraviolet light with its endocrine effects should be obvious issues that need to be addressed in the context of both understanding disease and optimizing human health.

The sun exposure experienced by the original humans should be regarded at as optimal because it was the environment for which the genome of the human species was selected, to result in what is now, its modern biological form. Therefore, it is logical that consideration should be given to reversing the traditional way that policy groups approach nutritional adequacy. Traditionally, the question is: "What is the minimal amount of nutrient needed to prevent disease?" Instead, it appropriate to ask, "At what point does human health suffer from progressively diminishing exposure to sunshine and vitamin D?". This is because the historic progression of these things has gone from abundance in the past, to the minimal levels of vitamin D and sunshine now regarded suitable for sustaining health.

Adaptation

Like all primates, humans are a species whose biology is best suited to inhabit tropical latitudes. The fitness of a species to its environment can be achieved through adaptation, or evolution. Fleagle explains that the nongenetic process of adaptation to environmental change is a characteristic that allows an organism to live and reproduce in an environment where it probably could not otherwise exist. Such adaptation can be achieved through processes other than natural selection. For example, *Homo sapiens* have adapted to environments through cultural and technological means such as clothing, shelter, heating, or air-conditioning. In contrast, natural selection is the process, whereby heritable features, be the anatomical or behavioral, that enhance the fitness of an organism relative to its peers, will increase in frequency in the population in succeeding generations [15]. Adaptation to diminishing vitamin D nutrition and sunshine happened because of human intelligence. But for present-day populations that are native to the tropics, their biology has certainly not adapted to less vitamin D and sunshine than what their ancestors experienced.

Natural Selection

Genetic variation develops in species because of the accumulation of random imperfections that occur during the replication of genes. Those imperfections are due to chemicals, radiation, or copying error. The overall assembly of genes within a species is referred to as a gene pool. Distinct differences in any specific gene from among individuals are referred to as alleles. Alleles may or may not alter the protein encoded by a gene. But as the number of alleles proliferates, the gene pool expands so that there is potential for some alleles of certain genes to provide certain individuals in a species with specific survival advantage (fitness) over other individuals who do not possess those alleles on their genes.

Natural selection is the process by which those individuals of a species, who possess genes that confer greater fitness of those individuals to their environment. "Fitness," in the context of natural selection, pertains to the ability to produce more offspring that are viable to the extent that they will give birth to offspring of their own. Natural selection increases the proportion of a population that exhibits a genetic makeup more fit for an environment.

The means by which the skin color of human populations became lighter as humans migrated away from the tropics involved only one final aspect of evolution: natural selection. There was no evolution in the complete sense of the word. A gene pool existed among those persons migrating out of Africa tens of millennia ago, from which genes could be selected that maximized the ability to give birth and to grow healthy offspring. The vitamin D hypothesis is a widely accepted mechanism driving natural selection for lighter skin color in persons migrating away from the tropics [22, 23].

The purpose of this paper is not to debate skin color or evolution, but rather to use their principles to address the question: What level of sun exposure and/or vitamin D nutritional status (serum 25-hydroxyvitamin D; 25(OH)D) should be regarded as optimal for human life?

In this broader context of what is optimal for all aspects of health, one needs to incorporate factors that have little to do with the traditional sense of fitness in the evolutionary sense. Evolutionary fitness relates simply to maximization of the production of healthy babies [45]. What modern medicine regards as optimal extends to other aspects of life, such as prevention of osteoporosis, cancer, heart disease, and immune disorders. These latter items are not traditional aspects of biology that would confer "fitness" to a species, because they pertain largely to the phase of life beyond the reproductive years. Cross-sectionally, there is abundant evidence that higher sunshine exposure and/or higher 25(OH)D lower mortality due to many diseases [8]. These beneficial relationships remain an undeniable fact, regardless of those who would dismiss the epidemiologically demonstrable beneficial relationships with 25(OH)D to lifestyle factors, or who would dismiss benefits for sun exposure based on perceived risks due to skin cancer. The relationships have to be due to one or the other or both sun and vitamin D. The health-policy questions remain: Exactly how much vitamin D and/or how much sun exposure should we be aiming for, to optimize health for the population? And should that advice be different for Blacks versus Whites?

