

Optimum Sun Exposure Times for Vitamin D Status Correction in Saudi Arabia

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Abstract: Vitamin deficiency is considered to be a major public health problem in Saudi Arabia, especially during summer. The major source of vitamin D is sun exposure. In this study, we aimed to determine the optimum time for sun exposure in four different cities (North, South, West and East regions) in the Kingdom of Saudi Arabia. In the current study ampoules containing 7-dehydrocholesterol in ethanol were exposed to sunlight every hour starting from sunrise until sunset in June 2013. Results indicated that the geographical location and the time of the day have a major influence in vitamin D production. In summer, conversion of pre-vitamin D₃ was observed to be elevated between 8.00-9.00 AM to 3:30-4:30 PM, with peak hours between 11:30 AM to 12:30 PM. Moreover in the east region (Dammam), conversion of pre-vitamin D₃ showed significant reduction by around 50%. In conclusion, the optimum sun exposure time for vitamin D₃ production in the north, south and west regions of Saudi Arabia during summer is from 8:30 AM to 10:30 AM, as well as 2:00 PM to 4:00 PM. Air pollution might be the cause for the decreased conversion of 7-dehydrocholesterol to pre-vitamin D₃ in the east region. Conservatively, the optimum time for sun exposure therefore in Dammam city is from 8:30 AM to 10:00 AM, as well as 1:00 PM to 2:30 PM. Knowledge of the optimum sun exposure times during summer can be highly effective in preventing vitamin D deficiency in Saudi Arabia.

Keywords: Vitamin D, Sunlight Exposure, Optimum Times, Saudi Arabia

1. Introduction

Vitamin D, the sunshine vitamin, plays an essential role in the regulation of calcium and phosphorus absorption as well as optimal bone health (1). However, the effects of vitamin D are not limited to mineral homeostasis and skeletal health maintenance. The presence of vitamin D receptors (VDR) in other tissues and cells in the body suggested that vitamin D physiology extends beyond bone homeostasis. Furthermore, the enzyme responsible for the conversion of 25[OH]D to its

biologically active form [Vitamin D(1,25[OH]D)] has been identified in other tissues aside from kidneys (2,3). During the past decade, numerous reports have shown that relatively high proportions of people have low levels of vitamin D (4-9). In sunny areas like Saudi Arabia, vitamin D deficiency is very prevalent in both adults and children (10-13).

The major source of vitamin D is the casual sun exposure and to a lesser extent, dietary intake. Even so, the natural diets that most humans consume contain little amounts of vitamin D, with the exception of wild-caught, oily fish, cod liver oil and

sun exposed mushrooms (14).

When human skin is exposed to sunlight, the solar UVB (290 to 315 nm) photons penetrate in to the epidermis. Then they are absorbed by 7-dehydrocholesterol, which is present in the plasma membrane (15-17). The absorption of these energies transforms 7-dehydrocholesterol (7-DHC) into pre-vitamin D₃. Because this photochemical process occurs in the plasma membrane, only the *cis,cis* conformer of pre-vitamin D₃ is formed, which, being thermodynamically unstable, is isomerized to vitamin D₃ (17). Once formed, vitamin D₃ 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 (18). The synthesis of pre-vitamin D₃ reaches a plateau of about 10-15% of the original cutaneous 7-DHC concentrations during a single prolonged sun exposure. At this point, pre-vitamin D₃ undergoes a process of photo-isomerization resulted into two biologically inactive products (tachysterol and lumisterol), so excessive sunlight exposure will not cause vitamin D toxicity (17).

Known factors that affect cutaneous production of vitamin D₃ include latitude, season, time of day, air pollution, cloud cover, glass shielding, melanin content of the skin, use of sun-blockers, age and the extent of clothing covering the body (19). When the sun is low on the horizon, the atmospheric ozone, cloud and particulate air pollution absorb UVB radiation, limiting the amounts that reach the surface of the Earth. The zenith angle of the sun plays a critical role in

vitamin D₃ 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 D₃ production is effectively absent early and late in the day and for the entire day during several winter time months at latitudes >35° (20-22).

