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The relationship between occupational sunlight exposure and non-melanoma skin cancer

Stephanie Soo Hwei Tan

Submitted in total fulfilment of the requirements of the degree of

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Abstract

Aims and Background: Australia has the highest incidence of skin cancer in the world and ultraviolet (UV) radiation exposure is the dominant environmental determinant of all major forms of skin cancer. Two recent systematic reviews and meta-analysis of the available epidemiological evidence clearly indicate that occupational ultraviolet radiation (UVR) exposure is a substantial risk factor for the development of non-melanoma skin cancer. This study is an initial attempt to investigate the role of occupational sunlight exposure in the development of non-melanoma skin cancer in men in Australia.

Methods: A case-control study was conducted. One hundred cases were recruited from the Skin and Cancer Foundation Inc. Controls included 14 age- and gender-matched subjects nominated by the cases. A questionnaire was administered through face-to-face interviews to collect information on pigmentary and genetic characteristics, occupational and recreational exposure assessment, and time of first diagnosis of non-melanoma skin cancer, confirmed with histopathological diagnosis. Conditional logistic regression models were implemented. Subsequently, a one-way analysis of variance (ANOVA) was used to investigate the relationship of each risk factor with occupational sun exposure.

Results: There was insufficient evidence to conclude that there was a relationship between occupational sun exposure and non-melanoma skin cancer, because of the small sample size of matched case-control pairs. As the results for the small sample size of the matched case-control group were not statistically significant, a one-way analysis of variance (ANOVA) was performed to compare the risk factors. Fitzpatrick Skin Type was the only risk factor that showed a statistically significantly different

occupational exposure profile (with a *P*-value of 0.035) but even then the differences were minor and only between skin phototype 2 and 3. There were no significant relationships between occupation exposure and the other risk factors.

Conclusion: Unfortunately, analysis of the small number of matched case-control pairs was not statistically significant and it was not possible to draw any conclusions regarding the role of occupational sunlight exposure in the development of non-melanoma skin cancer. We experienced unexpectedly high levels of reluctance from case subjects to propose control subjects to participate in the study, which impacted on data collection and subsequently the study results. It has been well established that solar UVR is a risk factor for skin cancer. Outdoor workers are potentially exposed to high levels of UVR.

More epidemiological studies are needed to improve our understanding and awareness of skin cancer as well as aid the development of prevention strategies at workplaces to reduce outdoor workers' exposure to UVR.

Declaration

This is to certify that:

- the thesis comprises only my original work towards the masters except where indicated in the Preface,
- due acknowledgement has been made in the text to all other material used,
- the thesis is less than 30000 words in length, exclusive of tables, maps, bibliographies and appendices.

_____

Stephanie Soo Hwei Tan

Student Number: 65273

Preface

This thesis is submitted in total fulfilment of the requirements of Master of Medicine (by research). It contains work done from February 2012 to June 2014. The thesis has been made solely by the author. Most of the text, however, is based on the research of others, and I have done my best to provide references to these sources.

It was sometime in mid-2011 that this idea was conceptualised. One of my supervisors, Associate Professor Rosemary Nixon was invited to present at an international conference on occupational skin cancer in Australia. In my attempt to assist her by performing a literature search of the available evidence, we discovered a lack of studies within Australia to investigate the role of occupational sunlight exposure in the development of non-melanoma skin cancer despite Australia having the highest incidence of skin cancer in the world and significant investment having been made to increase the awareness of skin cancer in the general public. Hence, we decided to embark on this project to gain a better understanding of the relationship between occupational sunlight exposure and non-melanoma skin cancer.

It was no easy task to turn this idea into reality. Recruitment was laborious and difficult due to unexpected reluctance from patients. To be involved in every step of the way of the project from conceptualising the idea to designing the study protocol to ethics submission to conducting the study has been an eye opening and fulfilling experience. It has given me the opportunity to gain an appreciation of the efforts made by researchers in their attempt to improve our knowledge and understanding of a specific field of interest.

This thesis contains information from the following paper and book chapters:

1. Upjohn E, Tan S. Chapter 3.2.1 Clinical Features of Squamous Cell Carcinoma with Involvement of the Face. In: Roldan JC, Jackson IT, Haerle F, editors. Atlas of Surgery for Facial Cancer. Thieme Publishers, Germany: 2011, in press

2. Upjohn E, Tan S. Chapter 3.2.4 Prognosis of Squamous Cell Carcinoma. In: Roldan JC, Jackson IT, Haerle F, editors. Atlas of Surgery for Facial Cancer. Thieme Publishers, Germany: 2011, in press

3. Sim M, Tan S, Nixon R. Chapter 26 Malignant Neoplasms of the Skin. In: Sisko Antilla, Paolo Boffetta, Kurt Straif, editors. Occupational Cancer. Springer Publishers, USA: 2012, in press

4. Tan S, Sinclair C, Foley P. Running behind a Tourist- Leisure related skin cancer prophylaxis. *British Journal of Dermatology* (2012) Aug;167 Suppl 2:70-5. doi: 10.1111/j.1365-2133.2012.11089.x.

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This work was made possible due to the generosity and kindness of many people.

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I am grateful to have been introduced to Associate Professor Claire Vajdic who has kindly shared her knowledge on epidemiological issues whenever I was in need of advice in an area that was new to me. Despite having never met her in person and only corresponded through emails, she was always willing to take the time to assist with any questions I had with my project.

I would also like to acknowledge Associate Professor Claire Vajdic and Dr Anne Kricker for sharing their questionnaire on assessment of sunlight exposure when I was constructing our questionnaire.

My sincere thanks to Dr Peter Gies who shared his extensive knowledge on quantification of ultraviolet radiation exposure.

I wish to thank the staff at the Skin and Cancer Foundation Inc for their support. To Nicole Rowley, for printing the long list of appointment listings with promptness whenever required.

This thesis was made possible with the unconditional love and support from my family and friends. To my brother Kevin Tan, for formatting the questionnaire and constructing the excel spreadsheet for my data. To Amelia Kok, for patiently teaching me how to construct pivot tables and create graphs on Excel. To Allan Lee, thank you for believing in me, for always being there to encourage me. To Adrian Chan, for ensuring this thesis is correctly formatted.