It has long been known that despite technological progress, human populations have seen progressive declines in serum 25(OH)D levels over the millennia (Fig. 21.1) [43]. Those older data on serum 25(OH)D have been confirmed in recent years; however, now there is the important new observation that deeply pigmented skin does not prevent the attainment of the same high 25(OH)D levels attainable in Whites [12, 31, 32]. Our best characterization of the nature of sun exposure and, hence, vitamin D nutritional status comes from those small and hard-to-access populations in the tropics whose lives and culture approximates those of the earliest humans. Luxwolda et al. reported serum 25(OH)D in five East African traditional-living ethnic groups across the life cycle: Maasai, Hadzabe, Same Sengerema, and Ukerewe [31, 32] (Fig. 21.2). What is notable are the lower serum 25(OH)D levels of urbanized Africans living in Africa compared to the Africans living a traditional culture. Those urban African levels are a match to the 25(OH)D of Canadians who are of European ancestry. That is, the 25(OH)D levels of White and Black people are the same for urban populations if they live at the latitude of their ancestors. However, once those of African ancestry move north, to Canada, most of them have serum 25(OH)D levels that are lower than 40 nmol/L. At 40 nmol/L, half the population is deemed to possess levels that are not sufficient for sustaining the bone

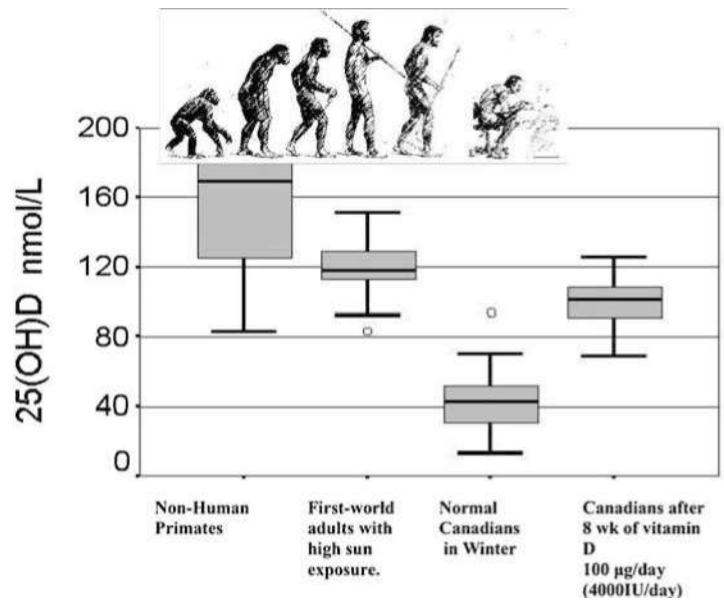

Fig. 21.1 Evolutionary perspective of circulating vitamin D nutritional status boxes show quartile values for 25(OH)D of the groups represented here, whiskers show the extreme, non-outlier values. Primary references to these images have been published previously [43, 44]

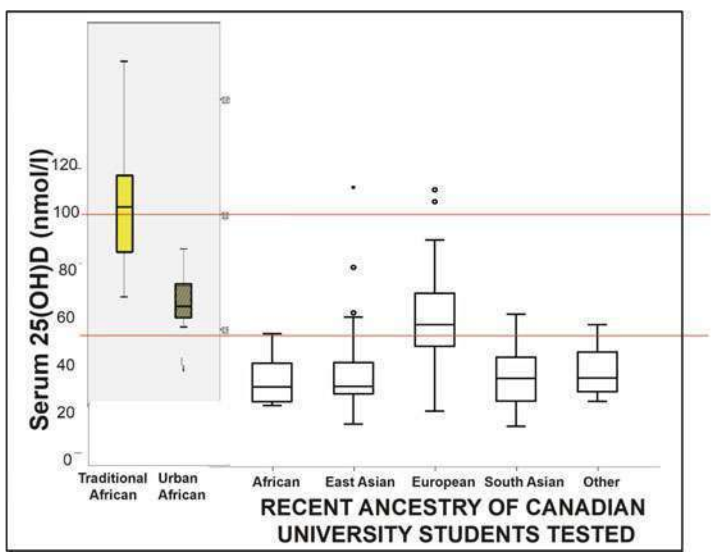

Fig. 21.2 The effect of culture, environment, and ancestry on serum 25(OH)D concentrations These results are compiled from publications that shared similar LC/MS methodology. The figure consist of boxplots which each shows the group's median boxed by the inter-quartile range, and the whiskers that show the highest and lowest values that were not outliers. To the left are data from Luxwolda et al., showing values from tropical Africa, both for Masai, who lived a traditional, pastoral lifestyle, and Bantu, who lived a modern urban lifestyle [31, 32]. To the right are data from two sample sets collected from separate cohorts of Canadian students at the University of Toronto during Winter 2007 [17] and at George Brown College during February 2012 [1]. Note the progressive decline in the African ancestry group, as they shift away from the more traditional culture and environment

health criteria advocated by the Institutes of Medicine [21].

