REVIEW

Sunlight robbery: A critique of public health policy on vitamin D in the UK

Oliver Gillie

Health Research Forum, London, UK

The British Isles have a very cloudy climate and as a result receive fewer hours of clear sunlight than most other industrial regions. The majority of people in these islands have low blood levels of vitamin D [25(OH)D] all year round. Few food products are fortified with vitamin D in the UK and the government does not recommend any vitamin D supplement for most adults in the UK. Diseases associated with vitamin D insufficiency such as cancer, heart disease, diabetes (types 1 and 2) and multiple sclerosis are more frequent in the UK, and particularly in Scotland, than in many other European countries and some, such as multiple sclerosis and diabetes (types 1 and 2), are increasing in incidence. Present knowledge suggests that the risk of some chronic diseases could be reduced if vitamin D intake or sun exposure of the population were increased. Yet policy and public health recommendations of the UK government and its agencies (*e.g.* the Health Protection Agency, the Food Standards Agency) and of Cancer Research UK have failed to take full account of established and putative benefits of vitamin D and/or sunshine. The epidemic of chronic disease in the UK, which is associated with and caused at least in part by vitamin D insufficiency, has not been adequately recognized by these agencies, and too often measures taken by them have been misguided, inappropriate or ineffective.

Received: December 9, 2009
Revised: February 15, 2010
Accepted: February 19, 2010

Keywords:
Cancer / Pregnancy / Public health / Sun / Vitamin D

1 Introduction

The British Isles has one of the least sunny climates of any region in the industrial world [1, 2]. A high latitude, together with cloudy weather and modern indoor living, combines to give people in the UK and Ireland low average levels of vitamin D [25(OH)D] in their blood [3–5]. It is vital therefore that the governments of the UK and the Irish Republic have policies on sunshine and vitamin D that take account of our weather.

Until now UK policy on sun exposure has followed international lines that have been developed in Australia and the United States and have been promoted by WHO [6, 7]. These are aimed at reducing skin cancer and advise avoidance of direct sun in the middle of the day and use of suncream. UK policy on vitamin D has, on the other hand, been idiosyncratic in so far as it advises that no vitamin D supplement is generally needed by babies until they are 6 months old [8, 9], is opposed to fortification of milk and most other products, and insists that no vitamin D supplement is needed by the majority of healthy adults [10]. So we are victims not only of our challenging climate but also of public health policies that maintain low levels of sun exposure as well as a low intake of dietary and supplementary vitamin D.

With hindsight it can be seen that it was unwise for advice on sun-exposure in the UK to be based on experience in Australia whose climate reaches into the sub-tropical zone, or on experience in the United States, which has abundant continental sunshine, particularly in the south and on the highly elevated central plain. Advice given to the British and Irish public in the past has in effect caused those

Correspondence: Dr. Oliver Gillie, Health Research Forum, 68 Whitehall Park, London N19 3TN, UK
E-mail: olivergillie@blueyonder.co.uk

Abbreviations: CR UK, Cancer Research UK; **DALYs,** disability-adjusted life years; **MS,** multiple sclerosis; **NICE,** National Institute for Clinical Evidence; **SACN,** Scientific Advisory Committee on Nutrition; **UVB,** ultraviolet B who fully implement it to be deprived of virtually all sun exposure [11]. Fortunately, as research has amply shown, many people do not respond to health messages, especially when the message is in conflict with personal perceptions of good health, *e.g.* a rosy or tanned as opposed to a pale complexion, and feels wrong, as sun avoidance messages have for many people in the UK [12–16].

Cancer Research UK (CR UK), the major UK source of advice on sun exposure, and the UK government's Health Protection Agency now appear to have recognized that their previous warnings to avoid exposure to sunlight were mistaken, based as they were on questionable assumptions and an inadequate appraisal of scientific evidence (http://www.healthresearchforum.org.uk/reports/scotland.pdf) [17, 18]. The latest advice from these authorities puts more emphasis on avoidance of burning than avoidance of sunshine (see Table 1). However CR UK and Health Protection Agency have not yet made it clear that people need to have some minimal sun exposure in order to maintain a healthy vitamin D level [25(OH)D], and they have not issued any corrective advertising warning of the danger of their previous advice, especially when adopted in full [19]. In addition CR UK has pursued a hostile campaign against sunbeds, which could be an effective and popular source of extra vitamin D [19].

Issues concerned with sun exposure and vitamin D have gained urgency following recognition of evidence linking vitamin D insufficiency with a wide range of chronic disease including heart disease, cancer, diabetes (types 1 and 2), multiple sclerosis (MS) and other ills [20–28]. However the strength of evidence supporting a causal role for vitamin D insufficiency in cancer has been challenged by the International Agency for Research in Cancer, Lyons, in a report [29], which has proved to be controversial [30, 31] but nevertheless influential. Causality of vitamin D insufficiency for a number of conditions has been found in controlled clinical trials [32–36]. Other evidence suggesting that vitamin D insufficiency causes chronic disease may be considered persuasive because of its consistency, its compliance with the Bradford–Hill criteria and an established mechanism based on sound laboratory work [20, 25, 37–43], together with support from evidence for reduction in mortality on meta-analysis of clinical trials of vitamin D supplementation [44].

Table 1. The SunSmart advice from CR UK

SunSmart advice pre-2006	SunSmart advice in 2006
• Stay in shade between 11 am and 3 pm • Make sure you never burn • Always cover up • Remember to take extra care of children • Then use factor 15 sunscreen More detailed instructions included the injunction to put on large amounts of suncream 20 min before going out into the sun, and to wear a hat. Favourite CR UK slogans were: "Keep your shirt on" and "There's no such thing as a healthy tan"	• Spend time in the shade between 11 am and 3 pm • Aim to cover up with T-shirt, hat • Remember to take extra care of children • Then use factor 15+sunscreen CR UK's message now emphasizes avoidance of burning. But CR UK has not announced its change of message and insists: "We never told people to avoid the sun."

