Sunlight
—Essential for Health

Hans B. Juneby

Environmental Medicine, Advanced Course, 15 ECTS
Department of Public Health and Clinical Medicine
Umeå University, Sweden, 2012
Abstract

Sunlight is recognized as one of the most important environmental factors that influence human health. There is strong evidence in the scientific literature that adequate exposure to sunlight is associated with many physical and mental health benefits, including reduced overall mortality, prevention of many deadly forms of cancer, as well as a number of metabolic, cardiovascular, autoimmune, infectious and neuropsychiatric diseases. Vitamin D deficiency, which is mainly due to insufficient exposure to sunlight, is now one of the most common medical conditions, estimated to affect more than a billion people worldwide. Health professionals, patients and the general public should receive more evidence-based information about the many health benefits of sunlight, and how to use it in prevention and treatment of disease.

Key words: Health; Prevention; Sunlight; Vitamin D
Introduction

Sunlight is absolutely essential for our life, health and well-being. It illuminates and warms the earth; generates and purifies fresh drinking water; purifies the air from harmful microorganisms; gives energy for photosynthesis in the green plants to bind carbon dioxide, generate fresh oxygen, and nutritious plant-based food. Sunlight profoundly influences every living organism: its very presence promotes the activities of the day; its absence gives us a night of quiet rest; its periodic variation in intensity marks the seasons of the year.

My interest in the health benefits of sunlight was greatly stimulated by Kime (1980), who brought together scientific data and practical medical application of sunlight to human health. Dr. Kime was a personal friend of mine, who practiced environmental medicine in California. The purpose of this study is to review the recent scientific literature on the relationships between sunlight and health. A literature search on the topic using PubMed and Scopus resulted in an extensive list of several thousand references, and I can only cover a small fraction in this literature review.

Sunlight is one of the most important environmental factors that influence human health (Stick & Pielke-Harms, 2006). Preventing and treating diseases with sunlight is known as heliotherapy or phototherapy, which no doubt is as old as mankind. The use of heliotherapy is recorded in ancient Egyptian papyri (Bayerl, 1997). Hippocrates, greatest of the Hellenistic physicians, also recognized the value of heliotherapy (Klarić et al., 2007). Scientific interest in the use of sunlight and ultraviolet irradiation in the treatment of various diseases started in the 19th century and reached a climax when Niels Finsen received the Nobel Prize in Physiology or Medicine in 1903 for his work on phototherapy of lupus vulgaris [dermal tuberculosis] (Roelandts, 2002).

Sunlight has a very strong influence on the regulation of the body's biological clocks. An interesting discovery is that skin cells contain clock genes that are influenced by melatonin, sunlight and low-dose UVB irradiation, which indicates that the skin may possibly be involved in circadian rhythm regulation. Melatonin also has antioxidant properties that protect the skin against potentially harmful effects of solar irradiation. (Mehling & Fluhr, 2006).

Melanopsin-expressing retinal ganglion cells are a newly discovered class of photoreceptors, which are responsible for sensing the light that regulates a number of non-visual functions, e.g. the pupil reflex, sleep, and pineal gland melatonin production. They send information about changing light conditions in the local environment to the master circadian pacemaker, which is located in the hypothalamic suprachiasmatic nuclei (Guido et al., 2010; La Morgia et al., 2011). These photoreceptors are most sensitive to blue light, with a peak at 460 nm. Blue light, which is an important part of natural sunlight, can be used to treat a number of health problems, including sleep disorders, jet lag, seasonal affective disorder, and premenstrual syndrome (Holzman, 2010).
Sunlight Exposure

Exposure to sunlight is the main source of vitamin D (Costanzo et al., 2011; Van Horn et al., 2011). An adult in a bathing suit exposed to a minimal erythemal dose (MED) of sunlight (causing a slight pinkness of the skin 24 hours after exposure) is equivalent to ingesting 10,000 – 25,000 IU [250 – 625 μg] of vitamin D. Exposing arms and legs to 0.5 MED is equivalent to ingesting about 3,000 IU [75 μg] of vitamin D (Holick, 2009). The MED may be reached after 15 – 20 minutes of sunlight exposure during the summer season in a person with light skin, and an equilibrium is reached after about half an hour, at which time there is no more net production of vitamin D. A person with dark skin needs 5 – 10 times longer sunlight exposure to reach the same dose. (Humble, 2007). A study by Olds et al. (2008) observed that increasing sunlight exposure from 2 to 4 MED does not result in a proportionately increased production of vitamin D.

Skin type and sensitivity to sunlight / UV radiation can be determined by using the Fitzpatrick Classification Scale, which has replaced the controversial race-oriented skin color classifications, e.g. Caucasoid, Celtic, Mongoloid, Negroid, Nordic, Oriental, etc. (Astner & Anderson, 2004).

<table>
<thead>
<tr>
<th>Phototype</th>
<th>Sunburn &amp; Tanning history (defines the phototype)</th>
<th>Immediate pigment darkening</th>
<th>Delayed tanning</th>
<th>Constitutive color (unexposed buttock skin)</th>
<th>UV-A MED (mJ/cm²)</th>
<th>UV-B MED (mJ/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Burns easily, never tans</td>
<td>None (–)</td>
<td>None (–)</td>
<td>Ivory White</td>
<td>20–38</td>
<td>15–30</td>
</tr>
<tr>
<td>II</td>
<td>Burns easily, tans normally with difficulty</td>
<td>Weak (+4 to +)</td>
<td>Minimal to weak (± 2 to +)</td>
<td>White</td>
<td>30–48</td>
<td>25–40</td>
</tr>
<tr>
<td>III</td>
<td>Burns moderately, tans moderately and uniformly</td>
<td>Moderate ++</td>
<td>Low +</td>
<td>White</td>
<td>40–55</td>
<td>30–55</td>
</tr>
<tr>
<td>IV</td>
<td>Burns minimally, tans moderately and easily</td>
<td>Moderate ++</td>
<td>Moderate ++</td>
<td>Beige-Olive, Lightly tanned</td>
<td>50–60</td>
<td>40–60</td>
</tr>
<tr>
<td>V</td>
<td>Rarely burns, tans profusely</td>
<td>Intense (brown) +++</td>
<td>Strong, intense brown +++</td>
<td>Moderate brown or tanned</td>
<td>70–100</td>
<td>60–90</td>
</tr>
<tr>
<td>VI</td>
<td>Never burns, tans profusely</td>
<td>Intense (dark brown) +++</td>
<td>Strong, intense brown +++</td>
<td>Dark brown or black</td>
<td>100</td>
<td>90–150</td>
</tr>
</tbody>
</table>

1 Adapted from Fitzpatrick’s Dermatology in General Medicine, McGraw-Hill Professional; 5th edition.

Figure 1. Fitzpatrick’s Skin Phototypes* (Astner & Anderson, 2004).