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Table of Contents

Abstract 2
Declaration 4
Preface 5
Acknowledgements 7
List of tables, figures and illustrations 11
1. Introduction 12
1.1 Basal Cell Carcinoma 15
1.2 Squamous cell carcinoma 17
1.2.1 Actinic keratosis 17
1.2.2 Squamous cell carcinoma in situ 19
1.2.3 Bowen's disease 19
1.2.4 Squamous cell carcinoma 20
2. Literature review 21
2.1 Incidence and Prevalence of NMSC in Australia 21
2.2 Ultraviolet Radiation (UVR) and Non-Melanoma Skin Cancer (NMSC) 22
2.3 UV Index 25
2.4 The National Health and Medical Research Council (NHMRC) Standard 26
2.5 Increased Exposure to UVR in Outdoor Workers 30
2.6 Increased Risk of NMSC in Outdoor Workers 34
3. Methodology 51
3.1 Study Design 51
3.2 Study Population 54
3.3 Inclusion and Exclusion Criteria 54
3.4 Exposure Assessment 55
3.5 Statistical Analysis 57
4. Results 58
4.1 Number of Cases and Controls 58
4.2 Characteristics of Case Subjects 59

4.3 Statistical Analysis **63**
4.3.1 Results for matched cases and controls **64**
4.3.2 Dotplots of the difference in exposure between cases and controls. **65**
4.3.3 Fitzpatrick Skin Type **66**
4.3.4 Summary **67**
5. Discussion **68**
5.1 Case-Control Study versus Cohort Study **68**
5.2 Case-Control Study Chosen for This Project **69**
5.3 Challenges of Case-Control Study **70**
5.4 Factors Influencing Choice of Study Design **78**
5.5 Strengths and Limitations of This Study **79**
5.6 Health Impact of Excessive Sunlight Exposure and Steps to Mitigate the Risk of NMSC **82**
5.7 Protective Behaviour and Preventative Strategies **83**
5.7.1 Slip on some protective clothing **84**
5.7.2 Slop on sun protection factor 30+ sunscreen **86**
5.7.3 Slap on a hat **87**
5.7.4 Seek shade **88**
5.7.5 Slide on some sunglasses **89**
5.8 Is Occupational Sunlight Exposure in Outdoor Workers a Risk Factor for NMSC? **91**
5.9 Importance of Reducing Sunlight Exposure in Outdoor Workers **95**
5.10 Workplace Sun Safety Interventions **96**
6. Conclusion **100**
Bibliography **102**
Appendix A - Participant Information and Consent Form for Case Subjects **112**
Appendix B - Participant Information and Consent Form for Control Subjects **117**
Appendix C - Questionnaire **122**

List of tables, figures and illustrations

Table 1. UV Index Categories 26

Table 2. A comparison between the WHO UV Index relating the sun's UVR intensity to the time taken to exceed the exposure limit (EL). The higher the UV Index the shorter the time to exceed EL. 29

Table 3. Estimated number of employees in major industries involving outdoor work 30

Table 4. Occupational Exposure 59

Table 5. Total Exposure 60

Table 6. Fitzpatrick Skin Type 63

Table 7. Pigmentary characteristics of case subjects 65

Table 8. Ultraviolet (UV) protection factor (UPF) ratings and protection categories 86

Table 9. Categories of lenses in sunglasses and labeling required 90

Figure 1. Dotplots of exposure for cases and controls 61

Figure 2. Dotplot of difference in occupational exposure 62

Figure 3. Dotplot of difference in total exposure 62

Figure 4. Distribution of Cases by Age 66

Figure 5. Distribution of Cases by Ethnicity 66

Figure 6. Distribution of Cases by Ancestry 67

Figure 7. Distribution of Cases by Fitzpatrick Skin Type 67

1. Introduction

Skin cancer is the most commonly diagnosed type of cancer in white-skinned populations. It is principally comprised of cutaneous malignant melanoma (CMM) and non-melanoma skin cancer (NMSC). The incidence of both CMM and NMSC has continued to rise over the last decade. Currently, between 2 and 3 million NMSCs and 132,000 CMMs occur globally each year. One in three cancers diagnosed is a skin cancer (1).

Australia has the highest skin cancer incidence rate in the world and it is estimated that approximately two out of three Australians will be diagnosed with skin cancer before the age of 70. This is due in part to the high ambient solar ultraviolet (UV) levels, combined with a predominantly susceptible fair-skinned population. NMSC is the most commonly diagnosed cancer in Australia, with approximately 430,000 new cases estimated to have been diagnosed in 2008. Of these 430,000 new cases, an estimated 296,000 were basal cell carcinomas (BCC) and an estimated 138,000 were squamous cell carcinomas (SCC). NMSC are not reportable by law to cancer registries, therefore the true incidence of BCC and SCC in Australia is not known. (2-5)

NMSC is the most common and expensive cancer in Australia, placing a high burden on the population, health care system and government. 2% of the Australian population (364,000 people) were treated for NMSC in 2001, with a total expenditure of $264 million making it the most expensive cancer. In comparison, colorectal cancer was the second most common cancer in Australia in 2001, with 12701 new cases and a cost of $235 million. The risk of NMSC increases with age, and the ageing of the Australian population will likely increase the burden of NMSC on the Australian health system. (3, 4, 6)

The most important risk factor in the development of skin cancer is exposure to ultraviolet radiation (UVR). Cumulative lifetime UVR exposure has been shown to be most important in the pathogenesis of SCC, whereas intermittent high-dose UVR exposure in childhood and adolescence may be more important in the aetiology of BCC and CMM. (7)

Skin cancers are less commonly considered occupational compared to other types of cancers related to workplace exposures, such as mesothelioma and bladder cancer. This is because skin cancers are very common in the community and the main aetiological factor, that is UVR, is ubiquitous. Therefore, occupational risk factors may not be identified when a skin cancer is diagnosed.

This current low awareness is despite a type of skin cancer being the first occupational cancer to be described in the literature. In 1775, Sir Percival Potts first described a type of SCC in the skin folds of the scrotum, which he termed soot-wart (8). This condition was predominantly found in young men who had worked as chimney sweeps as young boys, as they were able to do this work because of their small size. The cause of soot-wart was thought to be coal tar, which also contained traces of arsenic. This finding was one factor that led to the introduction of the Chimney Sweepers' Act in England in 1778, one of the first examples of legislation aiming to prevent health and safety problems in workplaces.