The present study aimed to determine the optimum time for sun exposure during summer by evaluating pre-vitamin D₃ production in four different regions of Saudi Arabia [Arar City (30°N) located at north area, Abha City (18°N) located at south area, Makkah City (21°N) located at western area and Dammam City (26°N) located at eastern province].

2. Methods and Materials

In the current study 7-dehydrocholesterol in ethanol was sealed under Argon in borosilicate ampoules, placed outside in direct sunlight on a cloudless day of June 2013 in each of the four regions after sunlight exposure for one hour intervals beginning from 6.00 AM to 6.00 PM. The samples were stored in the dark and evaluated by high-performance liquid chromatography (HPLC) for the conversion of 7-dehydrocholesterol to pre-vitamin D₃ and its photoproducts (tachysterol and lumisterol).

3. Results

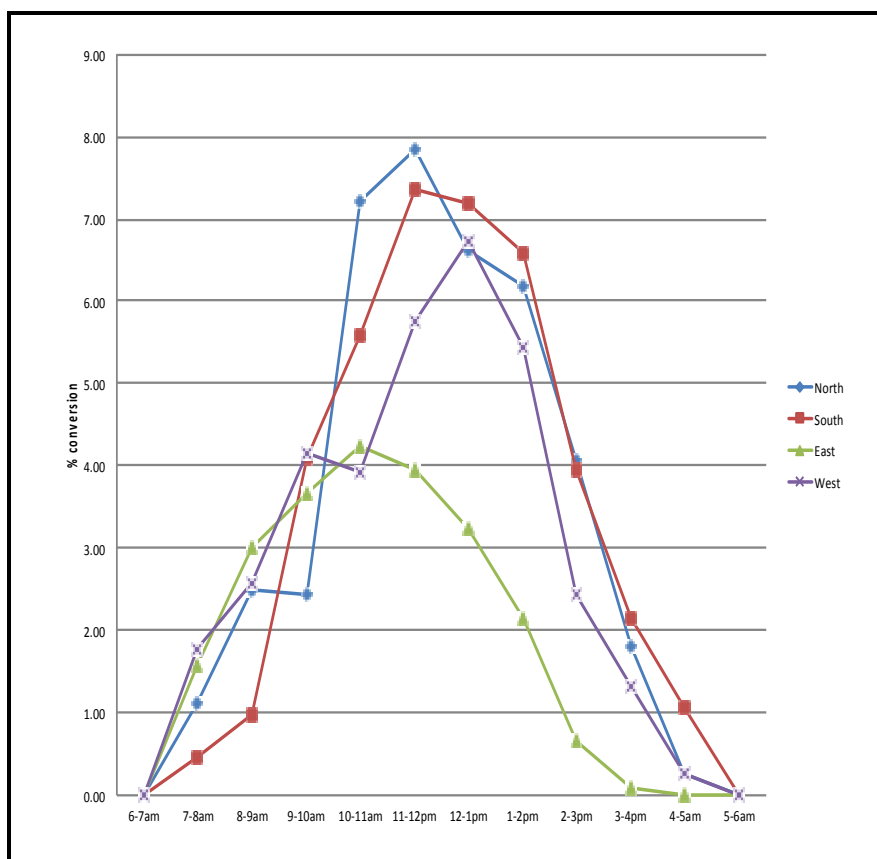


Fig. 1. Synthesis of pre-vitamin D₃ overtime in the four different regions in the kingdom of Saudi Arabia.

The conversion of 7-dehydrocholesterol to pre-vitamin D₃ in the ampoules is the most sensitive indicator for the cutaneous production of vitamin D from sun exposure. Using this method, we observed that although the sun was shining brightly beginning at around 6.00 AM in June, pre-vitamin D₃ were detected in the ampoules exposed to sunlight between 8.00-9.00 AM (fig.1). No significant pre-vitamin D₃ production was detected before 9.00 AM in Abha (fig.2). However, it was detected in other cities earlier at around 8.00 AM. Succeeding hours showed gradual pre-vitamin D₃ production increased and reached its maximum at around 11:30 AM in Dammam (fig.3) and around 12:30 PM in other cities. Pre-vitamin D₃ production gradually declined and none were observed in ampoules exposed to sunlight after 3:30 PM in Dammam (fig.3), 4.00 PM in Arar & Makkah (fig.4&5) and around 4:30 PM in Abha (fig.2).