The Fitzpatrick skin phototype classification (FSPC) is the most commonly used measure of skin type (Magin et al., 2011). The FSPC is simple and user friendly, but it can easily be biased by different factors, such as ethnicity and chronic sun exposure, which means that it may sometimes need to be complemented by more objective methods. Diffuse reflectance spectrophotometry (DRS) is an objective non-invasive method that can be used to confirm the clinical determination of constitutive skin color (González et al. (2010).

A Polish study of 295 healthy volunteers aged 18-55 with skin phototype II or III were subjected to broadband UVB radiation of incremental intensity on six squares (1 x 1 cm) on the forearm or back skin to determine their individual MED, defined as a perceptible erythema after 24 hours. Mean MED was 0.158 J/cm², with a significant difference between mean MED in phototype II (0.141 J/cm²) and phototype III (0.177 J/cm²). Women had a significantly higher mean MED (0.164 J/cm²) compared to the tested men (Narbutt et al., 2007).

A German study of 110 healthy volunteers was conducted to determine the MED for UVB 311 nm narrowband irradiation compared to the UVB broadband MED. The UVB 311 nm narrowband MED values ranged from 300.9 to 1,386.0 ml/cm² with an average of 838.88 ml/cm². The UVB broadband MED values ranged from 46.2 to 210.9 ml/cm² with an average of 108.45 ml/cm². There was...
an average difference of factor 7.91 between the MED for broadband and narrowband UVB. This study shows that there are significant inter-individual differences in MED of both UVB spectra, which means that each patient should have an individual MED determination before the start of phototherapy (Lehnen et al., 2005).

According to a German handbook (Gillmann, 1966), the human skin is significantly more sensitive to sunlight during the winter than during the summer. The UV sensitivity increases in the fall and remains high until the spring, which means that a sun exposure in March/April has a stronger effect than the same UV dose during the summer. This appears to follow the seasonal variations in sunlight intensity, and the opposite pattern should be seen in the southern hemisphere. However, a study by Lock-Andersen & Wulf (1997) only found marginal seasonal variations in skin sensitivity to UV radiation. Guidelines for sensible sun exposure are really needed (Holick, 2008).

Daily and seasonal variations in sunlight and UV intensity can be measured and expressed in the form of an ultraviolet index (UVI) for specific geographic locations. The UVI can be used as a guide to quantify healthy exposures to solar radiation for patients using heliotherapy, and to minimize the risk of harmful overexposure. A combination of the UVI and a person's skin type could give a good estimate of a personal minimal erythemal dose per hour (MED/h). The MED/h concept may become very useful in future heliotherapy research and practice (Moosa & Esterhuyse, 2010). This could be a good complement to various types of personal UV dosimeters, which are often used in heliotherapy (Vähävihu et al., 2010).

**Sunlight and Vitamin D**

Phytoplankton, zooplankton and most animals that are exposed to sunlight have the capacity to produce vitamin D (Novosad et al., 2011). Vitamin D is recognized as the sunshine vitamin, because when the skin is exposed to sunlight, specifically the UVB portion (290-315 nm), it converts 7-dehydrocholesterol (7-DHC) in the skin to vitamin D, which can be stored in fat cells and released when needed (Holick, 2004). Vitamin D is a steroid hormone that is activated in the liver to form calcidiol, 25-hydroxyvitamin D [25(OH)D], which is the major circulating form of vitamin D. This must later be converted in the kidneys to the biologically active calcitriol, 1,25-dihydroxyvitamin D [1,25(OH)2D]. Sunlight increases serum 25(OH)D concentration, but 1,25(OH)2D is not affected by sun exposure (Landin-Wilhelmsen et al., 1995).

Factors that limit the skin's production of vitamin D include: An increase in skin pigmentation (Clemens et al., 1982). Application of a sunscreen can reduce the production of vitamin D by as much as 99% (Matsuoka et al., 1987). Advancing age significantly decreases the production of vitamin D due to a lower skin content of the vitamin precursor 7-dehydrocholesterol. (Holick et al., 1989). The zenith angle of the sun, which varies with the latitude, season of the year and time of day, greatly influences the UVB radiation intensity and the skin's production of vitamin D, which is absent during most of the winter above latitude 35° north and below 35° south (Holick, 2009).

Vitamin D increases intestinal calcium absorption from 10–15% to 30–40% and helps to maintain maximum mineral content in the skeleton by optimizing the bone remodeling process (Holick, 2009). Vitamin D regulates many other vitally important biological functions in the body by acting on specific nuclear vitamin D receptors (VDR) with effects on the expression of more than 200 genes (Humble, 2007). Vitamin D acts as a true hormone and is essential to virtually every cell in the human body (Lopes et al., 2011).
According to Diamond and Mason (2009), serum 25(OH)D (calcidiol) levels of 50 – 75 nmol/L [20 – 30 ng/ml] and above are considered optimal for maintaining good overall health. A serum level of 20 ng/ml [50 nmol/L] or less is considered to be vitamin D deficient, 21 – 29 ng/ml is insufficient, and it should be at least 30 ng/ml [75 nmol/L] to maximize the health benefits of vitamin D. There is no danger of intoxication until the blood level of 25(OH)D exceeds 150 – 200 ng/ml [375 – 500 nmol/L], according to Holick (2008), who has come to the following conclusion (2009):

Both the adequate intake recommendations and safe upper limits for vitamin D are woefully underestimated. For every 100 IU [2.5 μg] of vitamin D ingested, the blood level of 25(OH)D increases by 1 ng/ml [2.5 nmol/L]. Thus, children during the first year of life need at a minimum 400 IU [10 μg] of vitamin D/day and 1,000 IU [25 μg] of vitamin D/day may be more beneficial and will not cause toxicity. The same recommendation can be made for children 1 year and older. For adults, a minimum of 1,000 IU [25 μg] of vitamin D/day is necessary and 2,000 IU [50 μg] of vitamin D/day is preferred if there is inadequate sun exposure. The safe upper limit for children can easily be increased to 2,000 IU [50 μg] of vitamin D/day, and for adults, up to 10,000 IU [250 μg] of vitamin D/day has been shown to be safe.

