

Environmental Burden of Disease Series, No. 13

# Solar Ultraviolet Radiation

---

## Global burden of disease from solar ultraviolet radiation

Robyn Lucas  
Tony McMichael  
Wayne Smith  
Bruce Armstrong

Editors  
Annette Prüss-Üstün, Hajo Zeeb, Colin Mathers, Michael Repacholi



World Health Organization  
Public Health and the Environment  
Geneva 2006

## WHO Library Cataloguing-in-Publication Data

Solar ultraviolet radiation : global burden of disease from solar ultraviolet radiation /  
Robyn Lucas ... [et al.] ; editors, Annette Prüss-Üstün ... [et al.].

(Environmental burden of disease series ; no. 13.)

1.Sunlight - adverse effects. 2.Ultraviolet rays - adverse effects. 3.Risk  
assessment. 4.Cost of illness. 5.Skin - radiation effects. 6.Eye - radiation effects.  
I.Lucas, Robyn. II.Prüss-Üstün, Annette. III.World Health Organization. IV.Series:  
Environmental burden of disease series ; no. 13.

ISBN 92 4 159440 3

(NLM classification: WD 605)

ISBN 978 92 4 159440 0

ISSN 1728-1652

### © World Health Organization 2006

All rights reserved. Publications of the World Health Organization can be obtained from Marketing and Dissemination, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (tel: +41 22 791 2476; fax: +41 22 791 4857; email: [bookorders@who.int](mailto:bookorders@who.int)). Requests for permission to reproduce or translate WHO publications – whether for sale or for noncommercial distribution – should be addressed to Marketing and Dissemination, at the above address (fax: +41 22 791 4806; email: [permissions@who.int](mailto:permissions@who.int)).

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by WHO to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either express or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the World Health Organization be liable for damages arising from its use.

The named authors alone are responsible for the views expressed in this publication.

Printed by the WHO Document Production Services, Geneva, Switzerland.

# Table of Contents

Preface.....	vi
Affiliations and acknowledgements.....	vii
Abbreviations.....	viii
Summary.....	1
1. Background.....	2
1.1 Introduction.....	2
1.2 Comparative risk assessment.....	3
1.3 Definition of the risk factor.....	4
1.4 Measurement of the risk factor.....	5
1.5 Defining the counterfactual exposure.....	7
2. Methods.....	10
2.1 Outcomes to be assessed.....	10
2.2 Estimation of risk factor-disease relationships.....	12
2.3 Evaluation of population attributable fraction.....	14
2.4 Development of disease models.....	17
3. Burden of Disease Assessment.....	18
3.1 Diseases with pre-existing BOD analyses completed.....	18
3.2 Diseases where adequate epidemiological data are available.....	18
3.3 Diseases with scanty global data.....	19
4. Outcome assessment for diseases caused by excessive UVR exposure.....	20
4.1 Cutaneous malignant melanoma.....	20
4.2 Squamous cell carcinoma.....	27
4.3 Basal cell carcinoma.....	35
4.4 Chronic sun damage/solar keratoses.....	42
4.5 Sunburn.....	46
4.6 Cortical cataract.....	50
4.7 Pterygium.....	55
4.8 Carcinoma of the cornea and conjunctiva.....	61
4.9 Reactivation of herpes labialis.....	67
5. Potential disease burden caused by complete removal of UVR exposure.....	72
6. Sources of error or uncertainty.....	77
7. Conclusion.....	78
8. Future directions.....	80
References.....	83
Annexes.....	88
Annex 1 Literature Review.....	88
Annex 2 Epidemiologic studies used for estimation of population attributable fraction and descriptive studies of disease distribution.....	163
Annex 3 Disease worksheets.....	173
Annex 4 WHO subregions by latitude.....	198
Annex 5 Distribution of skin pigmentation.....	201
Annex 6 Estimation of disease incidence/prevalence for diseases with scanty epidemiological data.....	204
Annex 7 Summary results for the year 2000.....	206