Tachysterol and lumisterol were detected in the ampoules exposed to sunlight between 9.00-10.00 AM and 3.00-4.00 PM, demonstrating that enough sunlight was available to convert pre-vitamin D₃ to these two photoproducts and thus beginning to establish a photo-equilibrium.

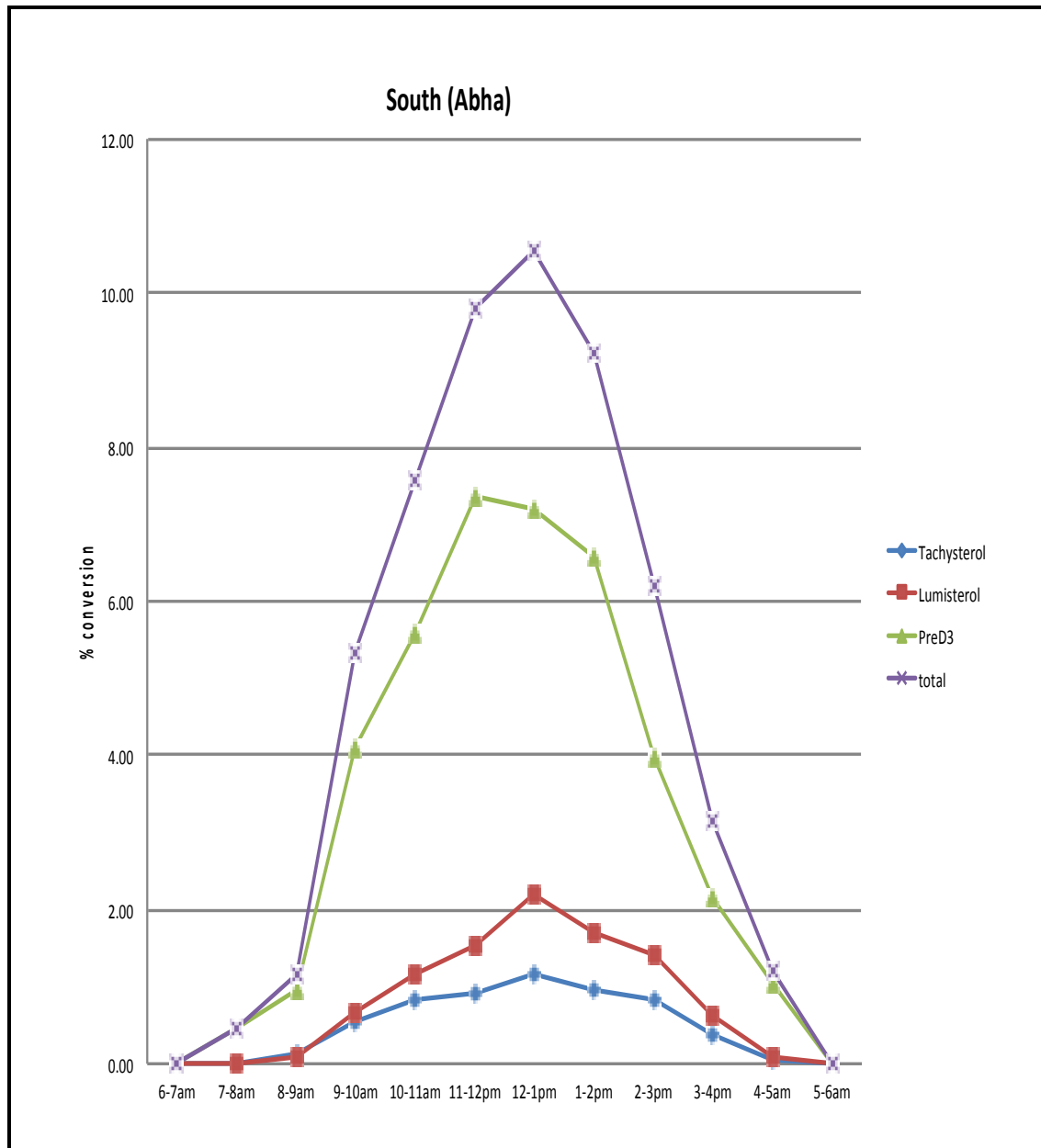


Fig. 2. Conversion of 7-dehydrocholesterol (7-DHC) to pre-vitamin D₃ overtime in June, 2013 in Abha, Saudi Arabia