2 Terminology

Vitamin D is most commonly measured in serum as 25-hydroxyvitamin D [25(OH) D] and this is the measure referred to wherever blood levels are mentioned in this review. Measurement of 25(OH) D is considered to be the best way of comparing blood levels of the vitamin in individuals and populations. Otherwise, when the word vitamin D is used in this article it refers to vitamin D3, also known as cholecalciferol, which is the product of chemical reactions in the skin that are catalyzed by sunlight and heat. Vitamin D3 also occurs in foods of animal origin whereas vitamin D2, or ergocalciferol, occurs in some fungi especially if they are exposed to the sun.

The British Isles comprise the United Kingdom (England, Scotland, Wales and Northern Ireland), the Isle of Man, the Channel Islands, and the Republic of Ireland. This geographical term is used here and from time to time elsewhere in this article because the common climate of these islands provides limitations on the maximum amount of vitamin D that can be acquired by the majority of the inhabitants. However most of the epidemiological evidence comes from studies undertaken either in the UK as a whole, or separately in England and Wales (often jointly) or Scotland, as I have endeavoured to make clear.

3 Why the British Isles get so little sun

Understanding of vitamin D insufficiency in the British Isles may be assisted by consideration of its climate and geographical position. The British Isles are located much further north than most people imagine. New England and Old England are often thought to lie at the same latitude and have similar climates. In fact their climates are very different and so Boston, which is often taken as a guide for advice on sun exposure in the UK, is not a suitable comparator unless corrections are made to allow for the different average daily intensity of solar ultraviolet B (UVB) and its seasonal variation. The British Isles extend from latitude 50 to 60 degrees. They begin in the south with the Channel Islands, adjacent to Brittany (northern France) and end with the Shetland Islands, which lie some 300 miles due west of the mid-Norwegian coast. Much of the British Isles is in fact on the same latitude as Labrador, Hudson's Bay or the Alaskan panhandle.

The climate of the British Isles is much influenced by warm water from the Gulf Stream, which ensures that our weather is temperate and snow seldom lies more than a few days in lowland areas. But the apparent mildness of the climate is deceptive. All of Europe lies above 40 degrees of latitude and so the sun is not strong enough during winter to enable much if any penetration of UVB to earth [45]. This ''vitamin D winter'' lasts for a period of 2 or 3 months in southern Spain to around 6 months in Scotland and Scandinavia. The climate of the British Isles is made even more extreme by cloud cover, which may reduce the amount of UVB that is effective in producing vitamin D to annual levels found in the Arctic [1].

The prevailing wind over the British Isles is from the west bringing with it rain and cloud. Much of this precipitation lands on Ireland explaining why grass grows so well there and why Ireland is known as the ''emerald isle''. The Irish landmass together with the mountains of Wales and Cumbria (in north east England) draw down rain and snow reducing cloud cover reaching eastwards and allowing greater penetration of sunlight over Eastern England. However Scotland is not protected by Ireland to the west so that wet cloudy winds can come in freely from the Atlantic, blowing down the lowland corridor, which links Glasgow and Edinburgh where the majority of Scots live. This explains why Scotland gets so little UVB and may account at least in part for the higher mortality in Scotland compared with England [17]. Premature mortality in Scots living in the Glasgow–Edinburgh central belt is close to that of the former East Germany (German Democratic Republic) and is the highest in Europe [46]. The high mortality of Scots cannot be fully explained by established risk factors such as smoking, drinking, diet and poverty [47]. This difference in mortality is known to epidemiologists as the ''Scottish effect'' and is evident when each social class is separately compared with England [47]. Norway, like Scotland, is exposed to prevailing wet westerly winds but Norwegians eat twice as much fish as Scots and many take a daily cod liver oil supplement, which is the best natural food source of vitamin D [48, 49].

Sweden, which generally has better health than Scotland, is given some protection from wet westerly winds by the mountains that separate it from Norway. Lund in Sweden is on the same latitude as Glasgow but gets on average about 50% more biological active UV radiation annually [1]. In fact Glasgow gets little more UVB annually than Kiruna, a Swedish town lying inside the Arctic Circle. So Glaswegians may get about the same annual dose of UVB as Inuit people living in the Arctic, but lack the advantages of their marine diet, which is naturally high in vitamin D. Telling evidence demonstrating Britain's low-sunlight climate comes from its sheep. In northern England and Scotland sheep, which remain outdoors all year round, have been found to suffer from rickets characterized by low levels of 25(OH)D. Farmers have been advised to treat the sheep with vitamin D supplements [50].

4 Evidence from evolution should be considered

The indigenous inhabitants of northern Europe have particularly pale skins. Skin color measured as UV reflectance is generally correlated geographically with the intensity of UV radiation from the sun and with latitude [51]. White skin has been found to make vitamin D some six to ten times faster than dark brown or black skin [52–54], although under certain conditions black and white skin may perform equally [55]. It has been widely accepted that white skin has an advantage of being able to make vitamin D more efficiently when light intensities are low because of cloud or because the summer season is near the beginning or end [52]. In effect, a white skin may extend the length of the summer season when vitamin D can be synthesized in Europe. Extension of the summer season is particularly important because, even though vitamin D reserves in the body have a relatively long half life of around 4–6 wk, blood levels [25(OH)D] become very low by the end of the long northern winter [56].

These considerations suggest that evolution of a new vitamin D economy has been important for human survival in Europe. Pale skin has probably evolved in higher latitudes by active selection for genotypes that are able to accrue and conserve more vitamin D [57, 58]. Vitamin D deficiency during pregnancy is associated with a number of adverse outcomes including increased risk of pre-eclampsia and gestational diabetes, as well as being crucial for development of the fetal brain and other organs and for protection against infections such as tuberculosis [59–63]. Selection pressure must have been intense to have driven the evolution of white skin in Europe suggesting that we need an optimal intake and synthesis of vitamin D for full Darwinian fitness, *i.e.* for full health that enables us to reproduce successfully [61, 64, 65]. If this argument is accepted as broadly correct then adoption of measures that needlessly restrict sun exposure in northern Europe has the effect of denying the accumulated advantages of some thousands of years of evolution.