Other skin neoplasms were later described among other occupations, such as mule spinners' disease found in the scrotal and vulval ruggae of cotton workers, which was first described in the early 20th century. This condition was thought to result from the groin area becoming soaked with mineral oil from straddling cotton-spinning machines. (9)

Since these early examples of occupational cancer of the skin, many other types of occupational cancer occurring in other parts of the body linked to workplace exposures have been discovered and become the focus of occupational cancer prevention. Yet occupational skin cancer continues to be an important problem in workplaces today in many countries around the world and yet is arguably under-recognised and under-reported.

Most of the epidemiological studies carried out on skin cancer related to UV exposure have been on the general population and related to recreational exposure. Nevertheless, some of the findings of these studies are applicable to occupational exposure. The main difference between occupational and recreational exposure is that occupational exposure usually results in a moderate dose on a regular basis at body sites accustomed to sun exposure, while recreational exposure results in an intermittent high dose often at body sites unaccustomed to sun exposure.

NMSC form in the lower part of the epidermis or in the squamous cells, but not in the melanocytes. They have the following clinical features.

1.1 Basal Cell Carcinoma

BCC is the most common cutaneous malignancy, arising from the basal layers of epidermis. Although this tumour very rarely metastasizes, it is capable of extensive tissue destruction from local invasion. UV exposure is thought to be the major risk factor in the development of BCC. About 85 percent of tumours occur on sun-exposed areas, particularly the head and neck, while approximately 15 percent of tumours occur on skin protected from sun exposure. (10, 11) Genetic susceptibility is thought likely to play a role in these cases (12). Individuals with light skin colour, blond or red hair, blue or green eyes, an inability to tan, a tendency to freckle easily, and a family history of skin cancer are at increased risk of BCC. BCC is extremely uncommon in dark-skinned races, and less common in Chinese, Japanese and other oriental populations (13, 14). Approximately 40 percent of patients who have had one BCC will develop another lesion within five years (15).

BCC may also arise in skin damaged by ionizing radiation, thermal injury, vaccination scars and chronic inflammation. Immunocompromised patients have an increased BCC risk that is postulated to be the results of impaired cell-mediated immunity, as well as of increased susceptibility to oncogenic viruses. However, immunosuppressed patients experience a greater relative increase in SCCs than BCCs. (16)

BCC usually develops as a flat, firm, pale area that grows into a small, raised, pink or red, translucent, shiny and waxy lesion, and the area may bleed following minor injury. Tumour size can vary from a few millimeters to several centimeters in diameter. Characteristics vary for different clinical sub-types, which include nodular, superficial, morphoeic or fibrosing, pigmented and the very rare variant, fibroepithelioma of Pinkus.

Nodular BCC are the most common form of BCC, accounting for over 50 percent of tumours. They are typically dome-shaped pearly papules and nodules which may have rolled translucent borders and telangiectasia. A papule is a superficial, elevated, solid lesion, generally considered <0.5 cm in diameter. A nodule is a palpable, solid, round or ellipsoidal lesion that is larger than a papule and may involve the epidermis, dermis, or subcutaneous tissue. The depth of involvement and the size differentiate a nodule from a papule. (123) Larger lesions with central necrosis are referred to by the historical term *rodent ulcer*. Superficial BCC occur most commonly on the trunk and appear as an erythematous patch (often well demarcated) that resembles eczema. On stretching the skin, superficial BCC may have a pearly edge. (124)

Morphoeic BCC is an aggressive variant. Clinically, it resembles a scar or a small patch of scleroderma and appears as a whitish to yellowish fibrotic plaque with poorly defined margins. The appearance of scar tissue in the absence of trauma or previous surgical procedure or the appearance of atypical-appearing scar tissue at the site of a previously treated skin lesion should alert the clinician to the possibility of morphoeic BCC and the need for biopsy.

Pigmented BCC is a sub-type of nodular (or superficial) BCC that exhibits increased melanization. Clinically, the lesions are fairly well defined papules or plaques with a translucent or pearly appearance and range in colour from pink to dark brown or black. Fibroepitheliomata of Pinkus are rare lesions that classically present as pink to flesh-coloured, sessile, dome-shaped nodules that may resemble a fibroepithelial polyp or seborrheic keratosis. It is most commonly seen in the lumbosacral area. (125)

1.2 Squamous cell carcinoma

SCC is a malignant neoplasm arising from the keratinocytes of the epidermis. Squamous cells are flat cells that look like fish scales, hence the word 'squamous' from the Latin *squama* meaning 'the scale of a fish or serpent'.

SCC of the skin is a heterogeneous disease both aetiologically and clinically, with different risk factors implicated in its development in different populations. (17) The rising incidence rates of SCC are thought to be due to a combination of increased sun exposure or exposure to ultraviolet light (18), increased outdoor activities, changes in clothing style, increased longevity, ozone depletion, genetics and in some cases, immune suppression.

Actinic keratoses, SCC in-situ (Bowen's disease) and SCC represent three parts of a continuous spectrum of disease.

1.2.1 Actinic keratosis

Actinic keratosis (AK) represents the earliest lesion in the development of SCC in sun-damaged skin. AK are very common and is more often seen in fair-skinned individuals with prevalence varying with geographical location and age. Patient who are immunocompromised following organ transplantation are 250 times more likely to develop AK. (19) An AK may follow 3 different paths: it may regress, it may remain unchanged, or it may progress to invasive SCC. The percentage of AK that progress to invasive SCC remains unknown, and estimates have varied from as low as 0.1% to as high as 10%. (20, 21) AK are often more easily palpated than seen. Lesions are usually multiple and comprised of either macules or papules with a rough scaly surface resulting from disorganized keratinization (dyskeratosis) and a variable degree of

inflammation. AK are frequently 1-3 mm in size, but can be as large as 1-2 cm. Lesions can develop significant thickening of the keratotic scale, and some may ultimately form a cutaneous horn. The edge of the keratosis is usually sharply demarcated and the reddening is usually closely confined to the area immediately below the area of abnormal scaling. While most AK are asymptomatic, occasionally they may become pruritic or tender.