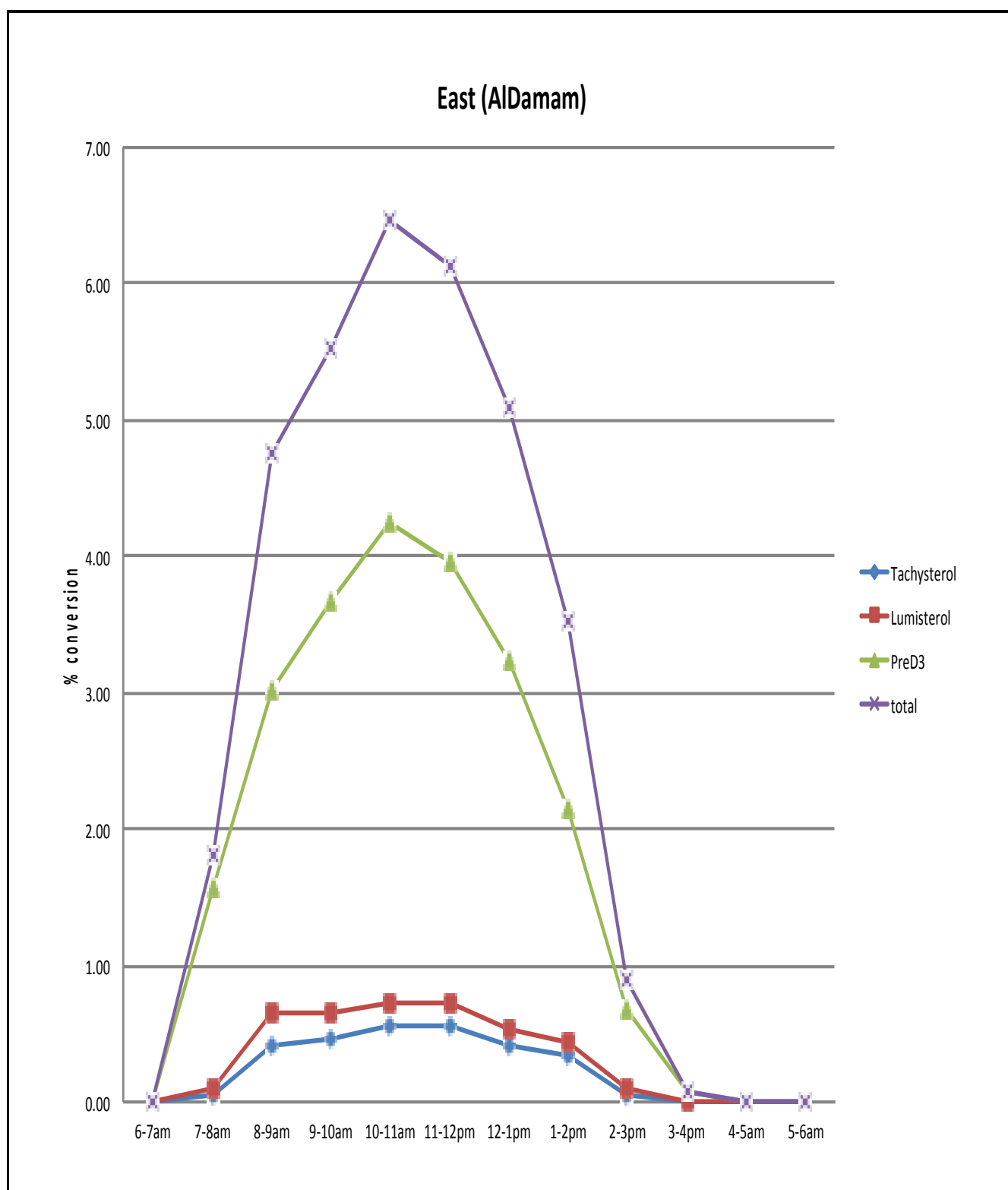


Fig. 3. Conversion of 7-dehydrocholesterol (7-DHC) to pre-vitamin D3 overtime on June,2013 in Dammam, Saudi Arabia