“The major cause of vitamin D deficiency globally is an underappreciation of sunlight’s role in providing humans with their vitamin D₃ requirement” (Holick et al., 2007). Vitamin D deficiency is now recognized as one of the most common medical conditions worldwide, which is mainly due to insufficient exposure to sunlight. It has now been classified as a pandemic (Holick, 2010; Dobnig, 2011). The increased prevalence of vitamin D deficiency is due to a modern lifestyle with lack of sunlight exposure, but also to an increased prevalence of obesity, where adipose tissue sequesters this fat-soluble vitamin (Bell, 2011).

Vitamin D status is influenced by variations in sun exposure due to geographic latitude, season, time of day, atmospheric composition, daily outdoor activities, clothing and body surface exposed to sunlight, skin pigmentation, sunscreen use, sex, age, obesity, dietary intake, etc. More than a billion people worldwide are estimated to have vitamin D deficiency or insufficiency. (Moy, 2011; Trémezaygues & Reichrath, 2010; Tsiaras & Weinstock, 2011).

It is estimated that 30 – 50% of both children and adults in North America, Europe, Asia, Australia and New Zealand are vitamin D deficient. Children and adults who live in the sunniest areas of the world, including the Middle East, India, and even in Florida (‘The Sunshine State’), are at risk of vitamin D deficiency due to lack of sunlight exposure and sun protection practices (Holick, 2009; Fields et al., 2011). According to Szabó (2011), it has been estimated that approximately three-quarters of all adults have serum levels of 25(OH)D that are below 30 ng/ml [75 nmol/L].

A study from Turkey shows that the traditional covered clothing style leads to vitamin D deficiency in women (Güler et al., 2007). Vitamin D deficiency is epidemic in India despite plenty of sunshine, leading to the suggestion that “There may be a public health need to fortify Indian foods with vitamin D” (Harinarayan & Joshi, 2009). However, Diamond & Mason (2009) point out that “Adequate sunlight exposure remains the simplest effective way to maintain vitamin D levels.”

Most people in Sweden do not get enough sunlight, especially during the winter season, due to the country’s geographic location, which limits the amount of vitamin D producing UVB light. Many become vitamin D deficient by avoiding exposure to sunlight, or simply by spending most of their time indoors. Insufficient exposure to sunlight results in low levels of vitamin D, which may cause a number of health problems. Humble (2007) confirms that vitamin D is a very important factor in the prevention and treatment of many common diseases, including common forms of cancer, cardiovascular diseases, diabetes, autoimmune and neuropsychiatric diseases.
Vitamin D Deficiency

Vitamin D deficiency leads to poor bone health and development, but also an increased risk of many chronic diseases, including diabetes type 1 and 2, rheumatoid arthritis, Chron's disease, multiple sclerosis, heart disease, stroke, infectious diseases, as well as an increased risk of dying of many deadly forms of cancer, including cancer of the colon, prostate and breast (Holick, 2009).

When children do not get adequate exposure to sunlight they often develop rickets, which was very common in the industrialized cities of northern Europe and North America at the turn of the twentieth century. Corresponding diseases in adults are the painful bone disease osteomalacia, osteopenia and osteoporosis, as well as myopathy, which can all be prevented by adequate exposure to sunlight and a sufficient intake of dietary calcium. A 20 ng/ml [50 nmol/L] serum level of vitamin D can prevent all cases of rickets and osteomalacia. A sufficiently high serum level of vitamin D (30 ng/ml [75 nmol/L]) can prevent the incidence of all fractures combined by 50%, and prevent 72% of falls in women (Humble, 2007; Holick, 2009).

In Sweden, the reported cases of rickets due to vitamin D deficiency has increased from 76 children in 2002 to 175 children in 2008 (Bågenholm et al., 2010). Nutritional rickets has been reported among both native and immigrant children in Denmark (Pedersen et al., 2003; Beck-Nielsen et al., 2009). A study from Norway shows that immigrant mothers and their children also have a high incidence of vitamin D deficiency (Madar et al., 2009). More than 90% of children born to mothers who wore a veil that prevented adequate sun exposure during pregnancy had vitamin D deficiency (Bejerot & Humble, 2008).

Many immigrants from sunny tropical countries can easily get a severe vitamin D deficiency after moving to Sweden, especially if they live in a large city with air pollution, mostly stay indoors, have dark skin and wear clothes that cover the whole body, which make it very difficult to get adequate exposure to sunlight (Humble, 2007). Svenberg et al. (2007) reported that a majority of male and female immigrants from Africa and the Middle East, who were examined at a Swedish primary care clinic, had severe vitamin D deficiency (less than 10 ng/ml [25 nmol/L]).

A French study by Le Goaziou et al. (2009) reported that young veiled females had a very high prevalence of vitamin D deficiency (82,5 % had a vitamin D level under 30 nmol/L). The covered women were significantly more vitamin D deficient than women who did not wear a covering veil. This shows that concealing clothes are a major risk factor for vitamin D deficiency by preventing healthy sun exposure.

High serum 25(OH)D concentrations may protect against early age-related macular degeneration in women younger than 75 years (Millen et al., 2011). According to a review by Hayes (2010), “Vitamin D appears to play a major positive role in biogerontology by reducing susceptibility in the elderly to chronic degenerative diseases”, including DNA damage control.

Vitamin D deficiency can be prevented or treated in nursing home residents by weekly frontal half-body UVB irradiation at 0.5 minimal erythemal dose (MED), which results in significantly increased 25(OH)D serum levels (Chel et al., 2011). In case of insufficient exposure to natural sunlight, Holick et al. (2007) agree that “Exposure to lamps that produce UVB radiation is an excellent source for producing vitamin D₃ in the skin and is especially efficacious in patients with fat malabsorption syndromes.” Exposure to sunlight or an UVB radiation emitting device is most effective in patients with severe malabsorption or those requiring long-term parenteral therapy (Pittas et al., 2010).
Solar and Artificial UV Exposure

Research shows that there are significant differences in UV radiation composition and intensity between natural sunlight and UV radiation produced by a typical solarium. The solar UV spectrum at noon contains 4–5% of UVB and 95–96% of UVA during a sunny day on the Mediterranean coast. Solarium tanning appliances may have a UVB radiation that varies from 0.5–4% of the total UV output, but this is restricted to no more than 1.5% in some countries (e.g. France and Sweden). The UV intensity of many tanning appliances may be 10–15 times higher than midday sunlight in the Mediterranean area (IARC, 2006).

“Unpredictable UV irradiance combined with insufficient customer guidance may give a high risk of negative health effects from solarium use” according to Nilsen et al. (2011). A review by Schneider and Krämer (2010) found that the typical solarium users are females between 17 and 30 with comparatively unhealthy lifestyles. They smoke cigarettes, drink alcohol, and eat unhealthy foods, combined with a general lack of knowledge about health risks.