Our vitamin D economy is in acute crisis today because modern Europeans have an indoor lifestyle encouraged by television, computers and other electronic entertainment as well as central heating and air conditioning. Furthermore we use sunscreens, now commonly included in cosmetics, that block UVB and hence synthesis of vitamin D in skin [66]. Much of our activity, even exercise, occurs indoors in artificial light or light filtered through window glass, which contains much UVA but no UVB. UVA actually breaks down pre-vitamin D in the skin with an entirely negative effect on balance of the vitamin [67, 68].

5 Australian advice for British people

Concern to prevent skin cancer led to the first strict "no-sun policy" in Australia in the early 1980s and this in turn led to a globally targeted programme organized by WHO [6]. It soon became conventional wisdom that *any* sun exposure during the 4 h around noon held a substantial risk of inducing skin cancer (see Table 1). Advice to avoid the sun was given out to the public all over the modern industrial world by WHO [69] (http://www.who.int/uv/intersunprogramme/en/) with little regard for differences in climate in different regions. The conflict between this advice and the need to obtain vitamin D for healthy development of bone was noted by the UK government's COMA committee (Committee on Medical Aspects of Food Policy) but was never resolved [70]. The suitability of this no-sun advice for the British Isles was challenged publicly by a book published in 2004 called *Sunlight Robbery: Health benefits of sunlight are denied by current public health policies in the UK*. This book spelled out the problem of vitamin D insufficiency in the UK and provided new advice to the public on sun exposure [11].

CR UK called its advice "SunSmart" and it appears to be based on an Australian programme with the same name. Australians, who are predominantly of British/Irish ancestry, need to be careful to avoid excessive sun exposure in Australia because the sun is so much stronger there. The incidence of malignant melanoma in Australia is about four times that of the UK but mortality from the disease is only about twice that of Britain [71]. The relatively high incidence in Australia is the result of screening together with a possibly broader diagnostic classification of skin lesions many of which have little potential for spread and have a low effect on mortality [72]. In the UK in 2007 there were 10 400 diagnoses of melanoma and 2047 deaths from the disease [73]. Deaths in the UK have increased from just over one *per* 100 000 in 1970 to 2.7 deaths *per* 100 000 in 2007 [73]. This compares with a much higher incidence of colorectal and breast cancers, which may be prevented by sun exposure [74]. In the UK there were 37 500 diagnoses and 16 000 deaths *per* year from colorectal cancer (incidence of deaths: 11.1 *per* 100 000), and 45 500 diagnoses and 12 000 deaths *per* year from breast cancer (incidence of deaths: 14.6 *per* 100 000), 2007 figures [73] (http://info.cancerresearchuk.org/cancerstats/).

Sunlight is widely recognized as an important risk factor for melanoma but the relationship is not simple. A meta-analysis of 57 studies suggests that a high continuous pattern of sun exposure is associated with reduced risk of melanoma, possibly because it maintains high vitamin D levels [25(OH)D] that protect against ill effects of UV radiation [75], yet there is an increased risk of melanoma from intermittent sun exposure, probably because it is associated with an increased risk of burning [76]. This is consistent with the well-established observation that outdoor workers have a lower risk of melanoma than others [77, 78]. People with more than 25 nevi or more than one atypical nevus are at higher than average risk of developing melanoma [79] while those with a Celtic genetic background may also be at higher risk [80] although this familial risk has been estimated to be very small [81]. Other factors that probably contribute to a higher risk of melanoma are immune suppression, diet, pesticide exposure, adsorbed hydrocarbons from polluted air and increased UVA exposures, which come from suncream usage and indoor lighting [66–68, 82–86]. On the other side of the equation the risk of breast and bowel cancer and much other disease may be reduced by vitamin D [42, 87–90] and hence by sunlight, which is our major source of the vitamin.

Australian authorities have become aware recently of the danger of vitamin D insufficiency if sun avoidance is too strict [91]. So Australians are now told by the Cancer Council of Australia to be sure to get some sun exposure to secure their supply of vitamin D [92]. (http://www.cancer.org.au/documents/Risks_Benefits_Sun_Exposure_MAR05.pdf). Unfortunately this new Australian advice does not appear to have been accepted yet in the UK.

6 Advice on sun exposure in the UK

The original SunSmart advice from CR UK (see Table 1) contains no positive statements about benefits of sunlight, only negative ones. In its original form, which remained in use until 2006, the CR UK SunSmart advice actively discouraged people from sun exposure of any kind. The SunSmart advice was written and approved by the UK Skin Cancer Working Party, a committee that draws its members mostly from the British Association of Dermatologists. It included no representatives from other disciplines in clinical medicine or for parts of the anatomy other than skin. Advice to avoid the sun, as given in the past by SunSmart in the UK, may have increased risks, not only of bone disease, but also of other chronic diseases likely to be caused at least in part by vitamin D insufficiency, including internal cancers [89, 90, 93]. Evidence showing that cancer patients diagnosed in summer do better than those diagnosed in winter suggests that exposure to sunlight may prolong the life of cancer patients, including those with melanoma, even after the tumour is well established [94]. The benefits of sun exposure in preventing cancer and other chronic disease are estimated by some authorities to substantially exceed any risk of skin cancer coming from sun exposure [95–98].

Moan *et al.* estimate that an increase in sun exposure, which might double the number of melanoma skin cancers, might save ten times more people from dying of internal cancers. In addition increased sun exposure might be expected to extend the life of people with cancer and reduce the risk of heart disease, diabetes (types 1 and 2) and many other diseases [95]. Lucas *et al.* have estimated the overall burden of disease considered to be caused by different types of sun exposure using disability-adjusted life years (DALYs).

DALYs are a time-based measure that combine years of life lost due to premature mortality and years of life lost due to time lived in states of less than full health [99]. Using this approach Lucas shows that UVR exposure is a minor contributor to the world's disease burden, causing an estimated annual loss of 1.6 million DALYs; *i.e.* 0.1% of the total global disease burden. However a markedly larger annual disease burden, 3.3 billion DALYs, might result from reduction in global UVR exposure to very low levels [99] by sun avoidance of the type that has been recommended by CR UK and other authorities (''no sun policy'') [6]. If this is the case then the WHO initiative on sun exposure, of which CR UK's SunSmart strategy is one example, must have caused more disease, including cancer, than it could ever prevent and been responsible for an excess of premature deaths over the years.