AK are more common in middle-aged or elderly subjects on habitually sun-exposed areas such as the face, scalp and dorsum of hands. The sides of the neck are involved in both sexes, but the ears are predominantly in men – presumably due to the sun protection afforded by longer hairstyles in women. The vermillion border of the lower lip may show keratosis, with a much higher incidence in men than women. Usually, patients demonstrate a background of solar-damaged skin with telangiectasias, elastosis, and pigmented lentigines.

Several clinical variants of AK are recognized which include hypertrophic AK with a cutaneous horn, lichenoid AK, proliferative AK, pigmented AK and actinic cheilitis. (22-24) Hypertrophic AK present as thick scaly papules and plaques. A lichenoid AK is often mistaken clinically for a BCC because of its pink, pearly appearance. They are less common on the face and are seen more on the upper torso and upper extremities. Proliferative AK tend to be larger than 1 cm and frequently recur following cryotherapy. A pigmented AK may require biopsy to differentiate it from solar lentigo or melanoma in situ of the lentigo maligna type. Actinic cheilitis develops on the vermillion border of the lower lip as diffuse scaling or dryness. It may be clinically indistinguishable from frank SCC and a biopsy is often necessary in this situation. (25) SCC of the lip has a higher metastatic rate when compared to cutaneous SCC developing on glabrous skin which emphasizes the importance of making an early

diagnosis. (26)

1.2.2 Squamous cell carcinoma in situ

SCC in situ is the earliest form of SCC. It comprises full thickness intraepidermal carcinoma. Most lesions of SCC in-situ are typically indolent and enlarge slowly over years, seldom progressing to invasive carcinoma. The hallmark of SCC in situ is a persistent, progressive, slightly raised, red, scaly or crusty plaque. On the face with its plentiful pilosebaceous units, follicular involvement can result in treatment resistant SCC in-situ that recurs following topical treatments such as cryotherapy.

1.2.3 Bowen's disease

Bowen's disease is a form of intraepidermal SCC with a low potential to progress to invasive malignancy. Growth is usual but spontaneous partial regression occasionally occurs. Solar radiation is an important cause of these lesions (27-29). Bowen's disease is uncommon in individuals with pigmented skin, and aetiological factors other than UVR exposure may be important, such as human papilloma virus infection. (30)

Clinically, lesions of Bowen's disease often present as solitary, sharply demarcated, pink to fiery red scaly plaques that resemble superficial BCC or lesions of psoriasis or eczema. Ulceration is usually a sign of development of invasive carcinoma, and may be delayed for many years after the appearance of intraepidermal change. An association between Bowen's disease and internal malignancies, particularly of the respiratory, gastrointestinal and urogenital tracts, was reported in earlier studies, when arsenic exposure was more common. (31) More recent data have found no increased risk of such cancers in these patients and it may therefore be of historical importance only. (32, 33)

1.2.4 Squamous cell carcinoma

Invasive SCC begins when atypical keratinocytes breach the dermal basement membrane and invade the dermis. Having traversed the epidermal basement membrane, the tumour then acquires the ability to invade locally into fat, muscle, bone or cartilage, and to metastasize to regional nodes as well as distant sites. (34)

SCC usually arises in areas of photodamage: with AK, hyperkeratosis, irregular pigmentation and telangiectasia, or in the case of lip SCC, leukoplakia of the lip. The first clinical evidence of malignancy is often induration and pain on palpation. SCC present clinically as papules, plaques or nodules that are skin-coloured, pink or red. The tumour surface may be smooth, keratotic or ulcerated and the lesion may be exophytic (outward growth) or indurated (hardened). They are often friable and bleed with minor trauma and can be pruritic or painful. SCC must be excluded in any non-healing erosion or ulcer or skin lesion that repeatedly bleeds.

Most invasive SCC occurs on the head and neck, the next common site is the trunk. Invasive SCC have the potential to recur and metastasize. (35)

The available evidence indicates that occupational UVR exposure is a substantial risk factor for the development of cutaneous SCC and also clearly is a significant risk for developing BCC. Although many outdoor workers are intensively exposed to UVR during working hours, there is still an ongoing debate about the relationship between occupational exposure and skin cancer risk. Work-related UVR-induced skin cancer is not considered as an occupational disease in many countries.

This project is an epidemiological study to investigate the relationship between occupational sunlight exposure and development of NMSC in Australian men.

2. Literature review

Historically, occupational skin cancer has only been considered as due to industrial exposure to chemical carcinogens or ionizing radiation. Nowadays, skin cancer is a widespread disease, especially in Caucasians, and is considered to be rarely induced by occupational carcinogens, but rather by UVR and constitutional factors (skin type). Intensive occupational UVR can, at least in theory, induce skin cancer, and it should be considered as an occupational disease. However, the relationship of skin cancer to occupation is often confounded by previous or concurrent sun exposure from leisure pursuits.

2.1 Incidence and Prevalence of NMSC in Australia

Cancer registries in Australia, despite its frequency and cost implications, do not usually record NMSC. There is no simple method to monitor the incidence or prevalence of NMSC. Not all NMSC that are treated have pathological confirmation, which makes it impossible to collate information for a state-based or an Australia-wide population based registry such as those that exists for other cancers.

Incidence has been measured in defined communities at different locations across Australia and nationally using a series of household surveys conducted in 1985, 1990 and 1995 (36-43). A fourth national survey was conducted in 2002 to measure the incidence of treated NMSC and to investigate trends since 1985 by histological type, sex, age group, latitude and skin type. The estimated number of NMSC cases in Australia for 2002 was 374 000. The incidence of treated NMSC in Australia in 2002 was more than five times the incidence of all other cancers combined. The risk of being treated for NMSC before the age of 70 years in Australia was 69% for men

and 58% for women. Incidence rises more steeply with age for SCC than for BCC. Despite overall increases in the age-standardised rates of both BCC and SCC between 1985 and 2002, BCC rates for people younger than 60 years showed no substantial increase but the rates increased in those aged 60 years and older. For SCC, there was no significant increase at ages younger than 50 years but rates in those aged 50 years and older increased. The strong inverse association with latitude, the higher rates for Australian-born people and for people whose skin does not tan, all highlights the role of sun exposure in skin cancer risk (3).