Public health campaigns have been developed to inform the public about the role of UV radiation as the most important environmental risk factor for the development of (non-melanoma) skin cancer. Many of these campaigns advocate a strict 'no sun' policy, which tends to ignore all the positive effects of sunlight, according to Reichrath (2009), who points out that “about 90% of all vitamin D needed by the human body has to be formed in the skin through the action of UVB radiation and it has been shown that strict sun protection causes vitamin D deficiency.” An Australian study highlights the problem that sun protection guidelines often make it difficult to balance vitamin D requirements with sensible sun exposure (Stalgis-Bilinski et al., 2011).

According to Terushkin et al. (2010), “There are well-known detrimental side effects of ultraviolet irradiation. Therefore, oral supplementation remains the safest way for increasing vitamin D status.” However, Chel et al. (2011) point out that cutaneous vitamin D production from UVB exposure may be preferable to oral supplementation because “it cannot cause toxic levels, it helps to prevent polypharmacy and, moreover, there are indications that UVB exposure has beneficial effects on health and well being by mechanisms other than the vitamin D pathway alone.”

Problems caused by vitamin D deficiency due to insufficient exposure to sunlight and low dietary intake have recently been discussed in a number of articles in Läkartidningen (the Journal of the Swedish Medical Association). Bruce (2007) points out that UVB in sunlight plays an important role for the production of vitamin D in the skin at the same time as it may increase the risk of skin cancer. This conflict between risk and benefit shows the importance of giving sound advice on how to reap the health benefits of sunlight while avoiding the harmful effects of excessive UV exposure.

The Swedish Women’s Lifestyle and Health cohort study had 38,472 participants aged 30 – 49, with a 15 year follow-up until the end of 2006. The study found that women who had frequent sun exposure during adolescence had a lower all-cause mortality than women with less sun exposure. Frequent sunbathing vacations (more than once a year during three decades) resulted in lower risk of all-cause and cardiovascular disease (CVD) mortality. However, women who used a solarium once or more per month for at least a decade had a higher risk of all-cause mortality, compared to women who never used a solarium. The conclusion was that “Solar UV exposure was associated with reduced overall and CVD mortality, whereas artificial UV exposure was associated with increased overall and cancer mortality among Swedish women” (Yang et al., 2011).
Grant et al. (2011) have estimated the health benefits of increasing the mean serum concentration of 25(OH)D to 105 nmol/L in the five Nordic countries. According to this study, it is possible to achieve the following reductions of the mortality rates: Denmark 17%, Finland 24%, Iceland 24%, Norway 18%, and Sweden 18%. “Reaching these levels would require changes in health policies with respect to solar ultraviolet-B (UVB) irradiance, vitamin D fortification of food, availability of vitamin D and calcium supplements, and attitude toward use of UVB lamps.” The authors conclude that “Adverse effects of oral vitamin D intake are limited, and those from UVB irradiance are minor compared with the benefits.”

Regular suberythemal exposure to a UV lamp that emits ultraviolet radiation similar to sunlight, which produces vitamin D₃ in the skin, is an excellent alternative during the winter months when there is insufficient exposure to natural sunlight according to Chandra et al. (2007). Moderate, healthy exposure to natural sunlight or artificial UV light should not cause a sunburn (erythema). The popular notion that a tanned person looks more healthy than a pale individual may lead to harmful overexposure. “Campaigns targeted at males need to reduce the perceptions that tanned females are healthier, thinner, and more attractive. Educational efforts targeting females need to reduce attraction-based motivations” (Banerjee et al., 2008).

**Sunlight and Cancer**

Sunlight and vitamin D are associated with a significantly decreased risk of dying from many deadly types of cancer, including cancer of the colon, prostate and breast. It is believed that the local production of 1,25-dihydroxyvitamin D in the breast, colon, prostate, and other cells regulates a variety of genes that control proliferation as well as genes that inhibit angiogenesis and induced apoptosis. A sufficiently high serum level of vitamin D (30 ng/ml [75 nmol/L]) can prevent the incidence of all cancers combined by 75% (Holick, 2009).

The positive, cancer-preventive effects of sunlight are achieved by regular, short or moderate exposure to sunlight, while excessive exposure has negative effects. The reason is that the skin only contains a limited amount of 7-dehydrocholesterol at any given time, which can be converted to vitamin D by exposure to sunlight within 15 – 20 minutes. Continued or excessive exposure to sunlight beyond this time leads to the production of harmful substances in the skin, which increase the risk of malignant melanoma and other types of skin cancer (Björn & Björn van Praagh, 2005).

Humble (2007) confirms that there is extensive epidemiological evidence that vitamin D prevents the incidence of several common types of cancer, including cancer of the breast, colon, rectum, uterus, ovaries, prostate, and lymphoma. A case-control study showed that a higher lifetime UV light exposure reduced the risk of non-Hodgkin lymphoma (Smedby et al., 2005a & 2005b). Since there is strong evidence that vitamin D deficiency increases the risk of cancer generally, the campaign to reduce the incidence of skin cancer by reducing the exposure to sunlight is actually more likely to increase the risk of cancer (Humble, 2007).

The Norwegian radiation experts Moan and Porojnicu (2006) point out that exposure to natural sunlight and/or suberythemogenic solarium exposure produce large amounts of vitamin D from 7-dehydrocholesterol in the skin, which results in many positive health effects that outweigh the negative effects in terms of skin cancer mortality. Their conclusion is that we should “consider modifying our restrictive attitude towards sun exposure and use of solaria.”
Low levels of vitamin D are associated with a wide range of serious diseases, including more than a dozen types of cancer, according to Terenetskaya and Orlova (2005). “Regardless of the fact that UV overexposure is liable to cause adverse health effects,” they recommend appropriate doses of UV radiation from artificial sources to synthesize vitamin D in the skin, which is absolutely essential for human health, especially during the winter season.

Sun exposure is a well established risk factor for malignant melanoma according to Smedby et al. (2005a). One form of malignant melanoma in adults has been associated with episodes of heavy overexposure (sunburn) during childhood. However, sun exposure can also reduce the risk of dying from malignant melanoma. Sunnier European countries have lower melanoma mortality, according to Shipman et al. (2011), who compared the average annual sunlight hours in 36 European capital cities with each country’s melanoma mortality rate. More sunlight hours was associated with significantly lower melanoma incidence in both men and women, “indicating that sun exposure is unlikely to be the strongest factor affecting mortality from malignant melanoma.”

