# Is casual exposure to summer sunlight effective at maintaining adequate vitamin D status?

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## Summary

***Background/purpose:*** The advice that an adequate vitamin D status can be achieved by short, casual exposure to summer sunlight is ubiquitous. This review will examine the value of this advice.
***Methods:*** The results of experimental studies on changes in serum 25-hydroxyvitamin D [25(OH)D] concentrations following ultraviolet exposure are interpreted in the context of human exposure to sunlight.
***Results:*** It is shown that current advice about modest sun exposure during the summer months does little in the way of boosting overall 25(OH)D levels, while sufficient sun exposure that could achieve a worthwhile benefit would compromise skin health.
***Conclusions:*** Failure to understand the nature of human exposure to sunlight has led to misguided advice concerning the sun exposure necessary for an adequate vitamin D status.

The increasing literature suggesting that a number of chronic conditions, notably some internal cancers, might be related to vitamin D status (1, 2) has resulted in a reappraisal of public health advice on sun exposure. Today, we find advice to engage in modest sun exposure on websites of organizations dedicated to reducing the risk of cancer (http://www.sunsmart.org.uk/advice-and-prevention/vitamin-d/index.htm#A) and/or maintaining skin health (http://www.bad.org.uk//site/1221/default.aspx) that would have been absent just a few years ago.

The usual measure of vitamin D status is the circulating concentration of 25-hydroxyvitamin D [25(OH)D], which incorporates both vitamins $D_2$ and $D_3$ from the diet and vitamin $D_3$ from sun exposure. There is no universally agreed classification of vitamin D status, but Table 1 reflects what is probably general consensus (3).

## Public health recommendations on sun exposure

Adequate sun exposure is not easily defined, but one of the leading proponents of the beneficial effects of sun exposure has indicated that exposing the face, hands and arms (approximately 25% of the body surface area) two to three times a week to one-quarter of the exposure necessary to result in one minimal erythema dose (MED) in the spring, summer and autumn corresponds to the ultraviolet (UV) equivalent of an oral dose of 1000 IU vitamin D, which is said to be adequate to satisfy the body's requirement for vitamin D throughout the year (4, 5).

The provenance of this recommendation is unclear. It certainly does not originate from a study carried out in sunlight but most probably is an extrapolation from exposing one or two subjects to whole-body UV irradiation using fluorescent sunlamps, which emit some of their radiation at shorter wavelengths than those found in sunlight. It is not clear whether a correction was made for the differences in both the spectral power distributions of sunlight and fluorescent sunlamps and the action spectra for erythema and the production of previtamin $D_3$ in human skin. If this correction had been made, it would reveal that, for equal erythemal doses, sunlight will be more effective at producing this previtamin than fluorescent sunlamps.

The MED is not a well-defined unit of UV exposure and as a measure of erythemal exposure, the standard erythema dose (SED) is preferred (6); about 2–4 SED of sun exposure is required to produce 1 MED in unacclimatized white skin (7), making 1 SED typically equivalent to about one-third of an MED. So, in other words, receiving an exposure of around 0.75 SED to 25% of the body surface area two to three times a week during those parts of the year when this is feasible in temperate latitudes should be sufficient to prevent vitamin D insufficiency.

On the basis of the self-penned *Holick Formula for Safe Sun* (5), calculations have been made of the associated exposure times at any time of year and geographical latitude to result in one-fourth of an

  

**Table 1.** Serum 25-hydroxyvitamin D [25(OH)D] concentrations that correspond to different levels of vitamin D status (adapted from Pearce and Cheetham (3))

| Serum 25(OH)D (nmol/l) | Vitamin D status | Manifestation |
|---|---|---|
| < 25 | Deficient | Rickets, osteomalacia |
| 25–50 | Insufficient | Associated with disease risk |
| 50–75 | Adequate | Healthy |
| > 75 | Optimal | Healthy |

MED for exposure around solar noon (8). For countries at temperate latitudes, such as the United Kingdom (50–60°N), these exposure times range from around 5 to 15 min in people with skin types ranging from I to IV for mid-summer exposure to around 15–60 min in mid-March and mid-September (8). In the period November through February in the United Kingdom, the solar UV intensity is too low to result in sufficient exposure to reach the equivalent of an oral dose of 1000 IU vitamin D, especially when low ambient temperatures mean it is unlikely that anything more than the face and hands will be exposed when outdoors.

