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Vitamin D
Light side and best time of sunshine in Riyadh, Saudi Arabia

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Low levels of 25-hydroxyvitamin D have been documented among inhabitants of the wider Middle East and North African countries. Sunlight has long been recognized as a major provider of vitamin D. In this study we aimed to determine the optimum time for sun exposure in the Central region of Riyadh, Saudi Arabia. Ampoules containing 7-dehydrocholesterol in ethanol were exposed to sunlight every hour starting from sunrise until sunset in July and December. Our results demonstrated that the time of the day has a major influence in vitamin D production. In this study, summer production of previtamin D_3 was observed to occur between 8:00 PM to 4:00 PM with peak hours between 10:00 AM to 12:00 PM. During wintertime however, the conversion began later at around 9:30 AM and ended sooner at 2:00 PM, with peak hours at 10:00 AM to 12:00 PM. In conclusion, the optimum time to get sun exposure for vitamin D_3 production in Riyadh, during summer is from 9:00 AM and before 10:30 AM, as well as after 2:00 PM until 3:00 PM, while during winter it's from 10:00 AM until 2:00 PM. These times are important on a public health perspective, as it's free, relatively safe and the most enjoyable. This strategy is a highly efficacious way for improving the vitamin D status for children and adults and preventing vitamin D deficiency.

Introduction

There is growing evidence that vitamin D sufficiency is required for optimal health. The role of vitamin D in both calcium absorption and metabolism for bone health is well known.[1] Furthermore, the presence of vitamin D receptors (VDR) in other tissues and organs suggest that vitamin D function extends beyond bone homeostasis.[1] Additionally, the enzyme responsible for conversion of 25-hydroxyvitamin D [25(OH) D] to its biologically active form 1,25-dihydroxyvitamin D [1,25$(OH)_2$D] has been identified in other tissues aside from the kidneys.[2,3] Research during the past two decades has illustrated the importance of vitamin D in reducing the risk of cancer,[4-6] multiple sclerosis[7,8] and type 1 diabetes mellitus.[9]

Globally, vitamin D deficiency has been noted in many countries. A high number of otherwise apparently healthy children, adolescents, pregnant women, and adults are vitamin D deficient.[10-15] Even in sunny areas like Saudi Arabia, vitamin D deficiency is very prevalent.[15-17] The major source of vitamin D for most humans is causal sun exposure and to a lesser extent from dietary intake. Even so, the natural diets that most humans consume contain little vitamin D, with exception of wild-caught, oily fish, cod liver oil and sun exposed mushroom.[18]

When human skin is exposed to sunlight, the solar UVB (290 to 315 nm) photons penetrate into the epidermis and are absorbed by 7-dehydrocholesterol, which is present in the plasma membrane.[19-22] The absorption of these energies transform 7-dehydrocholesterol into previtamin D_3. Because this photochemical process occurs in the plasma membrane, only the cis-cis conformer of previtamin D_3 is formed, which, being thermodynamically unstable, is rapidly isomerized to vitamin D_3.[23] Once formed, vitamin D_3 is ejected out of the plasma membrane into the extracellular space where it is drawn into the dermal capillary bed by the vitamin D–binding protein.[24] Excessive exposure to sunlight will not cause vitamin D intoxication because sunlight degrades any excess previtamin D_3 and vitamin D_3.[29]

Factors that affect cutaneous production of vitamin D_3 include latitude, season, time of day, air pollution, cloud cover, melanin content of the skin, use of sunblock, age and the extent of clothing covering the body.[20] When the sun is low on the horizon, the atmospheric ozone, clouds and particulate air pollution

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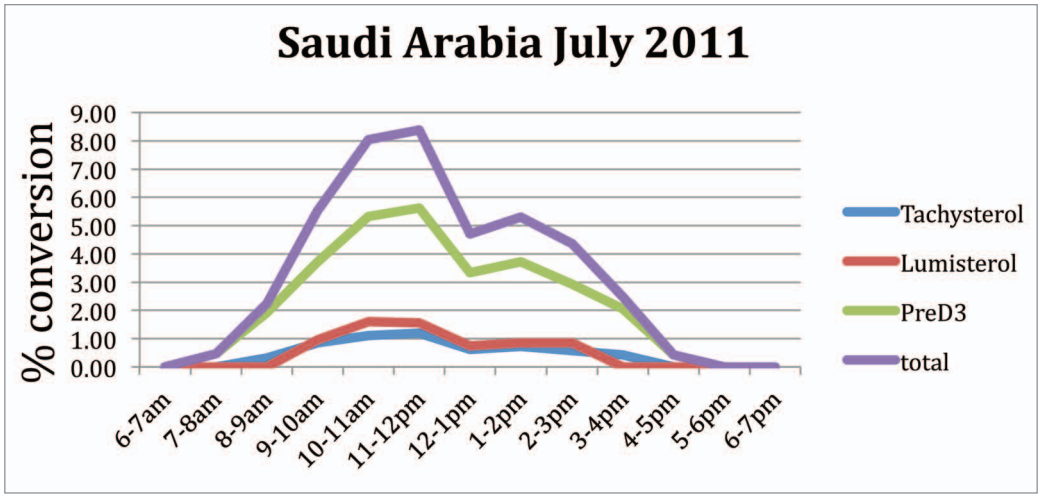

Figure 1. Conversion of 7-dehydrocholesterol (7-DHC) to previtamin D_3, lumisterol and tachysterol at various times throughout the day in July on a sunny day in Saudi Arabia.