Sunlight and artificial UV light exposure is not related to the number of pigmented nevi according to a study by Rampen et al. (1988), who also found that dysplastic nevi are clearly more common in subjects with short periods of UV exposure. A study by Stierner et al. (1992) confirms that UV light is not a major aetiological factor for dysplastic nevi. This is further indication that malignant melanomas, which often develop from dysplastic nevi, are not directly related to UV exposure.

Skin cancer patients appear to be very sensitive to sunlight according to Kime (1980). They sunburn more easily, and the burned area takes longer to heal. When the skin is burned, free radicals are formed, e.g. cholesterol alpha-oxide, which can cause cancer. Kime pointed to the role of a high fat diet, where polyunsaturated fats have been shown to stimulate cancer formation more than saturated fats, and suggested that the dramatic increase in malignant melanoma may be related to the increased use of polyunsaturated fats.

Sunscreen use may give a false sense of security and may actually increase the risk of melanoma according to Goldenhersh and Koslowsky (2011). No epidemiological studies have proved that malignant melanoma can be prevented by using sunscreens (Chaidemenos et al., 2008). The International Agency for Research on Cancer also reports that sunscreen use may increase the risk of melanoma in intentional sun exposure situations (IARC, 2001; Autier et al., 2011).

Colorectal cancer is the second leading cause of cancer mortality in the United States. Clinical and epidemiological studies indicate that a low serum vitamin D level increases the risk of this disease. Maintaining serum levels of vitamin D (calcidiol) above 32 ng/ml [80 nmol/L] may help to prevent or substantially lower the incidence of colorectal cancer according to Rheem et al. (2010).

Sunlight, Metabolic and Cardiovascular Diseases

There is strong epidemiological evidence that exposure to sunlight and vitamin D help to prevent the incidence of metabolic syndrome, obesity, type 2 diabetes, atherosclerosis, hypertension, coronary heart disease and stroke (Boucher, 1998; Zittermann et al., 2005; Humble, 2007). An Israeli study with 34,874 participants clearly shows that vitamin D deficiency is associated with coronary heart disease. More than three-quarters of the Israeli study population had vitamin D deficiency or insufficiency, which is similar to the prevalence found in less sunny regions of the world (Steinvil et al., 2011).
Swedish research shows that vitamin D is related to high blood pressure and other cardiovascular risk factors (Lind et al., 1995). Adult men born in the spring or summer have lower blood pressure than men born in the autumn or winter, with a mean systolic difference of 5.9 mm Hg, according to a Spanish study (Banegas et al., 2000), indicating that “the extent of early exposure to sunlight is implicated in determining later blood pressure.” Serial radiation with full-spectrum UV light lowers resting and exercise blood pressure and improves kidney function according to a German study (Krause et al., 2000). Ultraviolet light is essential for adequate vitamin D levels, but the effects of oral vitamin D supplementation in (generally low) daily dosages are poor, according to Bours et al. (2011).

“Sunlight deficiency could increase blood cholesterol by allowing squalene metabolism to progress to cholesterol synthesis rather than to vitamin D synthesis”, according to a study by Grimes et al. (1996) that looked at the relationship between geography, sunlight and the incidence of coronary heart disease. The conclusion is that “the increased concentration of blood cholesterol during the winter months, confirmed in this study, may well be due to reduced sunlight exposure.” Campaigns to reduce sun exposure to reduce the risk of skin cancer, and lifestyle changes resulting in less outdoor activities, have resulted in vitamin D deficiency, which adversely affects immune and metabolic functions (Ginter & Simko, 2009).

Research shows that almost all patients with acute myocardial infarction have vitamin D deficiency, and measures to correct this deficiency may be a simple way to help prevent heart disease (Pawlak & Kasprzak, 2011). A large American study showed a strong relationship between vitamin D deficiency and several risk factors for cardiovascular disease, including hypertension, high fasting blood glucose, obesity, and elevated serum triglycerides (Martins et al., 2007). A sufficiently high serum level of vitamin D (30 ng/ml [75 nmol/L]) can prevent the incidence of heart attack in men by 50%, and it can also prevent the incidence of peripheral vascular disease by 80% (Holick, 2009).

Type 1 diabetes is associated with vitamin D deficiency, most likely via immunological mechanisms. A prospective study with vitamin D supplementation in children showed an 80% reduced incidence of type 1 diabetes (Hyppönen et al., 2001). “Vitamin D increases insulin secretion in patients with type 2 diabetes” (Pawlak & Kasprzak, 2011). A sufficiently high serum level of vitamin D (30 ng/ml [75 nmol/L]) can prevent the incidence of both type 1 and type 2 diabetes by 50%, and a serum level of 50 ng/ml [125 nmol/L] can prevent the incidence of type 1 diabetes by 80% (Holick, 2009).

Sunlight and Autoimmune Diseases

Sunlight is a well established treatment modality for psoriasis. A study on Gran Canaria, Spain, shows that sun exposure causes a rapid reduction in local and systemic inflammatory markers in psoriasis patients, indicating that the significant clinical improvement observed is due to immune modulation (Søyland et al., 2011). Heliotherapy (sun exposure) and broadband UVB phototherapy of psoriasis patients results in a higher production of vitamin D compared to narrowband UVB phototherapy, but all three treatment modalities have a very good therapeutic effect in these patients (Osmancevic et al., 2010).

Vähävihu et al. (2008) found that a two week course of heliotherapy in the Canary Islands in January or March caused a marked healing of atopic dermatitis and significantly increased the patients’ serum vitamin D levels. However, erythema should be avoided, because sunburn could aggravate the eczema (Scheinfeld et al., 2003).
A review by Reynolds and Bruce (2009) found that musculoskeletal pain, fatigue and depression are often associated with systemic lupus erythematosus, and vitamin D deficiency is implicated in the pathogenesis of all these conditions. Cardiovascular disease, which is an important cause of premature death in systemic lupus erythematosus, is also firmly linked to vitamin D deficiency.

According to Cutolo et al. (2007 & 2011), low serum levels of vitamin D during the winter season help to explain the latitude-related prevalence of autoimmune diseases such as rheumatoid arthritis. Greater intake of vitamin D is associated with a lower risk of rheumatoid arthritis, as well as a significant clinical improvement that is strongly correlated with the immunomodulating potential in vitamin D treated patients with rheumatoid arthritis.

24 patients with rheumatoid arthritis were each given 100,000 IU [2,500 μg] of vitamin D per day for one year in a Swedish double-blind clinical trial. No toxic effects were observed during the study in spite of the extremely high daily dose of vitamin D. Objective and subjective improvement was noted in 16 (67%) of the treated patients, and only one treated patient (4%) experienced an objective and subjective deterioration. The consumption of analgesics and anti-inflammatory medicines decreased significantly. Morning stiffness had eased and hand strength had increased by the end of the study (Brohult & Jonson, 1973).