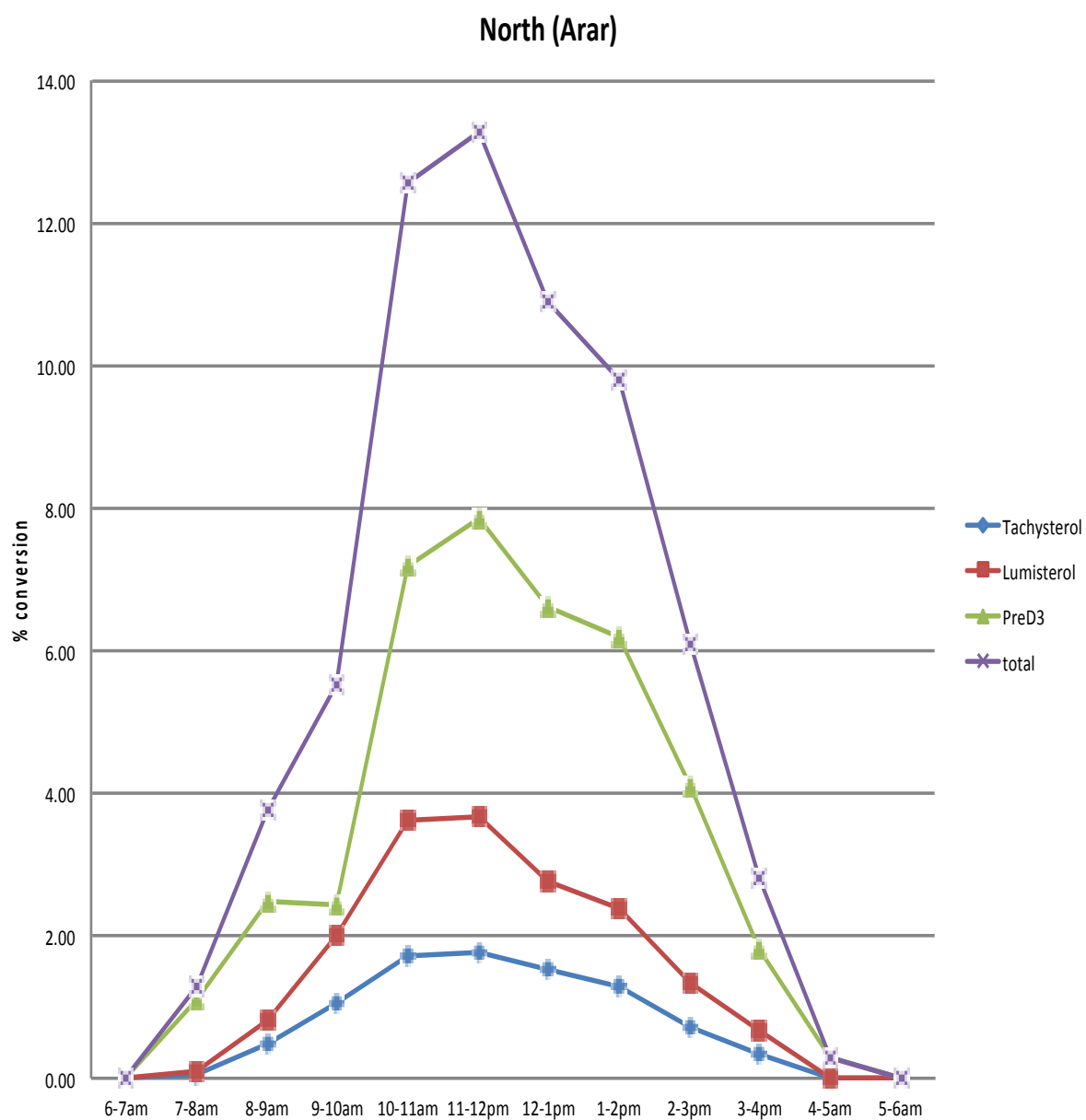


Fig. 4. Conversion of 7-dehydrocholesterol (7-DHC) to pre-vitamin D3 overtime on June, 2013 in Arar, Saudi Arabia

