The solar UV exposure time required for vitamin D$_3$ synthesis in the human body estimated by numerical simulation and observation in Japan

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After the discovery of Antarctic ozone hole, the negative effect of exposure of human body to harmful solar ultraviolet (UV) radiation is widely known. However, there is positive effect of exposure to UV radiation, i.e., vitamin D synthesis. Although the importance of solar UV radiation for vitamin D$_3$ synthesis in the human body is well known, the solar exposure time required to prevent vitamin D deficiency has not been well determined. This study attempted to identify the time of solar exposure required for vitamin D$_3$ synthesis in the body by season, time of day, and geographic location (Sapporo, Tsukuba, and Naha, in Japan) using both numerical simulations and observations. According to the numerical simulation for Tsukuba at noon in July under a cloudless sky, 2.3 min of solar exposure are required to produce 5.5 μg vitamin D$_3$ per 600 cm^2 skin. This quantity of vitamin D represents the recommended intake for an adult by the Ministry of Health, Labour and Welfare, and the 2010 Japanese Dietary Reference Intakes (DRIs). In contrast, it took 49.5 min to produce the same amount of vitamin D$_3$ at Sapporo in the northern part of Japan in December, at noon under a cloudless sky. The necessary exposure time varied considerably with the time of the day. For Tsukuba at noon in December, 14.5 min were required, but at 09:00 68.7 min were required and at 15:00 175.8 min were required for the same meteorological conditions. Naha receives high levels of UV radiation allowing vitamin D$_3$ synthesis almost throughout the year. According to our results, we are further developing an index to quantify the necessary time of UV radiation exposure to produce required amount of vitamin D$_3$ from a UV radiation data.