For these reasons it can be argued that the SunSmart programme should be abandoned and replaced with a positive programme such as the SunSafe advice (see Table 2). This is based on avoidance of sunburn together with a commonsense approach that prevailed in the UK before the SunSmart initiative. Since this suggestion was made, CR UK has modified the SunSmart message in small but significant ways (Table 1). It no longer advises ''stay in the shade between 11 am and 3 pm'' but now tells the public to ''spend time in the shade between 11 am and 3 pm'', and instead of telling people to ''always cover up'' it now advises much less categorically that people should ''aim to cover up''.

Table 2. The SunSafe advice from Health Research Forum

1. Sunbathe safely without burning – whenever you can
2. The middle of the day is a good time for sunbathing in the UK because UVB, which generates vitamin D in skin, is most intense at this time
3. Remove as many clothes as you can. Start by sunbathing for 2–3 min each side. Gradually increase from day to day to a maximum of half an hour *per* side in the UK, less abroad
4. Be cautious. Remember intensity of sun varies with season, time of day and cloud, and allow for differences between individuals in skin tone. Never bake
5. Do not use sunscreen creams while aiming to boost vitamin D
6. If feeling hot or uncomfortable expose a different area, cover up, or move into the shade. If continued exposure cannot be avoided, as in some sports, use sunscreen cream
7. The face is easily over-exposed so it makes sense to wear a hat when sunbathing and when in the sun for a prolonged time
8. When abroad, where the sun is generally stronger, expose your body for much shorter times until you find out how much is safe
9. Children benefit from sun exposure, but need guidance
10. A tan is natural and is generally associated with good health

The SunSafe advice encourages safe, careful sunbathing and safe exposure to the sun, which is our major source of vitamin D. Safe sunbathing raises vitamin D levels and so contributes to prevention of chronic disease caused by insufficient vitamin D. The SunSafe advice is based on up-to-date scientific evidence and on the commonsense approach to sun exposure that was taken in the UK before sun avoidance was promoted by CR UK's SunSmart advice. This guidance is aimed at people resident in the UK and Ireland, although general principles apply everywhere and extra care is advised abroad.

These new exhortations obviously allow for the possibility of some sun exposure and for a defense of the SunSmart advice, either legally, should it be challenged in the courts as the cause of illness, or in the media. However CR UK still does not advise any sun exposure beyond that which might be obtained casually during normal outside activities, nor does it suggest taking a vitamin D supplement to compensate for its advice to limit sun exposure. In September 2009 the CR UK website said: ''everyday casual sun exposure – rather than sunbathing – probably gives most people enough vitamin D.'' This is in conflict with evidence that around three quarters of the UK population have sub-optimal levels of vitamin D [25(OH)D] even in summer, and many are deficient [3]. Casual exposure in the UK cannot provide sufficient vitamin D, although it might possibly do so in Australia or the southern United States [3, 18, 65, 100–102]. Unacknowledged assumptions that intensity of sunlight and length of season provide similar opportunities for casual exposure in different countries or different parts of the UK appear to lie behind this assertion.

In 2002 a report of the UK National Radiological Protection Board asserted that ''10–15 min [sunlight] on unprotected hands and face in summer is all that is needed'' and that ''an adequate vitamin D status [could be maintained] with short exposures to sunlight, as encountered in everyday life (*e.g.* a walk to shops/school)''. This ''casual exposure'' advice was based on simple but defective logic: what you get is what you need. In fact there was never any cogent scientific evidence to support the idea that such limited exposure is sufficient [11].

In May 2007 UK's Scientific Advisory Committee on Nutrition (SACN) published a report, *Update on Vitamin D*. It acknowledged evidence for the health benefits of vitamin D but said the evidence was inconclusive and recommended no change in existing advice to the public. The official view, as expressed in the SACN report, remained that adults in the UK who are mobile and able to go out of the home obtain sufficient vitamin D by casual exposure to the sun and active sunbathing is not recommended [103]. Nevertheless in December 2007 the UK government gave pregnant and nursing mothers new advice warning that ''increasing numbers of children [are] at risk of vitamin D deficiency in the UK'' (http://nds.coi.gov.uk/content/detail.aspx?NewsAreaId = 2&ReleaseID = 341224&SubjectId = 2) [104]. This new advice recognized for the first time that food alone and casual exposure of hands and face to the sun does not provide enough vitamin D in the UK: ''It takes only 15 min exposure of the arms, head and shoulders in the sun each day during the summer months to make enough vitamin D for good health.'' The recommendation of a 15 min exposure appears to be based on Holick's ''Safe Sun Tables'' [105]. These suggest that a 15 min exposure of hands and arms may provide a light skinned person in the UK with between 800 and 1500 IU of vitamin D. Experiments undertaken by CR UK confirm that this appears to be a reasonable approximation [106, 107]. Rhodes *et al.* studied the effect of sunlamp treatment (from a Philips HB59B sunbed), which closely simulated midday summer sun in Manchester (53.8 degrees North), on 120 white volunteers who wore only a T shirt and shorts [106]. The 13 min sub-erythemal doses (1.3 SED) were given in winter when blood levels of vitamin D [25(OH)D] are low. After three exposures *per* week for 6 wk only 26% of the volunteers obtained optimum blood levels (>32 ng/mL or 80 nmol/L) as a result of the treatments. The Manchester researchers asked the question: ''Does the level of summer sunlight exposure recommended by UK national policy produce sufficient vitamin D levels?'' Their answer was ''NO!'', written in large capitals on the poster presenting their results at the 14th International Workshop on Vitamin D in Bruges [107].