Notwithstanding the uncertainty about its origins, the recommendation for short, casual sun exposure of 5–30 min as adequate for a healthy vitamin D status is ubiquitous. For example, advice from the UK's National Radiological Protection Board (9) (now part of the Health Protection Agency) is that '... short periods outdoors, as normally occur in everyday life, will produce sufficient vitamin D ...', and a recent clinical review (3) recommended that a fair-skinned person exposing the face and forearms for 20–30 min to the summer sun around mid-day two or three times a week is sufficient to achieve adequate vitamin D levels in summer in the United Kingdom. Similar recommendations are mirrored in other countries (10).

As an example of recommendations to the public, we find on the website of the National Osteoporosis Society (http://www.nos.org.uk/NetCommunity/Page.aspx?pid=535, accessed 30 October 2009): 'Exposure to sunlight every day between May and September will increase Vitamin D and help to keep bones healthy.... You should try to get 10 min of sun exposure to your bare skin, once or twice a day (depending on skin type), without sunscreen and taking care not to burn.'

In a recent study (11) designed to examine the effect of this advice on 25(OH)D concentrations, 35% of the body surface of subjects was exposed three times per week for 6 weeks on a sunbed and suncanopy to a UV exposure of 1.3 SED on each visit, which the authors state was the equivalent of 13 min of sunlight exposure on a cloudless summer day at noon in Manchester, United Kingdom (latitude 53°N). What was not stated was that this exposure time only applies to an unshaded, horizontal surface. People lying supine in the sun are irradiated only from above with some lateral, medial and posterior aspects partially or totally protected, whereas in the study, subjects were irradiated from both above and below simultaneously. Therefore, in order to achieve the equivalent magnitude of vitamin D synthesis, it would require a sunbathing subject to lie in the sun for around 26 min (i.e. either all this time supine, or half the time prone and half the time supine).

A similar oversight resulted from a Danish study (12) in which subjects were given 3 SED of simultaneous irradiation to all exposed body sites and this was said to be equivalent to about 30 min of sun exposure in the middle of a clear summer day in Denmark (56°N) when, of course, solar exposure to achieve the same change in 25(OH)D in a horizontal subject would require about twice this time.

But, more importantly, in both these experimental studies as well as in much public health advice, the confounding factors of posture, orientation with respect to the sun and the strong influence of nearby shade appear not to be appreciated. Certainly, lying horizontal under unshaded, cloudless skies at noon is not what most people would understand by casual exposure. Yet, these critical constraints seem to have been overlooked in public health recommendations and in studies aimed at determining sun exposure times to synthesize vitamin D (13).

The human form, by virtue of its complex geometry, receives highly variable solar exposure across its surface area. People spend most of their time upright and move randomly outdoors with respect to the sun. Measurements of solar UV on a rotating vertical plane (simulating random motion outdoors) indicated a mean irradiance of about one-third that on a horizontal plane when the solar altitude is above 30° (14), as it is at midday between March and October in the United Kingdom. More complex estimates of the irradiance at different sites over the body surface relative to a horizontal plane (15) examined in more detail the influence of solar altitude and orientation with respect to the sun. While there are large differences depending on both variables, especially the latter, the average relative irradiance across the face was 67%, 38% and 24% for solar altitudes of 25°, 45° and 65°, respectively. However, at solar altitudes below about 45°, the solar UVB intensity is sufficiently weak that biological activity in the skin (either erythema or vitamin D synthesis) is low. Consequently, as a rule of thumb, we can say that an ambulant subject moving randomly under an open sky between mid-morning and mid-afternoon during the summer season receives an exemplary exposure of one-third that of ambient on a horizontal surface.

These values apply to an ambulant subject with no shade nearby. When the influence of shade is factored in, a person walking around in an urban environment would receive an exposure on vertical body surfaces (hands, face, arms, legs) of typically one-sixth (16) of the ambient exposure on an unshaded, horizontal surface due to the combined effect of body geometry, random orientation with respect to the sun and partial obstruction of the sky (and possibly direct shading of sunlight) by nearby buildings. And on cloudy days, the relative irradiance on vertical body surfaces would be considerably less compared with ambient irradiance on clear sky days for which recommendations about adequate sun exposure have been made.

This estimate of the impact of posture and environment is supported by a wealth of measured data on personal exposure to sunlight. For example, the most extensive series of personal dosimetry studies to date carried out in Denmark (17) measured a median summer workday exposure of indoor workers of 0.2 SED (under what the author terms 'non-risk behaviour'), and 1.1 SED on workdays with what is termed 'risk behaviour'. On non-workdays during the summer (e.g. weekends), the corresponding median daily exposure was 0.5 and 2.9 SED for days of non-risk behaviour and risk behaviour, respectively. These data would suggest that 'short, casual exposure' equates to approximately 0.2 SED, i.e. about one-sixth of 1.3 SED, and that a dose of 1.3 SED would be regarded by the Danish group as being associated with risky behaviour.

