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A proposed methodology to estimate the cumulative life-time UVB exposure using geographic information systems: An application to multiple sclerosis

N. Schuurman[a], O. Amram[a], J. Saeedi[b], P. Rieckmann[c], I. Yee[d], H. Tremlett[e,*]

[a]*Department of Geography, Simon Fraser University, Canada*
[b]*National Neuroscience Institute, King Fahad Medical City, Riyadh, Kingdom of Saudi Arabia*
[c]*Department of Neurology, Sozialstiftung Bamberg Hospital, Bamberg, Germany*
[d]*Department of Medical Genetics, University of British Columbia, Vancouver, Canada*
[e]*Faculty of Medicine, Division of Neurology, Multiple Sclerosis Program and Brain Research Centre, Vancouver Coastal health Research Institute, University of British Columbia, Vancouver, Canada*

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Abstract
Background: The cause of multiple sclerosis (MS) is unknown; multiple risk factors have been implicated, including environmental exposures, such as sunlight. Many studies have relied on latitude alone as a crude proxy for sunlight exposure. We aimed to develop a protocol allowing a more detailed estimate of cumulative ambient ultra-violet B (UVB) exposure at critical time-periods over a patient's life-course.
Methods: 4010 definite MS patients with a 'movement history' from birth to the study end (2005) were selected from the University of British Columbia, Canada's MS Genetic database. Patient's place of resident from birth were tracked, each place being geocoded (latitude and longitude) and assigned a UVB value using the NASA Total Ozone Mapping Spectrometer (TOMS) dataset. Combined, these data allowed an estimated UVB value for each patient based on year and location.
Results: Using this protocol, we provide a potentially more detailed cumulative UVB exposure for critical periods in a patients' life history based on their individual spatial migration through time.
Conclusions: This protocol is intended to provide a framework for researchers to more accurately estimate UVB exposures for individuals over the course of their life history and may be useful for understanding etiology of MS and other chronic disease.

*Corresponding author. Tel.: +1 604 8220759; fax: +1 604 8227897.
E-mail address: helen.tremlett@ubc.ca (H. Tremlett).

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1. Introduction

Multiple sclerosis (MS) is a chronic, degenerative disease of the central nervous system for which the exact etiology is not yet understood. Multiple risk factors may be involved including interactions between susceptibility genes and environmental factors (Milo and Kahana, 2010; Sospedra and Martin, 2005). Several clinical and epidemiological studies support the hypothesis that vitamin D levels – perhaps mediated by ultraviolet B exposure – are able to modulate disease processes in MS (Ascherio and Munger, 2007; Simon et al., 2011; van der Mei et al., 2011). Early papers reported that the frequency of MS was greater between 45 and 64 degrees latitude – than at lower latitudes (Kurtzke, 1977). These reports were organized geographically (Kurtzke, 1980) in a map that revealed bands of higher prevalence in Northern and Central Europe as well as North America and parts of Southern New Zealand and Australia(Kurtzke, 1980).

Assignations of latitude have been variously derived based on place of birth, location at puberty or place of symptom onset or diagnosis (Detels et al., 1978; Hammond et al., 2000; Sloka et al., 2008). There are two main shortcomings with latitude correlation to date. First, selecting single latitude for assignation of UVB exposure does not take into account the role of the entire life history and movements (e.g., what was the UVB exposure at key points in a patient's history). Related to this is that the current methods are not able to account for increasingly mobile western populations (Beretich and Beretich, 2009). Second, latitude correlations do not measure actual ambient UVB exposure (i.e., the actual level of UV radiation reaching earth). Notable exceptions include recent use of satellite data to determine average UVB exposure at latitude (Beretich and Beretich, 2009; Sloka et al., 2008). Some have called for the calculation of more accurate population exposure estimates (Ebers, 2009), although to date, no standardized procedure has been developed. This paper introduces a method to calculate UVB exposure for patients at critical points as well as cumulative exposure over the course of their life history using widely available NASA data, with application to MS.

2. Methods

This was a retrospective study accessing patients with definite MS ((Poser et al., 1983) or (McDonald et al., 2001) criteria) through the University of British Columbia (UBC) MS Clinic where detailed family histories are taken by a trained genetic counsellor. From the ''UBC MS Genetic database'', we identified MS patients with information detailing -their movement since birth to study end (2005) as well as the date (year) and location of each change in place of residency were collated. This was linked to UVB data obtained using the NASA Total Ozone Mapping Spectrometer (TOMS) data set. TOMS data consists of several data sets collected by NASA satellites during the period 1979 to 2005 (excluding 1994–95). Our study used TOMS' Erythemal UVB data as it provides a record of UVB values reflected from the earth's surface. This accounts for cloud coverage and only captures UVB that reaches earth. The raw data is collected and recorded daily by NASA and covers the world's surface with 180 cells longitude, 288 cells latitude and a cell dimension of 1×1.25. The TOMS data UVB values consist of 3 digit values that required conversion (using a standard formula) in order to obtain the actual UVB value for each location. As the TOMS data did not provide UVB values for all locations within the study, a value of 999 (i.e., missing data) was assigned to areas without data.

In preparation for analysis, a UVB value was assigned to each year of each MS patient's life. This value was calculated by averaging daily NASA values over the year (e.g. sum of all days/number of days of data). A UV reference table was developed providing a UVB value for each location for each year included in the study for each patient. The reference table served the purpose of allowing us to assign the correct UVB value to the 'patient movement table' based on time and location. To populate the table, all unique patients' locations in the world were geocoded (approximately 2500 locations). Annual UVB surfaces were created for each year for which data were available. Days for which no data were recorded were then subtracted (i.e., 365 – days of no data). For years in which no UV data were recorded, averaged surfaces were created based on years for which data existed. Using the reference table, the correct UVB value could be assigned to each patient based on year and location.

Figure 1 illustrates the development of the patient movement table for assignation of a UVB value for each patient year since birth.

2.1. Data analyses

Geographic Information Systems (GIS) was the primary tool used to analyze and visualize the data. In order to ensure consistent projection within the software program, ArcGIS, the NASA surface cell dimensions of 1×1.25 were re-sampled at a cell dimension of 1×1 (ArcGIS only reads square cells). This required intermediary re-sampling with the raster application IDRISI so that cells could be imported into ArcGIS. After all the UVB surfaces were properly projected in ArcGIS, a reference table was created by overlaying the surfaces with the geocoded cities and extracting the UV value for each surface year. Figure 2.

3. Results

In total, 4010 definite MS patients were identified to have a movement history. As a group, they had resided in 2656 different localities for which a unique latitude, longitude and annualized UVB was assigned for every year of life. Of the patients in the database, 82% were born in Canada, 4.2% in the UK and 2.7% in the United States. Just over 10% were born elsewhere in the world. Most of these patients (87.1%) were of European ancestry and a breakdown of their ethnic backgrounds is given in Table 2. Other demographic or clinical information were not considered for this current methodological study.

Table 1 gives an example of cumulative UVB exposure at key points which might represent two patients' lives (original details have been changed). The first patient, in red (ID 1), resided in locations with relatively low sun exposure. The second patient, in yellow (ID 2), lived in several locations,