Despite the high incidence of NMSC, , it has a relatively low mortality rate at 1.6 per 100,000 population compared with the high mortality rates of male lung cancer at 53.2 per 100,000 population, female breast cancer at 22.8 per 100,000 and prostate cancer at 29.5 per 100,000 (44).

2.2 Ultraviolet Radiation (UVR) and Non-Melanoma Skin Cancer (NMSC)

UV is the most important cause of skin cancer. It also causes chronic cutaneous photodamage. The carcinogenic effects of UVR on the skin and eyes are well documented both experimentally and epidemiologically. The National Data Set for Compensation-based Statistics (NDS) collects data for claims lodged with Commonwealth, State and Territory workers' compensation schemes. Over three years (2001-2003) the NDS recorded 403 claims for neoplasms. The most common aetiological factor for compensated cancer claims during this period was sun exposure (22%). It is estimated that 34,000 NMSC per year are caused by occupational exposure (45). The rate of compensated skin cancer claims (per million employees) more than doubled in the five years from 1999 to 2004 (46). This increased recognition of skin

cancer as an occupational health and safety issue was boosted in 2003 by two landmark legal cases settled in favour of workers with occupational skin cancer (Australia Post and Boral) (47).

As ozone levels have been depleted, the atmosphere has lost a proportion of its protective filter function and increasing levels of solar UVR reach the Earth's surface. It is estimated that a 10% decrease in ozone levels will result in an additional 300,000 NMSC; although it appears that the ozone layer may now be repairing itself and is expected to get back to 'normal' range within decades.(1)

UVR, from sun exposure and suntanning equipment use, in both the UVA and UVB spectra, is the main aetiological factor in the development of skin cancer (48). Everyone is exposed to UVR from the sun and many artificial sources that are used in industry, commerce and recreation. UVR is a form of radiation given out by the sun. Unlike other forms of solar radiation, such as light and heat, UVR cannot be seen or felt. The UV region covers the wavelength range 100-400 nm and is arbitrarily divided into three bands: UVA (315-400 nm), UVB (280-315 nm) and UVC (100-280 nm). All UVC, and approximately 90% UVB, radiation are absorbed by the ozone, water vapour, oxygen and carbon dioxide in our atmosphere. The atmosphere less affects UVA radiation. Therefore, the UVR reaching the Earth's surface is largely composed of UVA with a small UVB component. UVR levels are influenced by (49):

1. Sun elevation: the higher the sun in the sky, the higher the UVR level. Thus, UVR levels vary with time of the day and time of the year. The highest levels occur around midday (solar noon) which is when the sun is at its maximum elevation during the summer months, especially at the time of the summer solstice, when the sun is closest to earth

2. Latitude: UVR levels are higher closer to the equator.

3. Altitude: a thinner atmosphere at higher altitudes absorbs less UVR. With every 1000 metres increase in altitude, UVR levels increase by 10-12%.

4. Cloud cover: UVR levels are highest under cloudless skies but even with cloud cover, UVR levels can be high. Scattering can have the same effect as the reflectance by different surfaces and thus increase total UVR levels.

5. Ozone: ozone absorbs some UVR that would otherwise reach the earth. While ozone levels vary during the day and with the season, other factors such as sun height and changes in cloud cover appear to have more influence on levels of UVR.

6. Ground reflection: UVR is reflected or scattered to varying extents by different surfaces, e.g. fresh snow can reflect as much as 80% of UVR, dry beach sand about 15% and sea foam about 25%.

Photobiological processes are wavelength dependent:, UVC hardly penetrates into the epidermis, UVB can reach the superficial dermis and UVA the deep dermis (50). UVR acts as a carcinogen both directly, by inducing cell damage (DNA mutation), and indirectly, by inducing immunosuppression (suppression of T lymphocytes). UVB radiation (280-315nm) acts directly through specific changes in oncogenes and p53 tumour suppressor genes, which are responsible for the initiation and progression of skin cancer. UVB radiation causes direct damage to DNA and RNA by inducing covalent bond formation between adjacent pyrimidines, leading to generation of mutagenic photoproducts such as cyclopyrimidine dimmers (TT) and pyrimidine-pyrimidine (6-4) adducts. This gives rise to mutations in keratinocytes and hence to

neoplastic transformation. Significant mutations affecting the telomerase gene and p53 tumour suppressor gene are important steps towards neoplastic transformation (51).

UVA (315-400nm) is less mutagenic than UVB, and causes indirect DNA damage via a photo-oxidative stress-mediated mechanism, resulting in formation of reactive oxygen species, which interact with lipids, proteins and DNA to generate intermediates that combine with DNA to form adducts. Several complex DNA repair systems are needed to prevent the harmful effects of these premutagenic adducts (52, 53). UVA radiation penetrates deeper into the skin, reinforces the carcinogenic effects of UVB rays and causes ageing and immunosuppression. In this way, both UVB and UVA are involved in the development of skin cancer.

Exposure to sunlight is the major cause of UVR exposure for outdoor workers. Solar UVR can reach a worker on the ground from three sources:

1. directly from the sun
2. scattered from the open sky
3. reflected from the environment

2.3 UV Index

UVR levels are reported as a 'UV-Index', which is a measure of the highest level of UVR each day, taking into account cloud cover and other environmental factors. The UV Index is an international standard measurement of how strong UVR from the sun is at a particular place on a particular day. The UV Index ranges from 0 to 17 and the higher the number the greater the risk of skin and eye damage. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) measures daily solar UVR levels using a network of detectors in Australian capital cities. The information is analysed

and distributed daily to news services and interested organisations. The World Health Organisation recommends that when the UV level reaches three or higher, a combination of sun protection control measures including sun protective clothing, hat, sunglasses, sunscreen and shade may be needed to eliminate or minimise exposure to solar UVR.

The UV Index has five categories as described in Table 1.