Samples derived from pregnant and lactating women were included. The most striking observation was that despite no supplemental vitamin D, the serum 25(OH)D levels went up during the second and third trimesters of pregnancy, at which point they averaged 150 nmol/L [32]. A smaller but similar rise in serum 25(OH)D that was seen in the traditional-living African ethnic groups was also seen in urban-living African women through pregnancy in women not receiving vitamin D supplement during pregnancy [24]. This natural increase in serum 25 (OH)D during pregnancy coincides with the pregnancy-related increase in vitamin D-binding protein [6]. If total 25(OH)D levels do not increase during pregnancy, then higher concentration of serum-binding protein will result in lower concentrations of the more tissue-accessible, free 25(OH)D. In African women living in their tropical environment, without a vitamin D supplement, the sharp increase in serum 25 (OH)D far exceeds the serum levels typically seen in Western societies. In fact, in Western societies, 25(OH)D levels trend downward during pregnancy [18]. Any objective interpretation from the perspective of basic biology leads to the conclusion that declining 25(OH)D levels during pregnancy are not physiological for humans.

Optimal Paleolithic Sun Exposure and Vitamin D Status

The geographic differences in serum 25(OH)D among people of sub-Saharan African ancestry (Blacks) have also been confirmed by Durazo et al., who tested people living in urban areas [12]. They acknowledge the concept that higher 25(OH)D levels may match our Paleolithic genome as suggested by [31, 32]. Durazo et al. agree that healthy urban adult populations in equatorial Africa have mean concentrations of 25(OH)D in the range of 75–110 nmol/L (30–45 ng/mL) [12]. However, they argued that there are no vitamin D-specific adverse outcomes for northern population groups such as American Blacks who they showed to have with significantly lower 25(OH)D values than among light-skinned persons. Those authors conclude that it is premature to assert that concentrations in the range of 30–45 ng/mL are more "genome appropriate" for humans [12]. However, they failed to account for the relationships between sun exposure, vitamin D nutritional status, and pregnancy.

It has been argued that it is normal for Blacks to have lower serum 25(OH)D levels than Whites and that the calcium biology of Black persons was an adaptation to their lower 25(OH)D [2]. This latter is an odd perspective, because its logic starts from Blacks living in the United States and works backward, with the teleological argument to explain a current situation. But the perspective ignores the fact that humans originated as Blacks in equatorial Africa and that all natural selection to adapt to temperate, northern environments has been specific to White populations, not Blacks [45].

The consequence of such low serum 25(OH)D levels during pregnancy has been elegantly shown in a post hoc analysis of a clinical trial conducted at the Medical University of South Carolina [48]. Wagner and Hollis conducted a clinical trial using 4000 IU/day vitamin D during pregnancy versus 400 IU/day. When the results were compared based on attainment of a serum 25 (OH)D threshold value of 100 nmol/L (double the 50 nmol/L recommended by the IOM), those women with serum concentrations exceeding 100 nmol/L had a 46% lower rate of preterm birth ($n = 233$, $p = 0.004$); among Hispanic women preterm birth rate was 66% lower ($n = 92$, $p = 0.01$); among African American women the preterm birth rate was 58% lower ($n = 52$, $p = 0.04$) [48]. Therefore, bringing serum 25(OH)D of pregnant women in the United States up into the range that is "normal" for traditional African women who are pregnant lowered the risk of premature birth.

In addition to the clear benefit of higher serum 25(OH)D in the context of preterm birth, [48], higher prenatal exposure to 25(OH)D levels is associated with improved cognitive development and reduced risk of ADHD and autism-related traits later in life [16]. These associations point to a tragic and potentially high public health burden given the low vitamin D status that seems to be accepted as normal for modern societies, as compared to anthropological norms.

Simple exposure to sunshine is well recognized as being a net benefit to human health and longevity, even without implicating vitamin D nutrition. From a public health perspective, uncontested benefits of sun exposure include certain cancers, multiple sclerosis, diabetes, cardiovascular disease, autism, Alzheimer's disease, and age-related macular degeneration [20]. One recent study estimated that approximately 12% of US deaths (340,000 persons per year) may be linked to inadequate sun exposure as reflected in serum 25(OH)D levels [8].