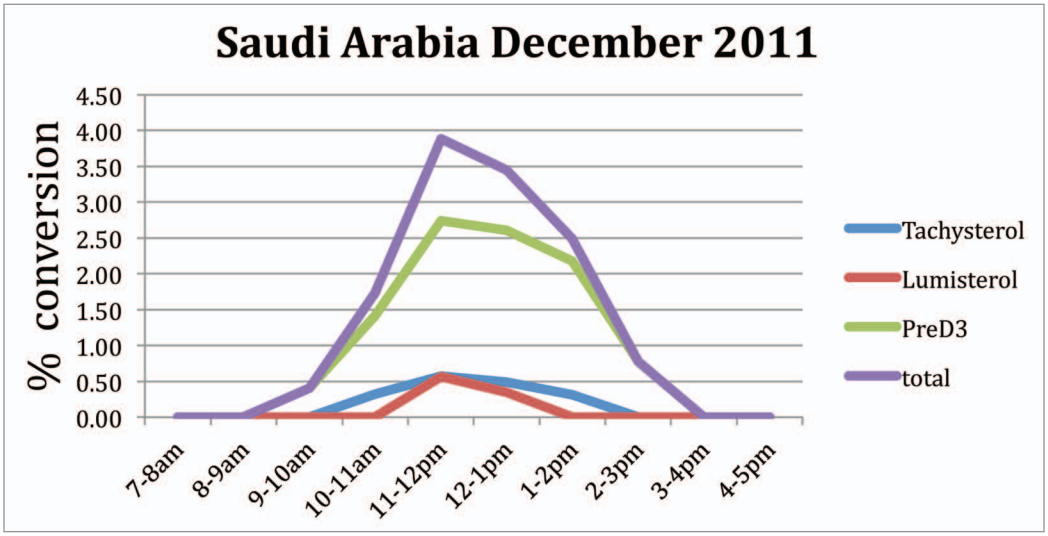

Figure 2. Conversion of 7-dehydrocholesterol (7-DHC) to previtamin D_3, lumisterol and tachysterol at various times throughout the day in December on a sunny day in Saudi Arabia.

absorb UVB radiation, limiting the amount that reach the surface of the Earth. The zenith angle of the sun plays a critical role in vitamin D_3 production. When the zenith angle is more oblique, the path length through the stratospheric ozone layer is increased and hence, fewer UVB photons are able to reach the earth's surface. Therefore, cutaneous vitamin D_3 production is effectively absent early and late in the day and for the entire day during several winter months at latitudes > 35°.[25-27]

Objectives

To determine the optimum time for sun exposure and evaluate of previtamin D_3 production during summer and winter in the central region of Riyadh, Saudi Arabia (latitude and altitude are 24° N, 620 min respectively).

Results

The conversion of 7-dehydrocholesterol to previtamin D_3 in the ampules is the most sensitive indicator for the cutaneous production of vitamin D_3 from sun exposure. Using this method we observe that although the sun was shining brightly beginning at 6:00 AM in July, no previtamin D_3 production was detected before 8:00 AM. Previtamin D_3 was detected in the ampule exposed to sunlight between 8:00–9:00 AM and gradually increased and was maximal between 11:00 AM and 1:00 PM. Previtamin D_3 production gradually declined and no previtamin D_3 was observed in ampules exposed to sunlight after 5:00 PM (**Fig. 1**).

Even though it remains sunny in Saudi Arabia in December and the sun rises before 7:00 AM there was no detectable