Categories	UV Index
Low	UV Index 1-2
Moderate	UV Index 3-5
High	UV Index 6-7
Very High	UV Index 8-10
Extreme	UV Index of 11 and above

Table 1. UV Index Categories

2.4 The National Health and Medical Research Council (NHMRC) Standard

The International Agency for Research on Cancer (IARC) concluded in 1992 that there was 'sufficient evidence in humans for the carcinogenicity of solar radiation', classifying UVR as a Group 1 carcinogen. The agency went further stating, 'Solar radiation causes CMM and NMSC' (54). In 1985, the International Radiation Protection Association (IRPA) produced guidelines with exposure limits that are derived from numerous scientific studies (both human and animal) of the acute effects of UV irradiation on skin and eyes. In 1989 the National Health and Medical Research

Council (NHMRC) published the *Occupational Standard for Exposure to Ultraviolet Radiation* as part of the NHMRC's Radiation Health Series (RHS 29) based on guidelines published by the International Non-Ionizing Radiation Committee of the International Radiation Protection Association (INIRC/IRPA) in 1985 and 1989. At its 1996 annual meeting, the International Commission on Non-Ionising Radiation Protection (ICNIRP) concluded that, while significant clarification has occurred with respect to health risk assessment from exposure to UV, recent data had not provided results suggesting the exposure limit values of the 1989 guidelines need to be amended. This was also stated in an overview document of recent and future ICNIRP activities published in Radiation Protection Dosimetry. Thus the original exposure limit still applies, as does the original IRPA/INIRC rationale for their development. The 2004 update of guidelines on limits of exposure to UVR evaluated and reviewed recent research on biological effects of UVR exposure and made no significant changes in the exposure limit values. The NHMRC standard provides UVR exposure limit values for exposure of the eye or skin in the spectral region between 180 and 400 nanometres (nm). The exposure limit values in the NHMRC standard do not differ from the ICNIRP guidelines and essentially restrict radiant exposure on unprotected skin to no more than 30 (55) joules per square metre (30 J/m^2). This means that for an eight-hour day, the effective irradiance in a second should not exceed one milliwatt per square metre (1 mW/m2). While the guidelines relate primarily to acute effects of UV radiation exposure, they may also provide sufficient protection against chronic effects. In 2006, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) took over the responsibility for review of Radiation Health Series (RHS) publications.

This NHMRC standard covers exposure to UVR incurred as part of a worker's occupation and includes both solar UVR and artificial sources of UVR. The Standard establishes threshold exposure levels for occupational exposure of the eye or the skin

during an 8-hour working day. It does not apply to UVR exposures of patients as part of medical treatment or for elective cosmetic purposes. These threshold levels are intended as upper limits for non-therapeutic and non-cosmetic exposure and should be considered as absolute limits for ocular exposure but occasional exposure of conditioned skin above these levels may not result in acute adverse effects. Given the variability in exposures to solar UVR due to highly variable ambient solar UVR levels, as well as behavioural effects and different exposure geometry, application of the exposure limits is not practical and limiting UVR exposure to as low as possible is the most effective approach. The exposure limits are typically exceeded within 5 to 10 minutes in summer by solar radiation during the 2 to 3 hours either side of noon at 0^0 to 40^0 latitude.

The following table shows that the duration required to exceed the exposure limits varies with the intensity of solar UVR.

UV Index	Tmax (mins)
3	26
4	20
6	13
8	10
10	8
12	7
14	6
16	4

Table 2. A comparison between the WHO UV Index relating the sun's UVR intensity to the time taken to exceed the exposure limit (EL). The higher the UV Index the shorter the time to exceed EL.

It compares the WHO UV Index relating the sun's UVR intensity to the time taken to exceed the exposure limit (EL). During summer when the UV Index value may be 12 for a typical clear sky day around solar noon, the time it takes for an individual with unprotected fair skin to exceed the exposure limit Tmax is 7 minutes, while the time to achieve erythema (sunburn) is approximately 11 minutes. Unprotected workers would therefore easily exceed the exposure limit within the 8-hour limit. (55)

A survey of 100 major companies that employed outdoor workers in Victoria in 1998 found that one-fifth had received compensation claims from employees relating to skin cancer or sun damage. Claims had been lodged against 21% of organisations surveyed compared to 11% in 1996. (56) There are many Australian workers potentially at risk from exposure to UVR. Table 3 shows the estimated number of employees in the major industries that involve outdoor work. The numbers of employees in the table have been aggregated from detailed occupation classifications from the Australian Bureau of Statistics 2001 census.

Industry	**Number of employees**
Rural	270,000
Construction	260,000
Transport	210,000
Gardens/nurseries/greenkeepers	80,000
Total	820,000

Table 3. Estimated number of employees in major industries involving outdoor work

2.5 Increased Exposure to UVR in Outdoor Workers

Outdoor workers receive significant exposure to solar UVR and very little has been done in Australia to quantify the exposure levels they would receive during the course of their work. In 1992, a UVR exposure study was conducted on the Sunshine Coast, Queensland as part of a program of the Sunshine Coast Regional Health Authority to reduce UVR exposure in outdoor workers. The study provides UVR exposure data on three groups of outdoor workers, physical education (PE) teachers, ground staff/ gardeners and lifeguards. The solar UVR exposures were measured using polysulfone (PS) film badges. The PE teachers received the highest UVR exposures while the lifeguards received the least. The lifeguards generally spent their time in specially constructed beach shelters, with occasional short periods out on the open beach. All groups had measured UVR exposures in excess of occupational guidelines. (57)

The most detailed study of workplace behaviour has been the Queensland audit of exposure to UVR among construction workers. The study was conducted during spring 2001 from 1 September to 30 November, with 16 sites audited in September, 50 in October and 41 in November. Twenty-five inspectors from Workplace Health and Safety Queensland took part in the study of 107 sites across Queensland. Inspectors were asked to monitor the UVR exposure of at least 2-3 workers per site for 4 hours, and these workers wore a UVR-sensitive polysulphone (PS) badge attached to the chest area. Of the almost 500 workers who participated in the study, there were 19 clearly separate occupations. The amount of time spent outside by workers varied considerably with occupation. Occupations where lower exposures were observed were the ones where significant proportions of time were spent either indoors or away from the direct sun. Those involved in these occupations were supervisors, inspectors, painters and cabinet makers who spent time indoors or working in shade (in the case of painters).

