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Systematic Literature Review: Health Risk & Threshold Limits of UVR for Long-term Space Habitation

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1. Introduction

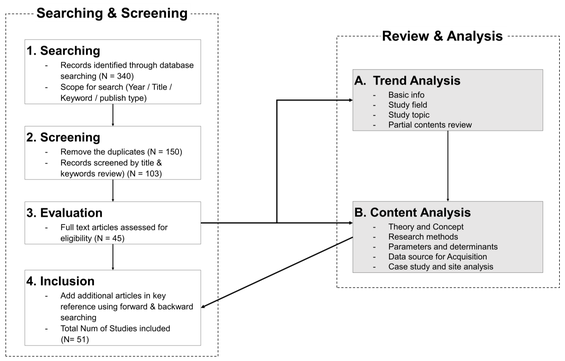
Background

- UV radiation is an important physical stressor for many exposed organisms, which has a diversity of positive and negative roles in the biosphere. Regarding the human health, eye and skin are the two primary organs of concern.
- In artificial environment such as space flight and space habitat, where the spectral quality is altered by controlled artificial man-made structures, the relationship between UV radiation and human health can be disturbed (Charles S. 2000).
- As the number of projects for building space habitat rises, it is increasingly crucial to reveal the optimal level of UV radiation exposure to provide healthy and sustainable closed loop system for the space settlements.

Key objective

- Aims at revealing the effects of UV radiation on burden of disease and optimal level of its exposure using the systematic literature review
  - Key determinants of UV Exposure
  - Evaluation methods for UV Risk and Disease
  - Optimal Exposure UV Level for Minimum burden of disease
- Expected to provide transferable implication from the ground evidences to space as well as offer guidance on UV radiation exposure for minimum burden of disease and long-term habitation in artificial environment.

2. Research Method



Procedures for Systematic Literature Review (SLR)

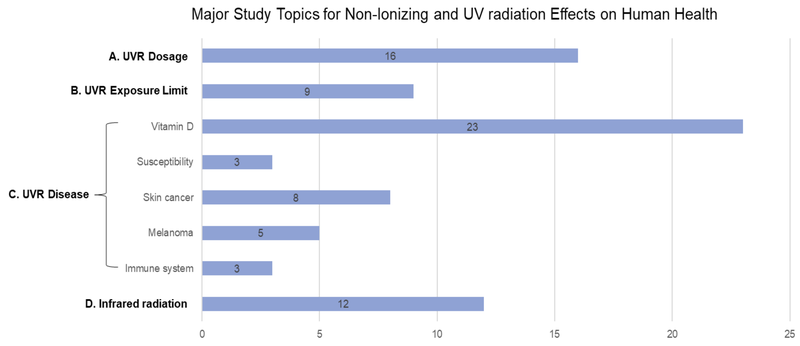
- SLR consists of five steps where are 1) searching, 2) screening, 3) evaluating, 4) inclusion and 5) trend & content analysis.
- Database: Scopus & Web of science | Collection Periods: Sep, 2019 to Feb, 2020 | Sample size (N): 51 journals and reports

Keywords used for Search

UVR Health Risk	UVR Threshold	Closed Loop System
- UVR safety	- Threshold Limit Value (TLVs)	- Space habitat
- UVR dose / dosage	- Optimal Value / Exposure Limit	- Space flight
- UVR guidance	- Minimum Burden of disease	- Controlled environ.
		- Autonomous system

3. Results

Part A : Major topics for UVR effects on Health Issues



- Over the last two decades, major topics of UVR effects on Human health can be grouped into four domains: dosage, exposure limits, disease burden, and other infrared radiation effects.

Part B : UVR Exposure & Burden of Disease

1. Dosage Calculation – How to exposure calculate

- Living organisms exposed to UV light irradiation are subject to an exposure (dose) which is a function of UV light irradiation multiplied by the exposure time as follows:

  UV dose (J/m2) = Irradiance (W/m2) x Exposure Time (seconds)

- The relative effectiveness of UV light wavelengths for this process is known as the germicidal action spectrum, which peaks at a maximum wavelength 265 nm

2. UVR risk factor measurement

- Ambient UVR is widely used as a proxy measure of personal exposure to UVR. It is measured in physical units or weighted using an erythemal response function to give biologically effective UVR
- Expressed as joules per square metre (Jm-2), minimal erythemal dose (MED), standard erythemal dose (SED) or the solar UV index.