Children born in November have a lower risk of developing multiple sclerosis later in life according to Fernandes de Abreu et al. (2011), who find that “There is now strong evidence linking vitamin D, the steroid hormone of sunlight, and Multiple Sclerosis (MS). Two of the most intriguing findings are the season of birth and childhood sun exposure effects. They both suggest that a vitamin D deficiency during these critical imprinting periods is a risk factor for MS.”

Vitamin D modulates cellular immune response and reduces TNFα-levels, which counteracts Th 1-mediated autoimmune reactions. Reumatoid arthritis, multiple sclerosis, type 1 diabetes, and the inflammatory bowel diseases are Th 1-mediated autoimmune diseases, which may be prevented by adequate sunlight exposure and vitamin D supplementation. Many of these diseases are more common in areas with less sunlight during the winter season, and they usually improve by spending time in warmer and sunnier locations (Humble, 2007; Peyrin-Biroulet et al., 2009). A 40 ng/ml [100 nmol/L] serum level of vitamin D can prevent the incidence of multiple sclerosis by 50%, and by 66% at 60 ng/ml [150 nmol/L] (Holick, 2009).

**Sunlight and Neuropsychiatric Diseases**

A large cohort study with 16,800 participants found an association between decreased exposure to sunlight and increased probability of cognitive impairment. This is the first study that examined the effects of two-week exposure to sunlight on cognition, as well as the first to look at sunlight’s effects on cognition in a large cohort study. (Kent et al., 2009).

Recent research indicates that vitamin D is important for the normal development of the brain and nervous system. Many neurons in the brain contain 1α-hydroxylase, which activates vitamin D, and also have vitamin D receptors (VDR), which make it possible for vitamin D to have an influence on these brain cells. New findings indicate that vitamin D has neuroprotective effects with potential importance in Parkinson’s and Alzheimer’s disease (McGrath et al., 2004; Humble, 2007).
A review by Dickens et al. (2011) found that low levels of serum 25-hydroxyvitamin D \([25(OH)D]\) are “associated with increased odds of prevalent cognitive dysfunction, Alzheimer’s disease and all-cause dementia in a number of studies, raising the possibility that vitamin D plays a role in the aetiology of cognitive dysfunction and dementia.” They conclude that further studies are urgently needed to establish if “vitamin D supplements are effective at minimizing cognitive decline or preventing dementia.”

A Norwegian study shows a connection between depression and low serum levels of vitamin D, as well as high parathyroid hormone levels and poor cognitive test results (Jorde et al., 2006). Another study shows that an alarmingly high percentage of Norwegians and immigrants with psychotic disorders have vitamin D deficiency. The conclusion is that “This has important clinical implications as it suggests possible beneficial effects of vitamin D medication/heliotherapy within this group” (Berg et al., 2010).

Gagné et al. (2010) report that there is a close link between the decrease in sunlight hours and intensity occurring during fall and winter and the onset of depressive symptoms associated with seasonal affective disorder (SAD). An American study shows that vitamin D has a better effect in seasonal affective disorder than broad spectrum phototherapy (Gloth et al., 1999). Other studies show that vitamin D can improve depression, fatigue and irritability. Depression, and maybe also schizophrenia, are very often associated with osteoporosis, which is a clear indication of vitamin D deficiency (Humble, 2007).

Epidemiological studies suggest that vitamin D deficiency during pregnancy could adversely affect the fetal brain and increase the risk of future schizophrenia. Vitamin D deficiency due to a poor diet and a lack of sunlight exposure are also common among chronic psychiatric patients (McGrath et al., 2004; Humble, 2007; Koster & Kühbauch, 2011).

Effective detection and treatment of inadequate vitamin D levels in persons with depression and other mental disorders (preferably by exposure to natural sunlight or full-spectrum UV light) may be an easy and cost-effective therapy which could improve patients’ long-term health outcomes as well as their quality of life (Penckofer et al., 2010).

Epileptic seizures, especially complex partial seizures, are less likely to occur on bright sunny days than on cloudy days with fewer hours of sunshine, according to Baxendale (2009 & 2011), who points out that “Sunlight is important in the endogenous production and regulation of melatonin and vitamin D, both of which influence seizure thresholds.” A review by Scorza et al. (2010) found that epileptic activity may be related to cardiac arrhythmias via the autonomic nervous system. It is well established that vitamin D deficiency is associated with coronary heart disease, and vitamin D deficiency might also increase the risk of sudden unexpected death in epilepsy.

**Sunlight and Infectious Diseases**

Modern research confirms the value of sunlight and vitamin D in the prevention and treatment of various infectious diseases, including upper respiratory tract infections and tuberculosis. Sunlight exposure has a long history in the treatment of tuberculosis, especially before the advent of modern chemotherapeutic agents, and vitamin D deficiency is a well known risk factor for this disease (Humble, 2007; Holick, 2009; Cutolo et al., 2011).
When a monocyte/macrophage is stimulated through its toll-like receptor by an infective agent, such as *Mycobacterium tuberculosis*, the signal upregulates the expression of specific nuclear vitamin D receptors (VDR) and 25-hydroxyvitamin D-1-hydroxylase. If the serum level is adequate (more than 30 ng/ml [75 nmol/L]), this enzyme converts 25-hydroxyvitamin D to the biologically active 1,25-dihydroxyvitamin D, which returns to the cell nucleus where it increases the expression of the antimicrobial peptide cathelicidin that promotes innate immunity and induces destruction of the infective agents (Liu *et al.*, 2006; Holick, 2009). Supplementation with vitamin D increases cathelicidin production. Vitamin D is also involved in the production of antimicrobial defensine peptides. Low vitamin D levels are associated with an increased incidence of upper respiratory tract infections (Bartley, 2010).

A study by Urashima *et al.* (2010) suggests that vitamin D supplementation (1200 IU/day) during the winter may reduce the incidence of influenza A in school children, and children with previously diagnosed asthma may have significantly fewer attacks. A study by Sabetta *et al.* (2010) found that maintaining vitamin D serum concentrations of 38 ng/ml [95 nmol/L] or more were associated with a significant two-fold reduction in the risk of developing acute viral respiratory tract infections and significantly fewer days of illness.