In fact the 2007 advice from the Department of Health does not recommend sufficient sun exposure to provide enough vitamin D to maintain blood levels of the vitamin [25(OH)D] at an optimum through the winter. A person needs to accumulate three or four times the daily optimum requirement on days when sun exposure is possible in order to provide for sunless summer days and for the winter months when the sun is not strong enough to make any vitamin D. Therefore to get optimum benefit from the sun in the UK people need to sunbathe more than three times a week if possible, exposing as much skin as possible, and/or sunbathe for longer than 13 min a day. Such increases in exposure can be difficult to achieve in the UK especially when sunny weather seldom lasts for more than a few days. Six consecutive weeks of weather that allow regular sunbathing, as in the Manchester sunlamp experiment, is almost unheard of in the UK. Furthermore someone sunbathing outside the peak midday hours or outside the midsummer months would have to remain in the sun for longer than 13 min to obtain an appreciable vitamin D increment.

Indeed a person living in the British Isles may need to expose as much of their body to the sun as possible for at least 40 min (20 min each side) or more, 6 days a week, to obtain sufficient vitamin D to last all year round. But this is not possible when the number of sunless summer days in the British Isles is taken into account. And so we may arrive at a simple conclusion: British and Irish people should sunbathe as often as possible, wearing as little as possible, for as long as possible without burning while resident in the British Isles [17, 18]. This is the best general advice that may be given and is particularly important for those people who do not take supplements.

It is often said that there is no point in exposing the body to the sun for longer than 20–30 min because maximum production of previtamin D by photolysis of 7-dehydrocholesterol in equatorial sunlight is achieved within that time [108] as the various processes of synthesis and breakdown reach equilibrium [109, 110]. However the time taken to reach equilibrium depends on the intensity of the sun and therefore on season, latitude, time of day and presence or absence of haze in the atmosphere. Except for midday on a clear day in midsummer (the nearest to equatorial conditions) it is likely to take considerably longer than 30 min for equilibrium to be reached. Furthermore the 30 min figure refers to a two dimensional area of skin presented to the light source. It will take three or four times as long for a three-dimensional body, presenting each surface in turn to the sun, to be fully exposed to the light source on all sides. The intensity of exposure also depends on anatomical orientation. A person lying prone at roughly right angles to the sun will receive more intense radiation *per* square centimeter than a person standing upright and receiving the sun's rays at an angle. Therefore, if a person is accustomed to sun exposure and conditions are suitable, vitamin D may continue to be produced usefully for well over an hour of exposure to the sun and often for as long as 3 or 4 h on a hazy summer day in the UK or Ireland.

Even so, in practice it is very difficult for anyone living in the UK to get enough vitamin D from the sun to provide them with an optimum blood level [25(OH)D] that will last through the winter. Some outdoor workers may be able to do it but even farmers these days drive tractors with air-conditioned cabs. Unlike New England where shorts are commonly worn in summer, very few people in Old England wear shorts, except for sports or on the beach. Few school children in Britain now wear shorts like they used to do. In the north of England and Scotland summer and winter clothing are often much the same except for a sweater and a heavy overcoat. So, very few people in the UK get enough vitamin D from the sun alone. Those who may are sports teachers, agricultural workers and men in the building trade, who may wear shorts and remove their shirts so they can sweat freely. So we may conclude that almost everyone living in the British Isles should take a vitamin D supplement, at least in winter, in addition to safe sunbathing in summer. Indeed advice to take 1500–2000 IU of vitamin D in winter has now been given by BUPA, Britain's largest independent health insurance provider (http://www.bupa.com/mediacentre/press-releases/161209-bupa-vitamin-d-cancer-announcement) [111].

These conclusions are borne out by a study of young adults in California, which involved measurements of sun exposure, vitamin D intake and skin reflectance together with serum levels of vitamin D [25(OH)D] [112]. This study appears to be the first to measure quantitatively all relevant observations necessary for definitive information on desirable levels of sun exposure. Hall *et al.* concluded that individuals with European ancestry who had high exposure to the sun (90 min/day, 35% body surface exposed = Tee shirt and brief shorts or skirt) did not need any supplement in summer but needed a supplement of 1300 IU/day in winter to achieve optimum serum levels of vitamin D (75 nmol/L) all year round. While those with European ancestry who had low sun exposure (20 min/day, 18% body surface exposed = Tee shirt only, or Tee shirt and long shorts or skirt) need to take 2550 IU/day in winter and 1000 IU/day in summer to achieve optimum levels. People with African ancestry and high exposure to the sun need to take 2250 IU/day in winter and 1000 IU/day in summer. While those with African ancestry who have low exposure to the sun need to take 3100 IU/day in winter and 2100 IU/day in summer to achieve optimum levels. For climatic reasons discussed earlier these levels of supplementation suitable for Davis, California (latitude 38.5°), would need to be increased substantially for people resident in the British Isles.

7 Other factors influencing vitamin D intake or synthesis

The summer holiday, most commonly taken in August, is a time when many people get some extra sunshine and maximum population levels of vitamin D [25(OH)D] are reached by 45-year-olds in the UK in the following month [3]. A sunshine holiday taken by Swedes in winter can increase serum levels of vitamin D [25(OH)D] by 14 nmol/L [113]. The importance of this holiday sunshine in northern countries is suggested by evidence obtained from time of birth of people who develop MS (MS) and other diseases in later life. Babies born in November, 2 months following the September peak in vitamin D levels [25(OH)D], are less likely to develop MS later in life. While babies born in May, following the nadir in vitamin D [25(OH)D] levels in January, February and March [3], have a higher risk of developing MS later in life [114].

Residents in sunny regions and higher serum levels of vitamin D [25(OH)D] are associated with a reduced risk of MS (MS) [25, 115] and direct action between vitamin D and a major MS gene has been found [41]. Similar evidence has been found suggesting that insufficient vitamin D may be a cause of diabetes type 1 [116]. Vitamin D insufficiency during pregnancy may also be associated with reduced mineralization of bone in offspring during childhood and vulnerability to fracture [117]. Various interpretations of the data on birth month and MS are possible. One simple interpretation, which may gain strength from application of Ockham's razor, suggests that a sunny summer holiday with plenty of opportunity for safe and careful sunbathing is especially important for health of pregnant mothers and their babies, particularly in less sunny countries. If this conclusion is accepted it leads to advice diametrically opposed to that given in the past by the UK government and CR UK, which have advised avoiding direct sunlight, particularly on holidays [11, 17].