## List of tables

Table 2.1	Candidate, and selected, health outcomes to be assessed for the burden of disease related to ultraviolet radiation. ....	11
Table 4.1	Incident cases of Malignant Melanoma 2000 .....	22
Table 4.2	Mortality from Malignant Melanoma 2000 (0.1% of total global mortality).....	23
Table 4.3	Disease burden due to malignant melanoma in DALYs (000) .....	24
Table 4.4	Disease burden from malignant melanoma attributable to ultraviolet radiation DALYs (000) – upper estimates.....	25
Table 4.5	Disease burden from malignant melanoma attributable to ultraviolet radiation DALYs (000) – lower estimates .....	26
Table 4.6	Incident cases of SCC.....	30
Table 4.7	Deaths from SCC .....	31
Table 4.8	Disease burden due to SCC in DALYs (000) .....	32
Table 4.9	Disease burden from SCC attributable to ultraviolet radiation DALYs (000) – upper estimates .....	33
Table 4.10	Disease burden from SCC attributable to ultraviolet radiation DALYs (000) – lower estimates .....	34
Table 4.11	Incident cases of BCC.....	37
Table 4.12	Deaths from BCC in 2000 .....	38
Table 4.13	Disease burden due to BCC in DALYs (000) .....	39
Table 4.14	Disease burden from BCC attributable to ultraviolet radiation DALYs (000) – upper estimates .....	40
Table 4.15	Disease burden from BCC attributable to ultraviolet radiation DALYs (000) – lower estimates.....	41
Table 4.16	Prevalent persons with solar keratoses.....	44
Table 4.17	Burden of disease due to solar keratoses (=attributable BOD) DALYs (000) .....	45
Table 4.18	Incident cases of sunburn 2000 .....	48
Table 4.19	Burden of disease due to sunburn (attributable BOD) DALYs (000).....	49
Table 4.20	Incident cataracts 2000 (from GBD 2000, (99)) .....	51
Table 4.21	Burden of disease from cataract DALYs (000) (from GBD 2000, (99)) .....	52
Table 4.22	Burden of disease due to cortical cataract DALYs (000).....	53
Table 4.23	Disease burden from cataract attributable to UVR DALYs (000) .....	54
Table 4.24	Prevalence (persons) of pterygium 2000 .....	57
Table 4.25	Burden of disease from pterygium DALYs (000).....	58
Table 4.26	Disease burden from pterygium attributable to UVR DALYs (000) – upper estimates.....	59
Table 4.27	Disease burden from pterygium attributable to UVR DALYs (000) – lower estimates .....	60
Table 4.28	Incident cases of SCCC (2000).....	63
Table 4.29	Burden of disease from SCCC DALYs (000) .....	64
Table 4.30	Disease burden from SCCC attributable to UVR DALYs (000) – upper estimates .....	65
Table 4.31	Disease burden from SCCC attributable to UVR DALYs (000) – lower estimates .....	66
Table 4.32	Incident herpes labialis 2000 .....	68
Table 4.33	Burden of disease from RHL DALYs (000) .....	69
Table 4.34	Disease burden from RHL attributable to UVR DALYs (000) – upper estimates .....	70
Table 4.35	Disease burden from RHL attributable to UVR DALYs (000) – lower estimates.....	71

Table 5.1	Proposal for staging of vitamin D deficiency <sup>1</sup> .....	73
Table 5.2	Incident cases of vitamin D deficiency 2000 under a scenario of zero UVR exposure .....	75
Table 5.3	Potential disease burden due to complete removal of UVR exposure, DALYs (000) .....	76
Table 7.1	Burden of disease due to excessive UVR exposure, DALYs (000) and deaths .....	78

## List of figures

Figure 1.1	Causal Web for Health Impacts due to Ultraviolet Radiation .....	3
Figure 1.2	Monthly averaged annual ambient erythemally weighted UVR, 1997-2003.....	6
Figure 2.1	Schematic diagram of the relation between ultraviolet radiation (UVR) exposure and the burden of disease .....	6
Figure 2.2	Distribution of UVR exposure in a theoretical population .....	16
Figure 2.3	Distribution of UVR exposure in two different (theoretical) populations .....	16
Figure 3.1	Methods of calculating attributable burden.....	18
Figure 4.1	Disease model for SCC.....	29
Figure 4.2	Disease model for BCC – all regions .....	36
Figure 4.3	Disease model for solar keratoses .....	43
Figure 4.4	Disease model for sunburn .....	47
Figure 4.5	Disease model for pterygium.....	56
Figure 4.6	Disease model for SCCC - ABC regions.....	62

## Preface

Human exposure to solar ultraviolet radiation has important public health implications. Evidence of harm associated with overexposure to UV has been demonstrated in many studies. Skin cancer and malignant melanoma are among the most severe health effects, but a series of other health effects have been identified. The current report provides a quantification of the global disease burden associated with UV. The information presented forms a knowledge base for the prevention of adverse effects of UV exposure that is achievable with known and accessible interventions. UV prevention focuses on protecting the skin and other organs from UV radiation. On the other hand, a moderate degree of UV exposure is necessary for the production of Vitamin D which is essential for bone health. Additionally, evidence emerges that low Vitamin D levels are likely to be associated with other chronic diseases. Thus, public health policy on ultraviolet radiation needs to aim at preventing the disease burden associated both with excessive and with insufficient UV exposure.

This volume is part of a series on global estimates of disease burden caused by environmental risks, and guides for estimating the disease burden from specific risks at country or local level. This Environmental Burden of Disease (EBD) series responds to the need to quantify environmental health risks as input to rational policy making. Quantification of disease will provide information on the health gains that could be achieved by targeted action on protecting against specific environmental risks to health. An introductory volume (No. 1 of the series) provides further details on methods used for such quantification.