Furthermore, as part of the Melanoma in Southern Sweden (MISS) study Lindqvist et al. analyzed the mortality data on 29,518 women across a 20 year period [28]. Women were categorized into four groups: from sun avoiders to those seeking out high sun exposure. Compared to the high exposure group, the sun avoiders were determined to have a risk factor for death of a magnitude that is similar to that of smoking [28] More recently, the same group reported that for this Swedish cohort, living in this low-UV region, the women possessing fair phenotype exhibited 8% lower mortality than non-fair skin women, despite a moderately higher skin cancer mortality among fair skin women [29].

Our species, *Homo sapiens*, has existed in its modern form for 100,000 years. It is reasonable to assume that since that time, there has been no further species-wide evolutionary change. Among some human populations, there has been natural selection driven by geography and environment, and in particular, as driven by sun exposure. Humans first appeared in the tropics, and most of our population still resides there [27]. The large majority of medical and epidemiological research has focused on populations living in temperate regions. Consider that 57% of the world's population lives within 30° of the equator, yet with a mere 5.7% of the population lives north of 49° latitude [27], a region that has produced far more basic and epidemiological research on the topics of latitude and vitamin D. There is very little known about health or disease relationships for the biologically normal sun exposure of the tropics. In fact, most physicians and health policy makers intensely focus on giving advice that populations should minimize such exposure [39, 40]. Evidently, it is normal to assume that "normal" human populations are those that live outside the tropics.

It is not biologically natural for humans to inhabit temperate latitudes with their seasonality and to shield their skin from sunlight. Tropical sunshine, along with its higher intensities of ultraviolet light throughout the year, is the striking features of the environment in which the human species arose. With our technologies that provide shelter, heat, and clothing, we modern humans create artificial microenvironments that are only a partial substitute for life in the tropics. What is missing are substitutes for the tropical the exposure of skin to sunshine. The vast majority of modern societies that presently inhabit the tropics possess serum 25(OH)D levels that match the lower 25(OH)D levels of the inhabitants of temperate climes. Cultures of sun avoidance are now common among modern populations living in the north as well as in the tropics.

Because of migration and cultural changes, most of the human population no longer resides at the optimum environment (Fig. 21.3). For humans, biological changes due natural selection did occur among human populations that moved away from the tropical environments for which our species was originally optimized. Furthermore, as humans migrated away from the tropics, they adopted behaviors that related to sun avoidance, such as indoor living, indoor work, shade-seeking behavior, and clothing. The consequences of that environmental change are well known: lower vitamin D nutritional status and diminished exposure of skin to ultraviolet light. Recent decades have seen large changes in the ethnic demographic within first-world countries. It is well known that for non-White immigrants, sun exposure and vitamin D nutritional status are much lower than they are for Whites. Furthermore, most nutritional and epidemiological research offers minimal insight

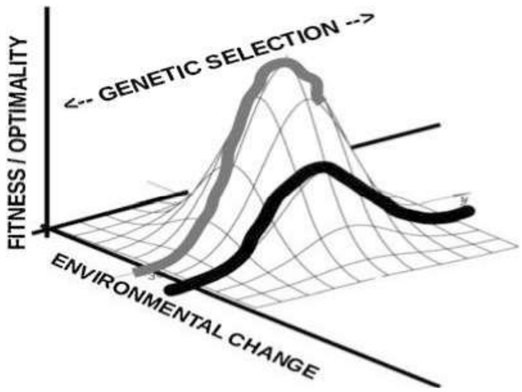

Fig. 21.3 The interactions between an environment change and natural selection as those influence the fitness of a species to its environment. The term, optimality, is used here to refer to those aspects of human health that are not likely to influence the reproductive process that relates to traditional biological sense of fitness of a species. The major premise here is that the genetic makeup of a species was achieved through the process of natural selection for those characteristics that maximize reproductive success. Hence, by definition, the biology of a species is one that is optimized for life in the environment in which the species evolved. The heavy, light-gray line represents the role of genetic variation at the optimal environment for the species. The heavy, black line represents the role of genetic variation at an environment that is substantially different from the original environment that was optimal. Natural selection cannot completely correct the deficiencies of a nonnatural environment. In other words, natural selection can achieve a local maximum, but it cannot reattain the level fitness/optimality of the original environment [33]

to the health of non-White sub-populations living in first-world countries. The classical view of evolution implies that for a given genome, natural selection within a population selects for features that produce a relative optimum for the environment (Fig. 21.3). A change in environment imposes new stresses that are accommodated through adaptation and further natural selection from within the preexisting genome, with the end result that biology largely – but not completely – adapts to the new environment. I contend that the adaptation to the new environment is an incomplete one, in that the fitness/optimality can only occur within the range of the genome available. Table 21.1 lists conditions that would support the contention illustrated by Fig. 21.3, which the biology of the human species has not fully adapted to its avoidance of sunshine, with its environmental effects of diminished ultraviolet light and vitamin D production.