The Manchester study (11) showed by careful experimentation that after 6 weeks, with a UV exposure of 1.3 SED on each visit, their protocol resulted in subjects achieving a mean 25(OH)D concentration from a baseline of 44 to 70 nmol/l, i.e. a mean increase of 26 nmol/l. But rather than this exposure regime simulating 13 min of casual exposure, it more closely reflects either sunbathing horizontally while being informally dressed for 20–30 min around the middle of a cloudless day in midsummer or the exposure of an ambulant subject in an urban environment during a period of about 1 h; either exposure is not what most people would understand by 'short, casual exposure'. And given that most people, especially during the working week, would not be dressed informally and might have only about 10–20% of their body surface area exposed, achieving an increase in serum 25(OH)D of 26 nmol/l over the summer period might require about 2 h sun exposure in an urban environment a few times per week. This assumes that vitamin D synthesis increases in proportion to exposed body surface area, an assumption that is probably not true (18).

This mean increase in serum 25(OH)D of 26 nmol/l is similar to the mean difference between summer and winter 25(OH)D concentrations found in many observational studies (Table 2). A study of note is that by Hyppönen and Power (26) who measured serum 25(OH)D concentrations in over 7000 white British people from the 1958 birth cohort when they were 45 years of age during the period September 2002 to April 2004. Detailed results were presented, including the average 25(OH)D stratified by season and region of residence, as well as time spent outdoors at different times of the year. They found that during the summer, just 5.5% of respondents claimed to spend $<30$ min/day outdoors, with 42.1% spending between 0.5 to 3 h and 52.4% spending 3 h or more outdoors per day; clearly, the vast majority of people spending much longer than 20–30 min outdoors two or three times per week but still only achieving a mean summer to winter difference of 19.2 nmol/l (Table 2). These times outdoors are similar to those observed in a Danish study (27), where during a summer season, a mean of 2.9 h (range 0.3–6.5 h)/day was spent outdoors. It is evident that current public health advice about 10–20 min of daily casual sun exposure during the summer months, if then followed by sun avoidance, would do little in the way of significantly boosting overall 25(OH)D levels, a view shared by others (10).

## Improving the impact of sunlight on vitamin D status

So what might reasonably be done to improve the beneficial impact of solar UV exposure? Because sun exposure regulates the cutaneous production of vitamin D by causing its photodegradation (31), the production of vitamin D is limited, no matter how long a person is exposed to sunlight. Hence, not only is it not possible to synthesize large stocks of cutaneous vitamin D by prolonged sun exposure, but doing so simply increases the risk of adverse consequences. In practice, there is no benefit in a daily exposure in excess of a few SED, achieved through prolonged exposure in combination with avoiding shade and/or orientation of body sites more directly to the sun, such as occurs in sunbathing.

Advising people to expose more skin during the working week is unlikely to be successful, given the many demands on time in our urban societies. However, there is greater opportunity at weekends through encouraging outdoor physical activity. Not only would this be beneficial to health in terms of obesity, diabetes and coronary disease, but people would also receive some subliminal UV exposure to a greater fraction of the body

**Table 2.** The variation in serum 25-hydroxyvitamin D [25(OH)D] concentrations with season and latitude

| | | | | Serum 25(OH)D (nmol/l) | | |
|---|---|---|---|---|---|---|
| Location | Reference | Latitude | Sex | Winter | Summer | Difference |
| Miami | (19) | 26°N | Male | 62.3 | 77.5 | 15.3 |
| Miami | (19) | 26°N | Female | 56.0 | 62.5 | 6.5 |
| Geelong | (20) | 38°S | Both | 50.0 | 78.0 | 28.0 |
| Boston | (21) | 42°N | Female | 60.0 | 85.4 | 25.4 |
| Kalamazoo, MI | (22) | 42°N | Both | 30.0 | 57.0 | 27.0 |
| SW Germany | (23) | 49°N | Both | 51.3 | 84.5 | 33.3 |
| Calgary | (24) | 51°N | Both | 57.3 | 71.6 | 14.3 |
| Bristol | (25) | 51°N | Both | 36.3 | 65.8 | 29.5 |
| Great Britain | (26) | 50–60°N | Both | 41.1 | 60.3 | 19.2 |
| Denmark | (27) | 56°N | Both | 56.4 | 82.2 | 25.8 |
| Aberdeen | (28) | 57°N | Female | 49.0 | 59.0 | 10.0 |
| Helsinki | (29) | 60°N | Both | 29.0 | 64.0 | 35.0 |
| Norway | (30) | 68°N | Both | 49.5 | 62.0 | 12.5 |
| Average $\pm$ SD | | | | $48.3 \pm 11.0$ | $70.0 \pm 10.3$ | $21.7 \pm 9.2$ |



 

surface in the process. But would the magnitude of UV exposure necessary to achieve a worthwhile benefit compromise skin health?