Plant operators who also had lower exposures drove machinery and were protected by enclosed cabins. The occupations with the highest UVR exposure were those where workers spent most of their time out in the open and included roofers, doggers (whose work involves guiding the placement of crane loads), traffic controllers (who guide both heavy vehicles and road traffic during construction), and pavers and tilers, who worked in the open on a highly reflective surface. Of the total 492 workers, only 49 or approximately 10% received UVR less than the occupational exposure standard. Almost half of the workers, 228, had measured exposures greater than four times the allowed exposure limit. In addition, it was found that 13%, 16% and 14% of workers had exposures between one and two times the allowed exposure limits (EL), between two and three times the EL and between three and four times the EL, respectively, whereas 7.3% of workers had exposures greater than 10 times the EL. The workers' exposures would have exceeded the allowed EL by even greater margins had the monitoring been conducted over an 8 instead of 4 hour period. The measured solar UVR exposures of 90% of outdoor workers of this study exceeded the Australian 8-hour exposure standard of 30 J/m^3, with approximately 50% of the workers exceeding the EL by more than four times. The very high measured UVR exposures were especially alarming when considered together with the lack of controls for minimizing exposures and the skin types of the workers as assessed in this study. The audit concluded that there is significant risk to the health of Queensland outdoor workers from occupational UVR exposure. (58)

Holman et al investigated the proportion of ambient UVR received at several body sites in five different occupations. Five volunteers were monitored: a classroom teacher, a physical education teach, a gardener, a roof carpenter and a bricklayer. Subjects wore polysulphone badges for 6 hours each day on 6 different body sites. The classroom teacher received the lowest levels of exposure, the physical education teacher received

intermediate levels of exposure and the outdoor workers (gardener, roof carpenter, bricklayer) received the highest levels of exposure. The outdoor workers received six-fold to eight-fold larger relative doses of UVR when compared to the classroom teacher. (128)

Parisi et al compared the erythemal UV exposures received on weekend and weekday for outdoor workers, home workers, adolescents, indoor workers, school staff and students for the complete season of spring 1996 in Brisbane. Outdoor workers received the highest erythemal UV exposures for both weekday and weekend population, which illustrated that a person's weekday habits are also reflected in their pursuits on the weekend. This suggests that outdoor workers are constantly exposed to high level of UVR which puts them at a much increased risk of developing NMSC compared to other occupational groups. This information confirms the importance and need for skin cancer prevention campaign in outdoor workers. (127)

Occupational health and safety (OHS) legislation states that employers and employees have responsibilities to reduce risk of injury and risks to health, which includes reducing sun exposure. The Australian Safety and Compensation Council (ASCC) (now SafeWork Australia) requested the development and fielding of the National Hazard Exposure Worker Surveillance (NHEWS) survey to determine the current nature and extent of Australian workers' exposure to selected occupational disease causing hazards, including direct sunlight. The ASCC in collaboration with Australian Occupational Health and Safety regulators and a panel of experts developed the NHEWS survey. The NHEWS survey is the first national research study on workplace UVR exposure from direct sunlight across all Australian industries. This quantitative research study was conducted between January and July 2008 and comprised 4500 telephone interviews with workers in all Australian industries. Workers who were exposed to high levels of direct sunlight (more than 4 hours per day) in the week prior

to the survey showed a number of demographic and employment differences to workers with no, low or medium exposure. The odds of being exposed to a high level of direct sunlight were higher in northern Australian states (Queensland, Northern Territory, Western Australia) than workers in southern states (New South Wales, South Australia, Victoria, Tasmania, Australian Capital Territory), higher for male workers compared to female workers, generally higher for smaller-sized workplaces, and higher for workers in the agriculture, forestry and fishing, construction, cultural, recreational and personal services industries when compared with the manufacturing industry. This report presents the research findings from a detailed analysis of the data related to Australian workers exposure to direct sunlight and measures provided in workplaces that control workers' exposure to direct sunlight. (59)

The NHEWS survey focused on workers from predetermined priority industries, this meant that it was not representative of the general Australian working population. The Australian Work Exposures Study (AWES) was conducted to gain a nationally representative view of the prevalence of exposure to solar UVR among Australian workers. AWES was a cross-sectional telephone survey across all industries. 22% of respondents were assessed as being exposed to solar UVR in the workplace, with exposure being more likely among males and those residing in lower socioeconomic status and regional areas after controlling for occupational group. Exposure to solar UVR was highest in farmers, painters, plumbers, heavy vehicle drivers, animal and horticultural workers and handyperson. (126)

A large number of people are exposed to varying levels of UVR at the workplace. However, the number of epidemiological studies focusing on NMSC in workers is limited and the findings are contradictory. Moreover, most studies are limited by a lack of individual exposure assessment, and are based only on census and registry data, or

occupation/industries as surrogates of exposure. Also, important confounders (e.g. non-occupational UV exposure, other relevant exposures) and/or effect-modifiers (e.g. skin complexion, individual UV sensitivity) were not sufficiently addressed in prior work.

2.6 Increased Risk of NMSC in Outdoor Workers

BCC and SCC are usually grouped under NMSC, but they are associated with different cutaneous distributions and different aetiological factors. Reliable incidence data for both tumours is lacking, and of course there is limited mortality data. Within populations of European descent, the incidence of SCC is lower in those with darker skins (Mediterranean skin type). In Australia and the U.S.A., the incidence of SCC increases with proximity to the equator. The incidence of SCC is related to geographical latitude of the domicile and measured UVB radiation. A decisive factor for the development of SCC is the cumulative lifetime UV exposure. In contrast to CMM and BCC, the incidence of SCC shows an exposure-response curve without any plateau phase. Benign UVR-induced skin changes (lentigo, telangiectasia and elastosis) also show a strong association with the incidence of SCC. (118, 120, 121) While BCC shares most of the risk factors for SCC, an important risk factor for BCC also include intermittent exposure to sunlight and a genetic predisposition. Although BCC usually occur in sun- exposed areas, unlike SCC, they may also occur in areas hardly exposed to sunlight at all and without any significant actinic damage, such as the trunk. UVR is the most potent causative factor for BCC but its effects are less evident than in SCC. (60) People who already have one SCC of the skin have an approximately 50% risk of developing a second malignant skin lesion (NMSC) in the following 3-5 years. (61)