Non-vitamin D Effects of Ultraviolet Light

Absorption of ultraviolet light by the skin triggers mechanisms that defend skin integrity and that regulate homeostasis systemically. However, this is accompanied by greater risk of skin pathology (e.g., cancer, aging, autoimmune responses). These effects are consequences of transduction of UV electromagnetic energy into chemical, hormonal, and neural signals, as determined by the nature of the chromophores and tissue compartments receiving specific UV wavelengths. Ultraviolet radiation can upregulate local neuroendocrine axes, and for this, UVB is markedly more efficient than UVA. The locally induced cytokines, corticotropin-releasing hormone, urocortins, pro-opiomelanocortin peptides, enkephalins, or others can enter the circulation to produce systemic effects, including activation of the central hypothalamic-pituitary-adrenal axis, opioidogenic effects, and immunosuppression [41]. All of these effects are independent of vitamin D production. However, because the preceding effects happen in the short term, their existence begs the question, if the non-vitamin D responses to ultraviolet light are indeed biologically meaningful, then what is the consequence of prolonged deprivation of ultraviolet light exposure?

One interesting example of a likely endorphin effect is a well-being experiment conducted by Feldman et al. In that experiment, subjects were given sunlamp treatments on three occasions per week for 6 weeks: randomly and blinded, once with an ultraviolet emitting lamp, once with a lamp not emitting ultraviolet light. At the third weekly occasion, subjects could select their preference treatment for the session. At 39 of 41 cycles of this study, subjects chose to have the ultraviolet light for their session, claiming that their choice elicited a more relaxed less tense mood [14]. Light has long been known to influence brain function [11, 35, 41] and the pertinent

Table 21.1 Evidence that natural selection has failed match the levels of fitness and optimality of the tropical environment where our species originated

Latitude/environment related
Adaptation involved lighter skin pigmentation which is more susceptible to burning and skin cancer
Part of that adaptation involved a change to pelvic bone to prevent rickets and osteomalacia, but predisposing to osteoporosis – this is the vitamin D paradox that despite lower 25(OH)D of American Blacks, they possess stronger bones [45]
Prevalence of winter seasonal affective disorder increases with latitude [35]
UVB exposure to skin lowers blood pressure by releasing nitric oxide from skin [49]
Blood pressure correlates inversely with distance from the equator [36]
Risk of rheumatoid arthritis higher at higher latitudes [34, 42]
Mortality higher with sun-avoiding behavior [28]
Higher latitude relates to greater risk and prevalence of schizophrenia [11]
Vitamin D related
Mortality from multiple health conditions decreases with higher serum 24(OH)D levels [8]
Low 25(OH)D levels during pregnancy relate to poor birth outcomes [4, 9, 48]
In older adults, lower serum 25(OH)D concentrations are prospectively related to increased risk of Alzheimer's disease [30]
Higher latitude relates latitude greater risk of dementia relationship [37]
Lower serum 25(OH)D relates to greater risk of multiple sclerosis [3]
Increased prenatal exposure to 25(OH)D levels is associated with improved cognitive development and reduced risk of ADHD and autism-related traits later in life [16]
Higher prenatal serum 25(OH)D levels relate to lower risk of autism and schizophrenia [10, 11, 47]

effects of light on immediate sense of well-being may serve the functional purpose of increasing more sunshine-related behavior, including the longer-term effects of improved vitamin D nutritional status.

Conclusion

Paleolithic nutrition has focused on foods consumed, but the Paleolithic model extends beyond diet to incorporate environment, which is equally relevant to health policies in the context of sunlight exposure and vitamin D nutrition. Biologically based thinking starts from the basic premise that disease risk may have an evolutionary underpinning and that modern human cultures and environments are probably not a substitute for what is natural or optimal [19]. Natural selection is a process that optimizes the choices from the available menu of options within the genome for fitness to reproduce. Within the relatively recent evolutionary context of modern human existence, the environmental stresses due to latitude, clothing, and sun avoidance cannot have altered biology optimally and certainly not across all population groups.

The perspective of health policy makers has been to adhere to what is prevalent among healthy populations, unless there is overwhelming evidence that more sun or more vitamin D intake produce a benefit. This approach is not well justified, because there are many adverse relationships associated with diminishing vitamin D nutrition status [8] and sun avoidance behavior [28]. Application of the Paleolithic nutrition way of thinking to vitamin D nutrition and ultraviolet light exposure is logical, both from the perspective of basic biology and from the perspective of epidemiology.

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