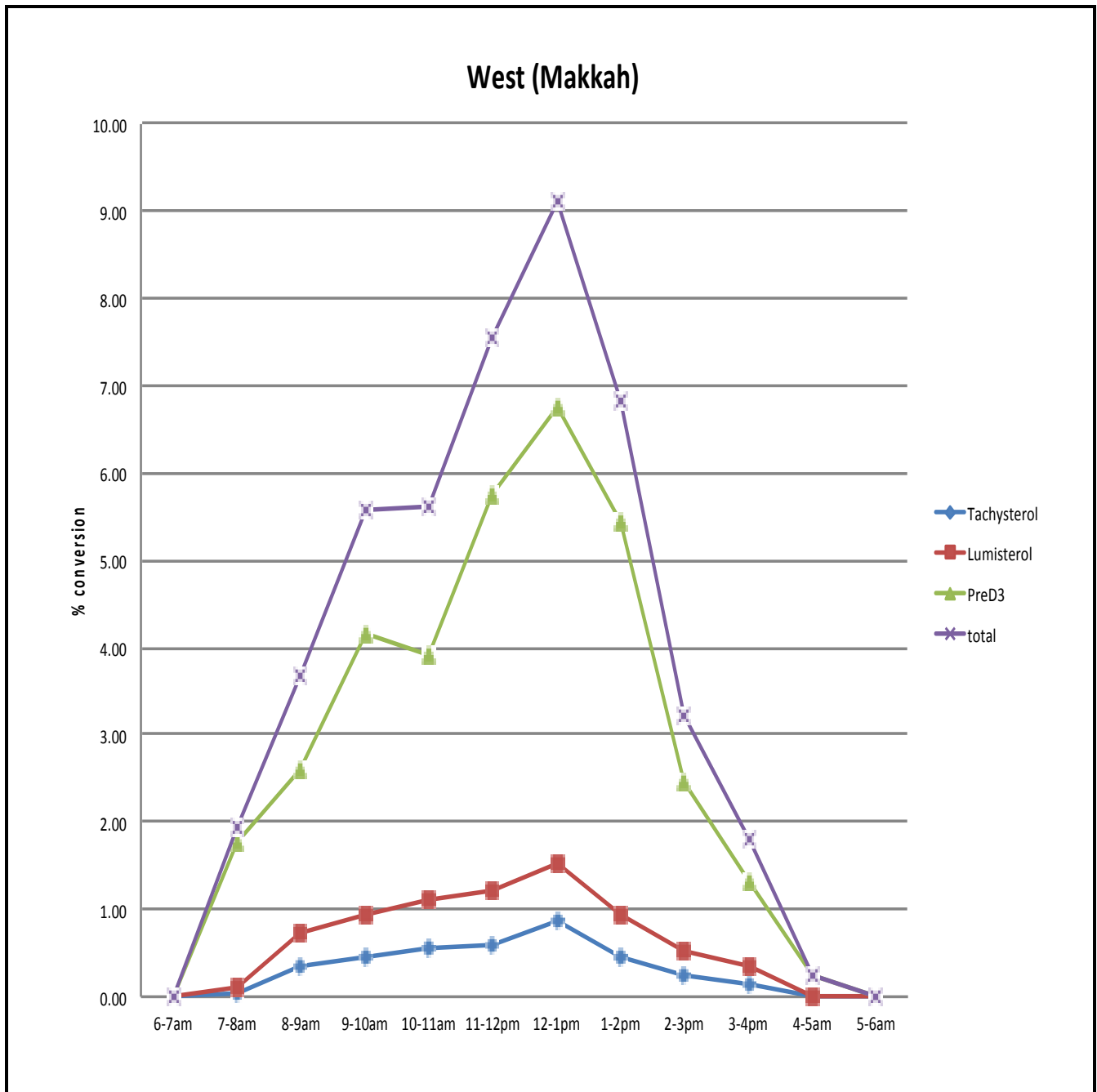


Fig. 5. Conversion of 7-dehydrocholesterol (7-DHC) to pre-vitamin D₃ overtime in June, 2013 on a sunny day in Makkah, Saudi Arabia

4. Discussion

The best way to increase vitamin D levels is to expose the skin to the sun especially in sunny countries like Saudi Arabia. This has never been known to cause toxicity because of self-regulatory factors in the skin. However, vitamin D deficiency is an all-year-round problem in the country, and this worsens during the summer as people avoid the sun because of extreme heat (23).