Vitamin D deficiency increases the incidence of bacterial vaginosis (BV), which is a vaginal infection that affects nearly 1 in 3 reproductive-aged women. It is a serious condition associated with a number of gynecological problems and adverse pregnancy outcomes, including preterm birth. There is a dose-response relationship where the prevalence of BV declines with increasing serum concentrations of vitamin D up to 80 nmol/L (Bodnar *et al.*, 2009). This suggests that BV could be prevented by adequate sunlight exposure and vitamin D supplementation. Heliotherapy can also help to improve the quality-of-life of patients with chronic recurrent vulvo-vaginal candidosis (Mendling & Birkner, 2011).

**Solar Water Disinfection**

Three quarters of the earth's surface is covered by water, but only about one percent of that water is available for human consumption, and it is often contaminated by microorganisms that can cause life-threatening waterborne diseases, which kill more than five million people each year. 60% of all infant mortality is caused by mostly water-related infectious and parasitic diseases. More than two billion people suffer from diseases linked to dirty water. One solution to this problem is solar water disinfection (Okpara *et al.*, 2011).

“Solar water disinfection (SODIS) is a sustainable household water treatment technique that could prevent millions of deaths caused by diarrhoea” (Kraemer & Mosler, 2011). Persuasion factors strongly influence the decision to use SODIS. “Knowledge about water contamination can be easily disseminated and people can be persuaded about the necessity of treating their water by using flyers and/or promoters to spread the corresponding information” (Kraemer & Mosler, 2010).

The use of promoters appears to be “the most successful strategy in terms of reaching people and changing their behavior toward SODIS use” (Tamas *et al.*, 2009). Data from a longitudinal SODIS promotion study by Tamas and Mosler (2011) indicate that “Overall relapers have lower values for all psychological variables compared to overall continuers.” Mosler and Kraemer (2011) point out that the adoption of home water treatment systems require long-term changes in behavior.
Solar UVA light penetrates the clear plastic bottles that are used in most SODIS applications. The UVA light is the main agent that inactivates bacteria, causing serious damage to the bacterial membranes. A study by Bosshard et al. (2010) suggests that damage to bacterial cell membrane enzymes “is a likely cause of membrane dysfunction (loss of membrane potential and increased membrane permeability) during UVA irradiation”, which ultimately leads to bacterial cell death. An elevated temperature may also make an important contribution to the water purifying effects of SODIS, e.g. in the inactivation of Cryptosporidium parvum (Gómez-Couso et al., 2010).

In Mexico and similar sunny locations, it is possible to achieve complete drinking water disinfection by using the simple and inexpensive method of solar disinfection (SODIS). Transparent plastic bottles of commercial beverages are filled with contaminated water and exposed to direct sunlight. A complete disinfection takes place by simply placing water bottles in the sunlight during the whole day. Using solar concentrators and bottles partially painted black increases the water temperature to 65°C and achieves a total disinfection in 2 hours. (Martín-Domínguez et al., 2005).

A study by Amin and Han (2011) shows that the disinfection efficiency of SODIS can be increased by about 40% when lowering the pH to 3. This can be achieved by adding a combination of 2.5 ml/L (0.25%) of pure lemon juice and 1.7 ml/L (0.17%) of vinegar to the SODIS-treated water, which helps to avoid taste and odor problems, while maintaining complete disinfection.

It has also been shown that addition of riboflavin (vitamin B₂) to the water significantly enhances SODIS efficacy against a number of microorganisms, including Escherichia coli, Fusarium solani, Candida albicans, and Acanthamoeba polyphaga trophozoites (Heaselgrave & Kilvington, 2010). UVA light, combined with riboflavin, inactivates pathogens by damaging the nucleic acids (DNA and RNA) in viruses, bacteria and other microorganisms. This technique has also been used to destroy nucleic acid containing pathogens in blood products (Ruane et al., 2004).

A successful solar water disinfection intervention in rural Cambodia reported a compliance rate of over 90%, with significantly reduced incidence of dysentery and nondysentery diarrhea. “This study suggests strongly that SODIS is an effective and culturally acceptable point-of-use water treatment method in the culture of rural Cambodia and may be of benefit among similar communities in neighboring South East Asian countries” (McGuigan et al., 2011). In contrast to this, SODIS interventions in Bolivia and South Africa have reported compliance rates below 35% (Christen et al., 2011; Du Preez et al., 2010). This illustrates the importance of effective public health education and promotion efforts in order to reach the goal of high long-term compliance.

It is very important to have a good supply of safe drinking water, but it is equally important to keep the water clean until it is consumed. Rufener et al. (2010) found that “In-house contamination of drinking-water is a persistent problem in developing countries.” Their field study in Bolivia revealed that about two thirds of the drinking vessels examined were contaminated by E. coli. SODIS had greatly improved the water quality, but “recontamination at the point-of-consumption significantly reduced the quality of water in the cups”. This highlights the importance of including basic hygiene education with all SODIS promotion programs in order to achieve the intended health benefits.
Summary

This literature review shows that modern scientific research clearly confirms the beneficial effects of sunlight in the prevention and treatment of many diseases. Like all effective medicines, sunlight must be administered in a proper way in order to enjoy its health benefits and avoid harmful side-effects. Sunlight is recognized as one of the most important environmental factors that influence human health (Stick & Pielke-Harms, 2006).

There are significant individual differences in sensitivity to sunlight due to skin color and various other factors. The simple and user friendly Fitzpatrick skin phototype classification scale (FSPC) is the most commonly used clinical measure of skin type (Magin et al., 2011). Diffuse reflectance spectrophotometry (DRS) is an objective non-invasive method that can be used to confirm the clinical determination of constitutive skin color (González et al., 2010).

Minimal erythemal dose (MED) of natural sunlight or artificial UV light, causing a slight pinkness of the skin 24 hours after exposure, is another measure of a person's individual sensitivity. There are significant inter-individual differences in the MED, which means that each person should have an individual MED determination before the start of phototherapy (Lehnen et al., 2005). A person with dark skin needs 5 – 10 times longer sunlight exposure to reach the same dose compared to a person with light skin (Humble, 2007).

Healthy exposure to natural sunlight or artificial UV light should not cause a sunburn (erythema). The popular notion that a tanned person looks more healthy than a pale individual may lead to harmful overexposure (Banerjee et al., 2008). Research shows that solar UV exposure is associated with reduced overall and cardiovascular disease mortality, but artificial UV exposure (solarium tanning) is associated with increased overall and cancer mortality (Yang et al., 2011).

Exposure to sunlight is the main source of vitamin D (Costanzo et al., 2011; Van Horn et al., 2011). Vitamin D deficiency is now recognized as one of the most common medical conditions worldwide, which is mainly due to insufficient exposure to sunlight. It has now been classified as a pandemic (Holick, 2010; Dobnig, 2011). The increased prevalence of vitamin D deficiency is due to a modern lifestyle with lack of sunlight exposure, but also to an increased prevalence of obesity, where adipose tissue sequesters this fat-soluble vitamin (Bell, 2011).