3. Determinants of UVR exposure & Related Disease

Significant deviations in exposure mainly due to distal and proximal factors (Lucan R et al, 2006, AGNIR, 2017)

1) Distal factors - Stratospheric ozone levels, Cloud cover, Latitude, Season, and Lower atmospheric pollution
2) Proximity factors - Behavior (sun-seeking, sun-protective), Genetic (Skin pigmentation, sun sensitivity disorder), Cultural (dress, behaviors), and Immune competence (HIV)
3) Disease - Cutaneous melanoma, Squamous cell carcinoma of the skin, Basal cell carcinoma of the skin, Solar keratoses, Sunburn, Cortical cataract, Pterygium, Reactivation of herpes labialis

4. Exposure limit for Minimum burden of Disease

Too much VS Too little : Overexposure to UV is the main cause of eye damage and skin cancer - cell carcinoma, and melanoma. Adversely, lack of UVR exposure also results in low vitamin D leading to significant bone and muscle pain, and poor bone mineralization

1) Skin cancer (Holick, M. F. 2014)

- Exposure limits to UV radiation for the general population in occupational settings for the skin is an 8-hour exposure period a day (ICNIRP, 2004)

2) Eye damage (ACGIH, 2003; Antony R. 2006)

- For the UV-A, exposure to the eye should not exceed 1.0 mW/cm for periods greater than 1000 seconds. For exposure times less than 1000 seconds, the dose should not exceed 1.0 J/cm .

3) Vitamin D (Grant, W. B, 2003; 2013)

- Vitamin D, produced when the skin is exposed to the sun's UV rays, controls calcium levels on the blood. Short periods of sun exposure is enough to for Vitamin D production. No specific regulations on it.

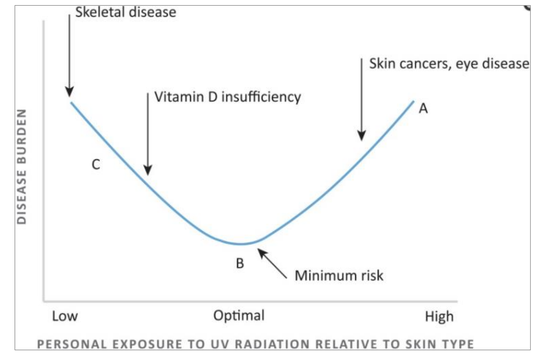
UVR exposure limit / Thresholds (ACGIH, 2003 ; ICNIRP,2004)

- UV-A (315 to 400nm): 1.0 J/cm2 for periods lasting less than 1000s.
- UV-C (100 to 280nm) : 3.1 mJ/cm2 at 275 nm for periods lasting less than 1000s.

4. Conclusion

Schematic diagram of the relationship between UVR exposure and the burden of disease

Point A & C represent inappropriate UVR exposure. Fair-skinned populations with high outdoor UVR exposure typify point A. Point C represents people with insufficient UVR exposure, whose dietary vitamin D intake will be also important in determining their vitamin D status. Point B represents optimal UVR exposure: A person with careful titration of correct UVR dose for skin type



(Lucas RM & Ponsonby, AL. 2002)

Producing quantitative formulation between UVR exposure and the disease burden is still in great challenge due to the lack of data for epidemiological studies and its varying sensitivity of exposure-response.

- For UVR radiation effects in an artificially enclosed environment system, no human experiments conducted in space except for plants and crops. Even more, the role of UVR in human health is not fully revealed on earth.
- For long-term habitation in space, Vitamin D production with UVR is the key since food intake can not fully sustain it
- Thus, consistent observation and monitor of UVR effects on human health with a large population on earth are necessary to accumulate the evidence to reveal optimal level of UVR for long-term space habitation.