Several factors may affect vitamin D production in the skin such as amount of sun exposure, time of the day, season, latitude, and skin color. Our results demonstrated that the time of the day has a major influence on cutaneous vitamin D

production.

In the current study, summer conversion of pre-vitamin D₃ was observed to start around 8:00 AM in Makkah, Arar and Dammam and around 9:00 AM in Abha. Peak conversion was around 11:30 AM in Dammam and 12:30 PM in other cities before declining onwards. These results were longer (9:00 AM- 3:00 PM) with peak hours between 10:00 AM and 12:00 noon in comparison with a previous study carried out in Riyadh (latitude 24° N), during month of July, 2012 (24). Likewise, Holick *et al.*, reported that pre-vitamin D₃ production in Boston (latitude 42° N) was more between hours of 10:00 AM- 4:00 PM during June, 2007 (25). When the sun is low on the horizon, the atmospheric ozone, clouds and

particulate air pollution absorb UVB radiation, limiting the amount that reaches the Earth's surface. The zenith angle of the sun plays a critical role in vitamin D₃ production (26). 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 (26). Therefore, cutaneous vitamin D₃ production is effectively absent early and late in the day and for the entire day during several winter time months at latitudes >35° (20-22). Dammam city, which is located in the eastern province, is considered an industrial city. Hence, air pollution could explain the significant reduction of pre-vitamin D₃ production by almost 50% than the other cities.

Moreover, the sun's path gradually drifts northward and by June, the sun rises considerably north due east and sets considerably north due west. This means that the sun's rays strike the ground more directly at higher latitudes, and explains the relatively higher amount of pre-vitamin D₃ in Arar (latitude 30° N) (fig.4) compared with Abha (latitude 18°N).

The maximum UVB time is believed to be responsible for both sunburn and skin cancer, so it's equally important to determine these time frames in each city. During the summer months in Riyadh, the maximum UVB time was recorded between 10:30 AM- 2:00 PM (27). Taking this into account, the optimum time for sun exposure therefore in north, south and west provinces is from 8:30 AM- 10:30 AM, as well as after 2:00 PM- 4:00 PM. Consequently, the suggested optimum time for sun exposure in Dammam city is from 8:30 AM- 10:00 AM, as well as after 1:00 PM- 2:30 PM.

The amount of UVB irradiation required for vitamin D sufficiency can be calculated from the amount of vitamin D produced from one minimal erythemal dose (MED). The MED can be defined as the amount of time needed to cause skin to turn pink. Several factors have been identified to affect the MED i.e. geographical location, skin pigmentation, percent of body fat, and age (28).

The production of vitamin D₃ from oral supplementation versus sun exposure has been evaluated in several studies. The whole body exposure of mid-day sun in summer for 10–15 minutes was comparable to taking 15,000 IU of vitamin D₃ orally (29). Based on this, exposure of hands, face and arms (around 15% of body surface area) should produce about 1000 IU of vitamin D₃. It has been suggested that the concentration of the pre-vitamin D₃ in the skin of Caucasians reaches equilibrium within 20 minutes of UVB exposure (17), with any excess 7-DHC being converted to inactive metabolites. Therefore, UVB exposure beyond the MED does not increase vitamin D production further that explains why it is impossible to get toxicity from UVB radiation.

Our study has encountered few limitations. The study was carried out during summer season only. Further studies are needed to determine the effect of change in the season throughout the year on skin production of pre-vitamin D₃. In addition, the study was conducted in four cities from different regions accordingly; optimum sun exposure times might not be the same from other geographical regions in the country

secondary to differences in weather, air pollution status and altitude.

In summary, the optimum sun exposure times during summer in the four cities of Saudi Arabia have been identified based on pre-vitamin D₃ conversion. A similar study is suggested during winter times. These suggested time-schedules for sun exposure during summer, once implemented by the general community, may effectively help battle the vitamin D deficiency pandemic in the country.

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