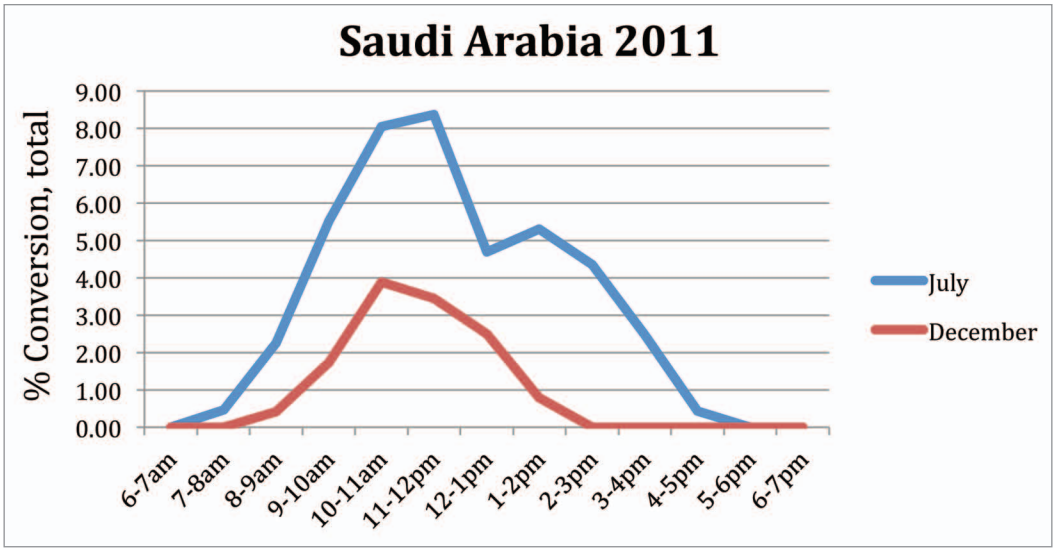

Figure 3. influence of season on the synthesis of previtamin D_3 and its photoproducts (% total).

previtamin D_3 production in the ampules until 9:00 AM. Previtamin D_3 gradually increased and was maximally produced between the hours of 11:00 AM and 2:00 PM and rapidly declined with no further production after 3:00 PM (**Fig. 2**). The effect of the season was evaluated in our study that showed reduction by 50% of conversion of 7-dehydrocholesterol to previtamin D_3 during winter (**Fig. 3**).

Tachysterol and lumisterol were observed in ampules exposed to sunlight between 10:00 AM and 3:00 PM in July and 11:00 AM and 2:00 PM in December demonstrating that enough sunlight was available to convert previtamin D_3 to these 2 photoproducts and thus beginning to establish a photoequilibrium.

Discussion

It is ironic that residents of Saudi Arabia, and the Middle East in general, suffer from vitamin D deficiency despite abundant sunlight year-round. A number of factors may affect serum vitamin D_3 production in skin such as skin color, season, altitude, time of the day, and amount of sun exposure. Our results demonstrated that the time of the day has a major influence in vitamin D_3 production. In this study, summer production of previtamin D_3 was observed to be increased between 9:00 AM to 3:00 PM with peak hours between 10:00 AM to 12:00 PM. During wintertime however, the conversion begins later at around 9:30 AM until 2:00 PM, with peak hour around 11:00 AM. It is important to know whether that time is feasible for sun exposure without harming the skin. Maximum UVB time, believed to be responsible for both sun burning and skin cancer was previously recorded at 10:30 AM to 2:00 PM, during the summer months of Riyadh.[28] Taking this into consideration, the optimum time for sun exposure therefore is from 9:00 AM and before 10:30 AM, as well as after 2:00 PM until 3:00 PM.

Similarly, Holick et al., have reported previtamin D_3 production in Boston (latitude 42° N) was significant between hours of 10:00 AM and 4:00 PM during June.[29] The effect of the season was evaluated in the same study that showed reduction by 80% in the conversion of 7-dehydrocholesterol to previtamin D_3 at noon time between June and October.[30]

The production of vitamin D_3 from sun exposure vs. oral supplementation has been evaluated in several studies. Data from Australian and New Zealand[31] has demonstrated that whole body exposure of mid-day sun in summer for 10–15 min is comparable to taking 15,000 IU of vitamin D_3 orally. Based on this, exposure of hands, face and arms (around 15% of body surface) should produce about 1000 IU of vitamin D_3.[29]

Al-Daghri and colleagues have recently documented the counterintuitive effect of season in vitamin D levels among Saudis. Because summer season confer lesser outdoor activities secondary to extreme temperature elevations, it was suggested to increase dietary intake of food products fortified with vitamin D and encourage vitamin D supplements.[30] From our study however we suggest a cost and reasonably risk-free alternative to restore vitamin D levels which is sun exposure between 9:00 AM and after 2:00 PM for 10–15 min during summer months.

Our study has a few limitations. The study was done in two seasons only. Further studies are needed to determine the effect of change in the season throughout the year on skin production of pro vitamin D_3. In addition, the study was conducted in the central region (Riyadh) only, and different optimum sun exposure times might not be the same from other geographical regions in the country secondary to differences in weather and altitude. Moreover the study was done in cloudless day.

In summary, the optimum time to get sun exposure for vitamin D production in Riyadh, during summer time is from 9:00 AM and before 10:30 AM, as well as after 2:00 PM until 3:00 PM while during winter time it's from 10:00 AM until 2:00 PM. These timings are important on a public health perspective, as it's free, safe and enjoyable. Furthermore it's a highly efficacious way for management and prevention of vitamin D deficiency.

Methods and Materials

7-dehydrocholesterol in ethanol was sealed under Argon in borosilicate ampoules, placed outside in direct sunlight on a cloudless day for 1 h intervals beginning from sunrise until sunset. The samples were stored in the dark and evaluated by high-performance liquid chromatography (HPLC) for the conversion of 7-dehydrocholesterol to previtamin D_3 and its photoproducts (tachysterol and lumisterol) as previously described.[21,23]

Disclosure of Potential Conflicts of Interest

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