Advice to the public on improving vitamin D levels often suggests eating more fish. While this is good general dietary advice because fish is a good source of protein, calcium and many useful micro-nutrients, including omega-3 fatty acids, it is fruitless, or simply provides false reassurance, when it comes to vitamin D. This is because many people do not like fish and will not eat it, while those who do eat more fish will only marginally increase their vitamin D intake even if they eat fish two or three times a week.

Air pollution [86] and demands of work that deprive people of sunlight continue to be associated with disease that is linked to vitamin D insufficiency. Mortality from colon and breast cancer, the cancers most commonly associated with vitamin D insufficiency, has been found to be correlated with acid haze and UV blocking aerosols in 20 Canadian cities in the 1970s and 1980s [118]. Night shift work, which often involves sleeping during daytime peak sunlight hours, has recently been declared by IARC (Lyons) to be carcinogenic to humans [119]. Night shift work shows greatest risk for breast cancer but risks from shift work have also been found for endometrial, colorectal and prostate cancer [120–127]. These are cancers known to be associated with vitamin D insufficiency [88]. Other factors may also be involved but it would seem wise that all shift workers have their blood vitamin D [25(OH)D] levels checked as an employment routine and that they be offered a vitamin D supplement to bring their blood levels up to optimum. Prisoners too get very little opportunity to expose their skin to the sun and so should be offered a suitable vitamin D supplement.

Between the 1930s and the 1960s UV lamps were used in nurseries, schools and hospitals to boost vitamin D levels of children and adults. UV lamps that simulate sunlight are very effective at producing vitamin D [106] and commercial sunbeds can also be a useful source of vitamin D [128]. However a campaign against sunbeds and tanning salons led by CR UK has emphasized risks of sunbeds without proper consideration of benefits [19]. A new approach is suggested by Moan *et al.* who advise that moderate sunbed exposures could be a useful source of additional vitamin D in winter [128]. Sunbeds remain popular, despite much adverse publicity, and so they have an important potential contribution to make towards improving population levels of vitamin D in the UK.

However design of sunbeds, including safety features and UV emissions, is now controlled in Europe by EU directives (ftp://ftp.cenelec.org/procedures_voting/TC61_22423_vot1E.pdf) [129]. Unfortunately these have not been written with provision of vitamin D benefit in mind and so currently the spectral output of lamps is not ideal. The amount of UVB is limited to 1.5% of total UV compared with 3–5% for midday, mid-latitude solar UV.

8 Fortification in the UK – how we lost our nerve

Few foods are fortified in the UK and there are historical reasons for this. In 1952 an "outbreak" of hypercalcaemia among infants in Glasgow and elsewhere was associated with some deaths. Excessive intakes of vitamin D were said to be the cause although there were no reliable assays for vitamin D in blood at that time and no measurements of vitamin D levels in the sick children were attempted. Nevertheless doctors became convinced that the hypercalcaemia was caused by an excessive intake of vitamin D [10]. At that time cod liver oil compounds, infant milks and cereals were all fortified with vitamin D in the UK.

The UK Ministry of Health and the Department of Health for Scotland concluded that the babies who died with hypercalcaemia had unnecessarily high intakes of vitamin D. Opinion reacted against fortification of milk and other foods with vitamin D. The result was that levels of fortification with vitamin D in cod liver oil compound, infant milks and cereals were reduced and milk sold to the public ceased to be fortified because there was no longer any market for it [10]. Margarine and a few breakfast cereals continued to be fortified and are so today, but only with small amounts of vitamin D (margarine at 7 μg/100 g and some breakfast cereals at 3–8μg/100 g). Many people do not eat margarine or breakfast cereals; for those who do these levels of fortification might just be enough to prevent rickets, but food sources alone do not provide a person with more than about 3 μg (120 IU) of vitamin D a day in the UK. This is only about 5% of the estimated optimum daily adult requirement for vitamin D [130–132], which is obviously problematic if advice is also given to avoid sun exposure.

Recent review of the Glasgow "outbreak" of hypercalcaemia has led to the suggestion that the infants with hypercalcaemia were actually suffering from Williams' syndrome and did not have an excessive vitamin D intake [133]. However worries about fortification of foods with vitamin D in the UK continue among professional scientists and doctors advising government. For example, CR UK have raised doubts about fortification on their website in September 2009 with the remark that excessive amounts of vitamin D in the diet can potentially cause harm. The CR UK comment provided no context and failed to explain that large doses of vitamin D (10 000 IU *per* day) may be taken for a year without ill effects [134–137].

Professor Alan Jackson, chairman of SACN's report on vitamin D, has said that he could not "recommend fortification of a wider range of foods without some assessment of the effects on the population" [138, 139]. In arriving at this view Professor Jackson quoted the UK's Expert Group on Vitamins and Minerals, which concluded in 2003 that, "for guidance purposes only, a level of 25 μg (1000 IU) a day supplementary vitamin D would not be expected to cause adverse effects in the general population when consumed regularly over a long period" [139]. In doing so he overlooked recent studies of safety and absence of toxicity of vitamin D in doses up to 10 000 IU *per* day [134–137, 140].

Milk has been fortified in the United States and Canada since the 1930s and is available as an option in some European countries. Introduction of mandatory fortification of milk and margarine in Finland in 2003 reduced the number of people with low levels of vitamin D [25(OH)D], although the effectiveness of fortification varied according to different reports [141, 142]. Fortification of semi-skimmed milk was also introduced in the Republic of Ireland recently without difficulty.

The birthday data for people with MS referred to above suggest that relatively small amounts of vitamin D given to pregnant women and children in fortified food or as a supplement might be effective in reducing the risk of MS. In Scotland, a country with the highest incidence of MS in the world, and indeed other parts of the British Isles, this might make an important contribution to reduction in the incidence of MS and possibly diabetes type 1 and other disease.