The methods for environmental burden of disease are part of a larger initiative - WHO has recently analysed 26 risk factors worldwide in the World Health Report (WHO, 2002). In 2006, a global estimate of the health impacts from environmental risks has shown that the 24% of global disease is due to the "modifiable" part of the environment<sup>1</sup>.

A separate guide is being prepared to assist in the estimation of health impacts from UV radiation at country level.

---

<sup>1</sup> Preventing disease through healthy environments - towards an estimate of the global burden of disease. WHO, Geneva, 2006.

## **Affiliations and acknowledgements**

The World Health Organization, through its INTERSUN programme, is actively engaged in protecting the public from health hazards of ultraviolet radiation. In the framework of this programme, an assessment of the global disease burden associated with solar ultraviolet radiation was performed by the National Centre for Epidemiology and Population Health (NCEPH) in Australia, implementing a contract between WHO and the New South Wales Cancer Council.

The principal authors of this report are:

- Dr. Robyn Lucas, National Centre for Epidemiology and Population Health, Canberra, Australia
- Prof. Tony McMichael, National Centre for Epidemiology and Population Health, Canberra, Australia
- Prof. Wayne Smith, Centre for Clinical Epidemiology and Biostatistics, Newcastle University, Australia.
- Prof. Bruce Armstrong, School of Public Health, The University of Sydney, Australia

The WHO and the authors wish to acknowledge the assistance of Ivan Hanigan (NCEPH) with reference retrieval and GIS mapping of population and UVR; Dr Diarmid Campbell-Lendrum (WHO) for his discussion of comparative risk assessment methodology; Dr Jenny Lucas (Bone Fellow, Auckland Hospital, New Zealand) for her help in the understanding of influences of vitamin D on the skeletal system; Dr Robin Marks for his helpful comments on disease models for skin cancers; and Dr Simon Hales for GIS expertise. Dr William B. Grant (Sunarc, USA), Reviewers at the German Bundesamt für Strahlenschutz, the US Environmental Protection Agency, the WHO (Drs Kate Strong and Andreas Ullrich) as well as Professor Rona M MacKie (University of Glasgow, UK) reviewed earlier drafts of the document.

Editorial and scientific support at WHO was provided by Drs. Annette Prüss-Üstün, Hajo Zeeb, Colin Mathers and Michael Repacholi.

## **Abbreviations**

BCC	Basal cell carcinoma
CMM	Cutaneous malignant melanoma
DALY	Disability-adjusted life year
GBD	Global burden of disease
NMSC	Non-melanoma skin cancer
PAF	Population attributable fraction
RHL	Reactivation of herpes labialis
SCC	Squamous cell carcinoma
SCCC	Squamous cell carcinomas of the cornea and the conjunctiva
UVR	Ultraviolet radiation

## Summary

A burden of disease analysis was undertaken to evaluate solar ultraviolet radiation as a risk factor for human illness. The objective was to assess the contribution of solar ultraviolet radiation to human ill health in both mortality and morbidity and taking account of the future stream of disability following disease diagnosis (using the disability – adjusted life year (DALY) as a common metric).

The initial step involved an analysis of the strength of the causal relationship between UVR exposure and a number of diseases identified in the literature as probably being related. Having identified nine disease outcomes with strong evidence of a causal relationship with excessive UVR exposure, and three diseases associated with under-exposure, an estimation of the population attributable fraction for UVR exposure was made for each of these outcomes, on the basis of published epidemiological studies.

Three separate methods were used to calculate the global burden of disease due to the above-identified diseases. The global burden of disease due to melanoma was already calculated as part of WHO's global burden of disease assessment. Calculated population attributable fractions for UVR exposure were applied directly to these estimates. For other diseases for which there are good epidemiological data on incidence and mortality, population level exposure-response relationships were developed. Using country-level population-weighted average (1997-2003) annual ambient UVR, incidence and mortality rates were imputed from these exposure-response curves and the burden of disease calculated and aggregated to WHO sub-regions. For those diseases for which much weaker epidemiological data were available, exposure to UVR was approximated by latitudinal position in ten-degree bands. Incidence and mortality rates were extrapolated from the available data to regions of similar latitude and the burden of disease calculated for each WHO sub-region.

Disease duration and disability weights for various health states were derived from the literature or estimated from diseases of similar severity based on the appreciation of a working group established for this study.

Globally, excessive solar UVR exposure caused the loss of approximately 1.5 million DALYs (0.1% of the total global burden of disease) and 60 000 premature deaths in the year 2000. The greatest burden results from UVR-induced cortical cataracts, cutaneous malignant melanoma and sunburn (although the latter estimates are highly uncertain due to paucity of data). Notably, a counterfactual of zero UVR exposure would not result in a minimum disease burden, but rather a high disease burden due to diseases of vitamin D deficiency.