A mathematical model (32) for estimating the variation of serum 25(OH)D concentration throughout the year as a consequence of sun exposure, and which uses as input variables ambient solar UV, time spent and behaviour outdoors, and area of skin exposed, was used to explore possibilities.

The model was run for the British population using as input variables the geographical and behavioural characteristics summarized by Hyppönen and Power (26). This type of behaviour, exemplified by the image shown in Fig. 1a, resulted in variations in serum 25(OH)D throughout the year indicated by the lower curve in Fig. 2. The model was run again with the same inputs but with the addition that for 2 h on 1 day each week from April through September, the UV exposure on exposed body sites relative to ambient was increased to reflect activity in a largely non-shaded environment, and the fraction of body surface exposed increased to reflect someone dressed in shorts and a short-sleeved shirt. Under these conditions, exemplified by the image shown in Fig. 1b, sub-erythemal exposure is still achieved for average levels of ambient summer UV in the United Kingdom.

With this approach of no advice concerning sun exposure during weekdays but only recommendation to engage in unprotected outdoor activity for 2 h on 1 weekend day between April and September, increased summer levels of serum 25(OH)D are predicted to result (upper curve, Fig. 2), but that during the winter months, there is little extra benefit to be had compared with the seasonal pattern shown by the lower curve in Fig. 2.

This example uses *average* daily ambient UV exposure for each month as an input variable and presumes that topical sunscreen has *not* been applied. Under these conditions in mid-summer in the United Kingdom, the UV Index (33) is around 4–5, increasing to 6–7 on days with no clouds and clear skies.

Consequently, advice to spend 2 h around midday without applying sunscreen and moving around upright in a largely unshaded environment during the summer months can result in either sub- or supra-erythemal exposure, depending on the prevailing conditions, that could compromise skin health. Hence, there appears to be little in the way of public health advice concerning the benefits of sun exposure that can be given as an effective means of maintaining 'adequate' vitamin D levels throughout the year. Instead, it has been argued that it would be safer and more effective to fortify more foods with vitamin D (34) and/or to consider the use of supplements during the winter months.

Failure to understand the nature of human exposure to sunlight has led to misguided advice concerning the sun exposure necessary for adequate vitamin D status (13, 35). Messages concerning sun exposure should remain focused on the detrimental effects of excessive sun exposure and avoid giving specific advice on what may be thought to be 'optimal' sun exposure. There already are seasonal variations in 25(OH)D reflecting changing behaviour and ambient UV, as a consequence of the desire of most people living in countries like the United Kingdom to take advantage of sun exposure whenever possible. Trying to improve on vitamin D status through sun exposure without compromising skin health is problematic.

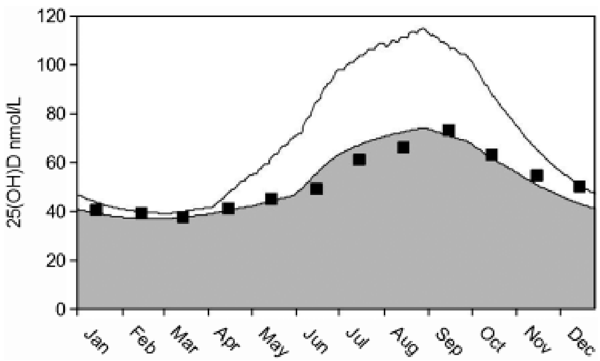


**Fig. 2.** Modelled annual variation in serum 25-hydroxyvitamin D [25(OH)D] (lower curve) using as input variables the geographical and behavioural characteristics of British people summarized by Hyppönen and Power (26), and the annual variation predicted for an exposure regime incorporating additionally 1 day of outdoor activity for 2 h each week dressed in shorts and a short-sleeved shirt between April and September (upper curve). The solid data points represent the geometric mean monthly serum 25(OH)D concentrations measured by Hyppönen and Power (26).


**Fig. 1.** Typical outdoor behaviour (a) during the working week in an urban environment and (b) during recreational activity in a largely unshaded environment.

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