A detailed assessment of the possible benefits and risks of fortification might be reassuring to the UK public but fortification of milk, orange juice and cheese is well established in other countries such as the USA and could be safely introduced in the UK without delay, at least on a non-mandatory basis. To be effective non-mandatory fortification might need to be supported by a permitted health claim that would enable more effective promotion. UK health claims for food are now controlled by EU regulations although derogation from the regulations might be possible for foods such as milk and bread that are not exported. In March 2010 the European Food Safety Authority's Panel on Dietetic Products concluded that "a cause and effect relationship has been established between the dietary intake of vitamin D and contribution to the normal function of the immune system and healthy inflammatory response, and maintenance of normal muscle function" [143]. This ruling should enable effective marketing of non-mandatory vitamin D-fortified products in Europe.

9 Supplementation in the UK – practical difficulties

The UK government advises that children of 4 years or older and adults up to 65 years of age need no supplement unless they are housebound or cover themselves fully with clothing when outside. This policy was reviewed by SACN and no change was recommended. It is difficult to see how SACN could have arrived at this conclusion when published surveys by Hypponen and Power and others show that most people in the UK have sub-optimal blood levels of vitamin D [25(OH)D] and would benefit from a vitamin D supplement in winter, while the majority need one in the summer as well [3, 101].

CR UK now say that "people with melanoma or bowel cancer might benefit from increasing their vitamin D levels, either through diet, supplements or UV exposure". But instead of suggesting a suitable dose of the vitamin they warn that "vitamin D supplements...can potentially cause harm if taken in large doses without medical supervision."

This recommendation creates difficulties for the public because at the time of writing few general practitioners have much knowledge of vitamin D that goes beyond its classic role in calcium and bone physiology [65]. They are also not generally aware that the small doses of vitamin D supplement recommended by SACN and in ready reference compendia are generally too low in the opinion of experts in the field [36, 134, 136, 137]. Until recently most vitamin D products available in UK pharmacies provided only 200 IU *per* day of vitamin D, at most 400. In the last 2 or 3 years health food stores have begun to sell tablets providing 400–1000 IU (10–25 μgm) without calcium or other vitamins, but Boots, Britain's largest pharmacist, does not stock a tablet providing more than 500 IU. There is also a shortage in the UK of suitable vitamin D in the form of registered "ethical products" available on prescription from doctors. There are none which provide more than 400 IU of vitamin D3 *per* tablet and these are all combined with calcium, which many patients do not like. Suitable vitamin D3 products, such as the German products Vigantol Oil or Dekristol, exist in other European countries but are not generally available in the UK. These European vitamin D3 products obtained their licenses before the formation of the European Union and are not licensed in the UK. Nowadays medicines are given licenses for the EU as a whole but this regulation does not act retrospectively. It is too expensive for manufacturers of these products, which have no patents and are not profitable, to apply for licenses in the usual way. Frustrated doctors have made requests to the English and Scottish governments that this bureaucratic problem be resolved by waiving normal procedures and providing licenses without charge, but to date no action has been taken on this [144].

Another approach that some families might adopt advantageously is home fortification if suitable products of vitamin D "sprinkles" were available. For example, a family of four might once a week supplement a meal to be eaten by all, with 50 000 IU of vitamin D. Allowing for wastage, this would provide each family member with about 10 000 IU vitamin D, the dose varying to some extent with portion size and thus body size of the individual. Vitamin D has such a low toxicity, wide therapeutic window and long half life [140] that this approach may be expected to be safe and effective. A trial putting vitamin D into bread in an old person's home has been successful [145] and adding sprinkles of micronutrients to baby food has been shown to be effective in Africa [146].

10 Westminster bungles supply of vitamins for mothers and infants

The provision of vitamin D supplements for pregnant mothers and infants is in a serious muddle in the UK. Advice and practice in Britain differs from that in most other industrial countries. Currently the UK is the only country among 31 in Europe, which does not recommend any daily vitamin D intake for women of childbearing age [147], and is therefore doing nothing to reduce the risk that women are vitamin D-deficient when they become pregnant [148]. Furthermore in 2003 the UK National Institute for Clinical Evidence (NICE) recommended, contrary to much established clinical opinion, that vitamin D supplementation should no longer be offered routinely to pregnant women. NICE based its opinion on a review of 207 scientific articles published between 1966 and 2006 culled from 4691 potential eligible reports, which had been identified. NICE concluded: "There are important limitations in the evidence reviewed in its paucity, currency and quality" (http://www.nice.org.uk/nicemedia/pdf/PH011guidance.pdf) [149].

The original recommendation that vitamin D should be taken in pregnancy, made by the government's COMA committee in 1991 and 1998 [70], was based on clinical knowledge and experience documented in scientific literature accumulated over many years, much of the experience acquired before 1966 [150]. For example, Hess arranged what was probably the first open label trial of daily cod liver oil for prevention of rickets, publishing his results in the Journal of the American Medical Association in 1917 [151]. But such work carried little or no weight with NICE experts who embraced modern criteria of evidence-based medicine and looked to double blind randomized clinical trials for guidance, discarding trials prior to 1966 whatever their merit. Following this fashionable line of reasoning NICE ruled against giving vitamin D to women in pregnancy (http://www.healthcarerepublic.com/news/932908/Calls-NICE-rethink-guidance-vitamin-D/) [152].