It is estimated that 30 – 50% of both children and adults in North America, Europe, Asia, Australia and New Zealand are vitamin D deficient. Children and adults who live in the sunniest areas of the world, including the Middle East, India, and even in Florida (‘The Sunshine State’), are at risk of vitamin D deficiency due to lack of sunlight exposure and sun protection practices (Holick, 2009; Fields et al., 2011). According to Szabó (2011), it has been estimated that approximately three-quarters of all adults have serum levels of 25(OH)D that are below 30 ng/ml [75 nmol/L].

Many immigrants from sunny tropical countries can easily get a severe vitamin D deficiency after moving to Sweden, especially if they live in a large city with air pollution, mostly stay indoors, have dark skin and wear clothes that cover the whole body, which make it very difficult to get adequate exposure to sunlight (Humble, 2007). Svenberg et al. (2007) reported that a majority of male and female immigrants from Africa and the Middle East, who were examined at a Swedish primary care clinic, had severe vitamin D deficiency (less than 10 ng/ml [25 nmol/L]).
Vitamin D deficiency leads to poor bone health and development, but also an increased risk of many chronic diseases, including diabetes type 1 and 2, rheumatoid arthritis, Chron's disease, multiple sclerosis, heart disease, stroke, infectious diseases, as well as an increased risk of dying of many deadly forms of cancer, including cancer of the colon, prostate and breast (Holick, 2009).

There is strong epidemiological evidence that exposure to sunlight and vitamin D help to prevent the incidence of metabolic syndrome, obesity, diabetes, atherosclerosis, hypertension, coronary heart disease and stroke (Boucher, 1998; Zittermann et al., 2005; Humble, 2007). Research shows that almost all patients with acute myocardial infarction have vitamin D deficiency, and measures to correct this deficiency may be a simple way to prevent heart disease (Pawlak & Kasprzak, 2011). A sufficiently high serum level of vitamin D (30 ng/ml [75 nmol/L]) can prevent the incidence of both type 1 and type 2 diabetes by 50%, and a serum level of 50 ng/ml [125 nmol/L] can prevent the incidence of type 1 diabetes by 80% (Holick, 2009; Hyppönen et al., 2001).

Sunlight and vitamin D are associated with a significantly decreased risk of dying from many deadly types of cancer, including cancer of the colon, prostate and breast. A sufficiently high serum level of vitamin D (30 ng/ml [75 nmol/L]) can prevent the incidence of all cancers combined by 75% (Holick, 2009). The positive, cancer-preventive effects of sunlight are achieved by regular, short or moderate exposure to sunlight, while excessive exposure has negative effects (Björn & Björn van Praagh, 2005). Sunscreen use may give a false sense of security and may actually increase the risk of melanoma (Goldenhersh and Koslowsky, 2011).

Public health campaigns have been developed to inform the public about the role of UV radiation as the most important environmental risk factor for the development of (non-melanoma) skin cancer. Many of these campaigns advocate a strict 'no sun' policy, which tends to ignore all the positive effects of sunlight, according to Reichrath (2009), who points out that “about 90% of all vitamin D needed by the human body has to be formed in the skin through the action of UVB radiation and it has been shown that strict sun protection causes vitamin D deficiency.”

Grant et al. (2011) have estimated the health benefits of increasing the mean serum concentration of 25(OH)D to 105 nmol/L in the five Nordic countries. According to this study, it is possible to achieve the following reductions of the mortality rates: Denmark 17%, Finland 24%, Iceland 24%, Norway 18%, and Sweden 18%. “Reaching these levels would require changes in health policies with respect to solar ultraviolet-B (UVB) irradiance, vitamin D fortification of food, availability of vitamin D and calcium supplements, and attitude toward use of UVB lamps.” The authors conclude that “Adverse effects of oral vitamin D intake are limited, and those from UVB irradiance are minor compared with the benefits.”

Conclusions

Sunlight is one of the most important environmental factors that influence human health. There is strong evidence in the scientific literature that adequate exposure to sunlight is associated with many physical and mental health benefits, including reduced overall mortality, prevention of many deadly forms of cancer, as well as a number of metabolic, cardiovascular, autoimmune, infectious and neuropsychiatric diseases. Health professionals, patients and the general public should receive more evidence-based information about the many health benefits of sunlight, and how to use it in the prevention and treatment of disease.
References


Pawlak, M., Kasprzak, J.D. (2011). Vitamin D and cardiovascular disease - Recent reports
[Witamina D a rozwój chorób układu kraenia - Przegląd pismiennictwa].
Polski Przegląd Kardiologiczny, 13 (2), pp. 114-117.

to hospitals in Copenhagen during a 10-year period. Acta Paediatrica, 92, pp. 87-90.

Penckofer, S., Kouba, J., Byrn, M., Estwing Ferrans, C. (2010). Vitamin D and depression:
Where is all the sunshine? Issues in Mental Health Nursing, 31 (6), pp. 385-393.

Medical Hypotheses, 73 (1), pp. 94-96.


'acquired' nevocytic nevi and dysplastic nevi is not related to ultraviolet exposure

Reichrath, J. (2009). Skin cancer prevention and UV-protection: How to avoid vitamin D-deficiency?
British Journal of Dermatology, 161 (SUPPL. 3), pp. 54-60.


cancer with vitamin D. Scandinavian Journal of Gastroenterology, 45 (7-8), pp. 775-784.

Roelandts, R. (2002). The history of phototherapy: Something new under the sun?

Inactivation of Selected Viruses and Bacteria in Platelet Concentrates Using Riboflavin and Light.
Transfusion, 44 (6), pp. 877–885.

Rufener, S., Mäusezahl, D., Mosler, H.J., Weingartner, R. (2010). Quality of drinking-water at source
and point-of consumption-Drinking cup as a high potential recontamination risk: A field study in

hydroxyvitamin D and the incidence of acute viral respiratory tract infections in healthy adults.
PLoS ONE, 5 (6), art. no. E11088


Benefits of sunlight: Vitamin D deficiency might increase the risk of sudden unexpected death


Stick, C., Pielke-Harms, L. (2006). Exposure times to acquire a minimal erythemal dose depending on the time of day and on the season - Diagrams for the German coasts [Sonneneexpositionzeiten im tages- und jahresverlauf - Diagramme für die Deutschen küsten]. Physikalische Medizin – Rehabilitationsmedizin – Kurortmedizin, 16 (6), pp. 319-325.


