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Measuring sun exposure in epidemiological studies: Matching the method to the research question

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ABSTRACT

Sun exposure has risks and benefits for health. Testing these associations requires tools for measuring sun exposure that are feasible and relevant to the time-course of the health outcome. Recent sun exposure, e.g. the last week, is best captured by dosimeters and sun diaries. These can also be used for medium-term sun exposure e.g. over several weeks, but incur a high participant burden. Self-reported data on "typical time outdoors" for working and non-working days, is less detailed and not influenced by day-to-day variation. Over a longer period, e.g. the lifetime, or for particular life stages, proxies of sun exposure, such as latitude of residence or ambient ultraviolet (UV) radiation levels (from satellites or ground-level monitoring) can be used, with additional detail provided by lifetime sun exposure calendars that include locations of residence, usual time outdoors, and detail of sunburn episodes. Objective measures of lifetime sun exposure include microtopography of sun-exposed skin (e.g. using silicone casts) or conjunctival UV autofluorescence. Potential modifiers of the association between sun exposure and the health outcome, such as clothing coverage and skin colour, may also need to be measured. We provide a systematic approach to selecting sun exposure measures for use in epidemiological health research.

1. Introduction

Exposure to ultraviolet (UV) radiation is implicated in both adverse and beneficial health outcomes, and its accurate measurement is essential to conducting research into these relationships. Choosing an appropriate sun exposure measure is an important part of study design, to capture the most appropriate period of sun exposure relevant to the health outcome under examination. Other considerations include practicality, suitability for the study population and cost. Inappropriate application of a sun exposure measure has the potential to produce biased estimations of disease and risk factor associations [11] and threaten the validity of the study. Some individual sun exposure measures have been validated and reviewed previously (see for example [9,77]). In this paper, we provide a comprehensive analysis of the uses, strengths and weaknesses of a range of instruments that are used to quantify sun exposure, and present a decision tree (Fig. 1) to assist researchers in choosing the most appropriate tool(s) for their research question.

UV radiation at Earth's surface is composed predominantly of UV-A radiation (wavelength $\lambda = 315–400$ nm) with a small percentage (<5%) of shorter wavelength UV-B radiation ($\lambda = 280–315$ nm). UV radiation in the UV-B waveband penetrates only to the epidermis and upper layers of the dermis, where it is absorbed by a range of chromophores [15]. Absorption by DNA can result in UV signature mutations that may lead to skin cancer development [60]. Absorption by 7-dehydrocholesterol initiates the synthesis of vitamin D. Irradiation in the UV-A waveband penetrates to the deeper layers of the skin, causing oxidative damage that can contribute to skin cancer development, although cutaneous nitric oxide may also have beneficial effects on health [43]. Measurements of UV radiation are commonly provided in units weighted to the erythemal action spectrum [52], such as the standard erythemal dose (SED), minimum erythemal dose (MED), or the UV Index [15].

The intensity of ambient (at Earth's surface) UV radiation varies by latitude and altitude, season and time of day, and with cloud cover [49]. An individual's exposure to UV radiation depends on the ambient UV radiation and the time spent outdoors; the received dose of UV radiation to the skin or eyes additionally depends on the use of sun protection such as clothing, shade, and sunscreen.

1.1. Considerations for Study Design

An initial consideration is whether data are required at a population or individual level. For example, consider the different measurements required to examine the variation in skin cancer incidence across populations in different locations, compared to that required to test risk factors for skin cancer within a population at a specific location.

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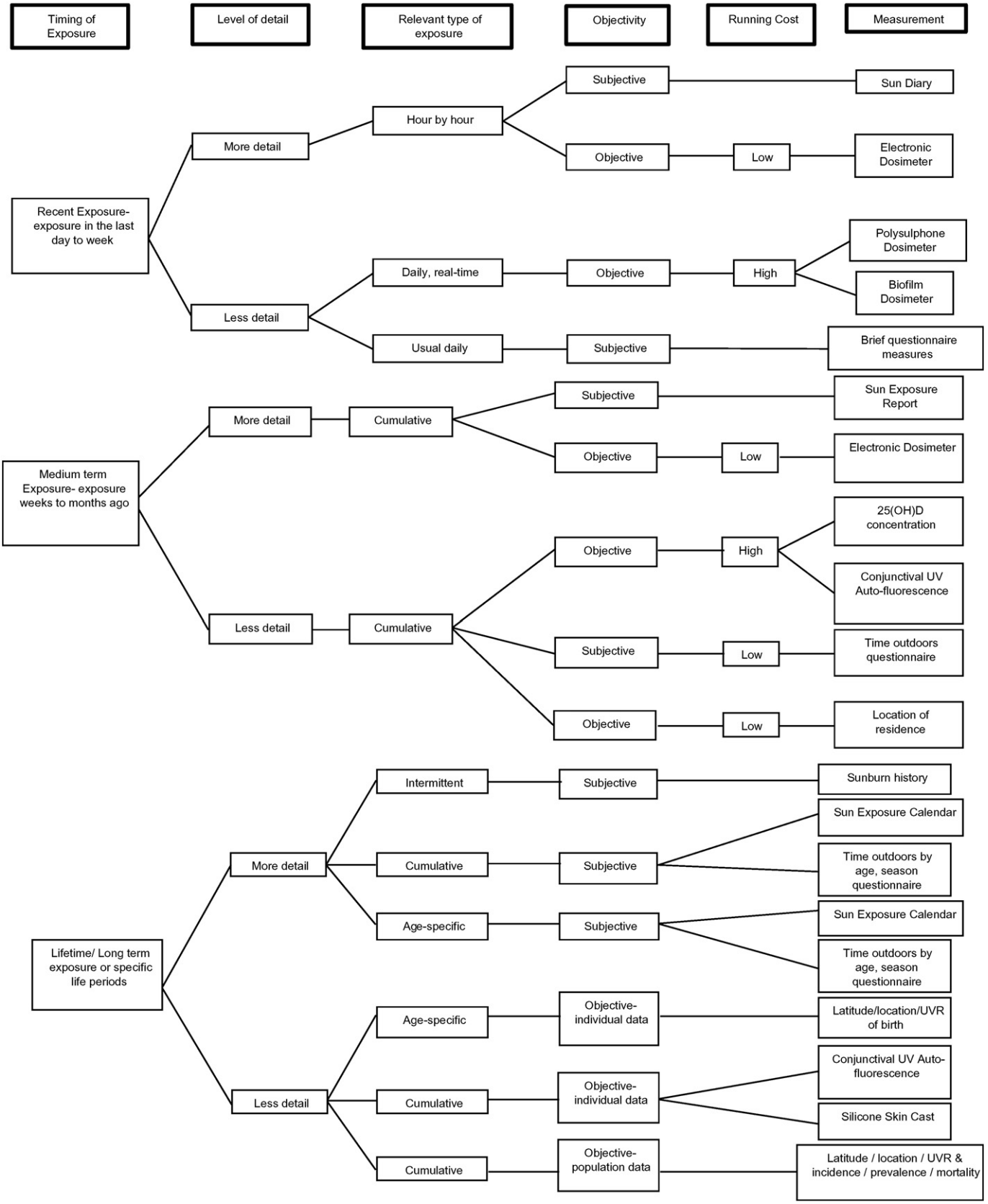

Fig. 1. Decision tree.

Another important consideration in choosing a measure of sun exposure is the relevant time period of exposure, including whether estimating exposure during particular life stages e.g. in utero, childhood or adulthood, is required. Measures of sun exposure can be separated into those that best capture long-term/cumulative (over past years, including specific life stages), medium-term (over the preceding few weeks