A change in the clinical status quo on the basis of a lack of evidence from trials cannot easily be justified scientifically or logically, especially if there are no adverse effects of note. The logic of the NICE conclusion has something in common with the finding that "effectiveness of parachutes has not been subjected to rigorous evaluation by using randomized controlled trials" [153]. So, after an intervention by the Royal College of Paediatrics, NICE was over-ruled by the UK Chief Medical Officer who endorsed the pre-existing 1998 recommendation that pregnant and nursing mothers should be given a vitamin D supplement of 400 IU daily. Subsequently, in 2008, NICE produced revised guidance for mothers and children in low-income households, which endorsed the original COMA recommendations of 1991 and 1998 [154], which said that pregnant and breastfeeding women and children under four may benefit from a supplement containing 10 μg (400 IU) of vitamin D. However this advice has not generally been implemented because obstetricians who run the pre-natal screening of women have until recently lacked suitable vitamin supplements that they can prescribe, which are free of calcium and vitamin A. In 2005–2006 the government launched its own vitamin D supplements, Healthy Start Vitamins, one product for mothers and another for babies [8]. The original intention was that the Healthy Start Vitamins would be sold over the counter through pharmacies. However the shelf life of the baby product was too short and so pharmacies have declined to stock it. This left the government with a major problem because the product had needlessly been registered as a medicine and so could not be sold outside pharmacies. So Healthy Start baby vitamins are now only distributed *via* clinics and "community pharmacies" (run by the National Health Service or local authority) where they are offered to some "mothers in need", which does not mean mothers who need vitamin D but rather mothers who qualify for welfare benefits.

For some reason pharmacies agreed to sell the second Healthy Start product made for mothers [155], but in practice very few women get this product because government failed to promote it, either directly to women or to the health professionals who advise them in pregnancy. Government, as part of its policy of decentralization, has devolved the decision on whether or not to spend money on Healthy Start vitamins to local health authorities (called Primary Care Trusts). This means that government can herald the success of its policy initiative without having the responsibility of implementing it. Primary Care Trusts may reclaim the cost of Healthy Start vitamins given to women on benefits from central government but government records show that very few did so in the first 4 or 5 years of the scheme.

The policy of restricting Healthy Start vitamins to mothers on benefits makes no sense because the prevalence of vitamin D insufficiency in the UK is not known to vary greatly with social class or financial status. Mothers not on benefits are advised to buy Abidec, an over the counter pharmacy product that is formulated with vitamin D2 in a base of peanut oil and provides 200 IU *per* day. This is less than the 280 IU, which are recommended by government for babies over 6 months. Furthermore the efficacy of Abidec is probably considerably less because the vitamin D2 with which it is formulated is substantially less potent than vitamin D3, which is now generally recommended as preferable [156]. In the Irish Republic Abidec is available as Abidec D3, a reformulated version using vitamin D3, but this form has not been approved by the UK medicines regulatory authority and so is not available in the UK. The SACN report, published in 2007, failed to investigate actual supply of vitamins for mothers and babies and so omitted any mention of these difficulties in its report [10].

For many years mothers in the UK have been told that it is not generally necessary to give their babies any vitamin D supplement until they are 6 months old [8, 9, 157–159]. Sometimes this is qualified with advice that babies over a month old may be given vitamin D if mothers are deficient in the vitamin during pregnancy (http://www.healthystart.nhs.uk/) [160]. The advice seems to be unique to the UK but its basis is obscure. It may have originated in the scare following the "outbreak" of hypercalcaemia in Glasgow and elsewhere, already referred to, or it may be based on the observation that symptoms of rickets do not commonly manifest before 6 months of age, or, as related to me by a highly placed official in the Department of Health, on the prevalent concept that breast milk is complete in every respect and that breast feeding should be continued for 6 months. The advice has been repeated in almost every item of official advice given to mothers and it was repeated by the SACN report without any discussion of its scientific rationale. The SACN team failed to note that breast milk of mothers in industrial societies is very low in vitamin D[8] or that babies are often weaned from formula milk, which is fortified with D, as early as 3 months and so these babies need a D supplement earlier than 6 months of age.

Rickets was once known elsewhere as the English disease because it was first noticed in England, induced by our climate combined with the air pollution that followed our early industrialization. Now rickets has returned particularly in dark skinned children [158, 159] but also severe D deficiency has been found to cause heart attacks and heart failure in infants, which may be sufficiently acute for transplantation to be considered [161–164], while other serious complications of birth and later life have been linked to vitamin D insufficiency and may be prevented by repletion [59, 63].

Policy on infant vitamins in the UK lacks logic and coherence. It is a muddle requiring serious attention from senior doctors and nutritionists and action by government policy makers.

11 The cost of vitamin D insufficiency in the UK

The cost of vitamin D insufficiency disease (defined as capable of being alleviated by a daily intake of 2000–3000 IU vitamin D3) to 17 European countries with a total population of 363 million has been estimated to be 187 000 million Euros annually [165]. If this sum is apportioned according to population size, D insufficiency disease costs some £27 000 million a year in the UK, which compares with about £5000 million consumed by tobacco-related disease [166]. However the real cost of D insufficiency disease in the UK is almost certainly higher because the unfavourable climate of the UK creates greater D insufficiency giving it a greater disease burden than many other European countries.

12 Summary and concluding remarks – where do we go from here?

The recent history of public health policy in the UK with regard to vitamin D and sunshine is one of muddle and failure. A complete reassessment of the vitamin D requirements of people living in the UK is now required with special attention to ways in which these needs can be met by advice on sun exposure and supplements, by fortification and by provision of new vitamin D products. The SACN report has shown that this task is beyond the capability of an expert committee meeting occasionally and reviewing a self-selected fraction of the scientific literature. The literature is now vast and difficult for any non-specialist to master. Furthermore clinical practice concerning vitamin D insufficiency and associated disease in the UK is based on knowledge and experience, which now goes back at least 100 years. This clinical lore needs to be understood so that current policy can build on it and improve it. A better approach for an advisory committee might be to take evidence from a range of international scientists and clinicians with expert knowledge, study the advice they give and the publications they recommend, study best practice in other European countries, and come to conclusions based on that process. Such a task may seem too arduous, but the cost of improving vitamin D levels in the UK population is very small compared with likely gains to human happiness, the public health and the public purse, which will be immense. Solving the vitamin D deficiency problems of the UK in the 21st century promises rewards comparable with the great strides in public health made in the 19th century by provision of pure water and in the 20th century by provision of better housing, cleaner air and reduction in smoking.

I have received no personal remuneration from commercial interests that might profit from any aspect of my work. In particular I have never accepted personal payments from makers of sunlamps or vitamin supplements, or their proxies.

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