Outdoor workers such as farmers, welders, watermen, police officers, physical education teachers, pilots and cabin attendants have an increased risk of skin cancer

(62). Delzell and Grufferman studied the mortality amongst farmers (9245 white and 3508 non white male farmers) in North Carolina and found that white farmers showed an increased relative frequency of deaths from NMSC (odds ratio (OR) = 1.9) compared with non-farmers (62). Vitasa et al examined the relationship between UVB radiation, NMSC and AK in a cross-sectional prevalence study of 808 white watermen (who make their living from the water, i.e., fishing) in Maryland. Overall, 25% of subjects were diagnosed with AK, 4.3% with SCC and 4.1% with BCC. Watermen with SCC or AK had higher average annual UVB doses than matched controls. High cumulative UVB exposure through natural sunlight was significantly associated with SCC, less strongly with AK, and was not associated with BCC (63). Diffey and Roscoe measured the UVR exposure of airline pilots during flight with UV-sensitive film badges worn on the epaulette nearest to the window and the level of exposure was found to be negligible. The distribution of skin cancers was compared with that of the total population, and cancers did not occur more often on the most exposed areas in the cockpit (head, neck, hands) suggesting that cosmic and not UV exposure may be causal (64). Marks et al reported a significant interaction of the relationship between outdoor work and SCC risk based on age, with an increase in SCC risk only in outdoor workers above age 55 years. (42). Radespiel-Troger et al performed an analysis of the association between outdoor work and skin cancer based on incidence data routinely collected by the population-based Bavarian cancer registry between 2001 and 2005. Eleven Bavarian districts with complete skin cancer registration were included in this analysis based on 2,156,336 person years. Cases were assigned to ‘indoor’, ‘mixed indoor/outdoor’, and ‘outdoor’ exposures categories according to their job title. The risk of BCC was substantially elevated in male (RR 2.9, 95% CI 2.2-3.9) and female (RR 2.7, 95% CI 1.8-4.1) outdoor workers compared to male and female indoor workers, respectively. They also found an elevated risk of similar magnitude for SCC in male (RR 2.5, 95%

CI 1.4-4.7) and female (RR 3.6, 95% CI 1.6-8.1) outdoor workers compared to male and female indoor workers. (65) Pukkala and Sarni followed-up a cohort of 30,940 male and 11,529 female seafarers registered in the files of Seafarers' Pension Fund in Finland for cancer. Officers and deck crew demonstrated an almost two-fold increased risk of NMSC at 20 years after the first employment or after 10 years of work aboard. (66)

Two recently published systematic reviews demonstrate the increased risk of NMSC in outdoor workers (67, 68). Schmitt et al performed the first meta-analysis that comprehensively summarized the published epidemiological evidence regarding the relationship between work-related UV light exposure and the risk of cutaneous SCC (67). Bauer et al reviewed the published epidemiological evidence regarding the relationship between work-related UV exposure and risk of BCC. Outdoor workers are at significantly increased risk of BCC (68).

Schmitt et al demonstrated in a systematic review and meta-analysis that occupational UVR exposure increases the risk for the development of cutaneous SCC. The authors identified 18 relevant studies after conducting a systematic electronic search in PubMed (up to May 2010) supplemented by a hand search. Two reviewers did data abstraction and study quality assessment independently. They pooled together the adjusted odds ratios (ORs) and corresponding 95% confidence intervals (CIs) of all included studies in a random-effects meta-analysis. Sensitivity analysis included meta-regression on study-specific covariates were conducted to explore the robustness of the results and to identify sources of heterogeneity between studies. Eighteen studies (six cohort studies, twelve case-control studies) met the eligibility criteria and were included in the systematic review. (67)

Eleven studies were conducted in Europe, five in North America, and two in Australia. All except one cohort study were recruited from the general population.

In the case-control studies, cases were identified directly from the general population or from population-based cancer registries in nine studies and from selected dermatological centres in three studies. Eleven studies utilized cancer registry data exclusively or supplemented by questionnaire data, while seven studies relied exclusively on primary data collected by questionnaire, interview and/or clinical examination. There was significant heterogeneity in the definition of 'occupational UV exposure'. Eight studies looked at specific occupations typically involving outdoor work such as farming, construction work or seafaring. Five studies estimated occupational UV light exposure on a continuous scale and compared participants with high versus low cumulative exposure. Five studies reported only whether outdoor work was performed ever or at a specific point in time without providing further details. In the majority of studies included (14 of 18 studies, 78%) the reference group was defined as 'mainly indoor work', 'low occupational UV light exposure', or included occupations actually performing outdoor work, mixed indoor/outdoor work, or the general population. This imprecise definition of the unexposed group is an important source of non-differential misclassification introducing bias towards the null effect. Thirteen studies assessed individual occupational UV light exposure while five studies exclusively relied on census or registry data and used the job description as a proxy for occupational UV light exposure. A quantification of occupational UVR exposure was given in ten papers and was not assessed in the remaining eight papers. Sixteen studies (89%) found an increased risk of SCC in individuals with occupational UVR exposure compared with individuals without occupational UVR exposure, with twelve studies reaching statistical significance. Two studies found no association between occupational UVR exposure and SCC occurrence. None of the studies found an inverse relationship between occupational UVR exposure and SCC occurrence. (67) Five studies were restricted to males. Information on important characteristics

and potential confounders such as ethnicity, smoking status and family history of skin cancer were frequently not reported. Seventeen studies (94%) considered age as an important confounder and sixteen studies (89%) considered age and sex, as important confounders. Other relevant confounders such as UV sensitivity, non-occupational UV exposure and smoking status were considered only in a minority of studies. None of the studies adjusted for family history of skin cancer. (67)

The results of the systematic review showed there was no significant difference between cohort studies (OR (95% CI): 1.68 (1.08-2.63)) and case-control studies (OR (95% CI): 1.77 (1.37-2.30)). The pooled OR (95% CI) was 1.77 (1.40-2.22). Meta-regression analyses suggested that the risk of SCC is increased in individuals with occupational UVR working in lower latitudes. Studies utilizing registries found significantly weaker associations between occupational UVR exposure and SCC than studies using only primary data and selected cases without the use of a cancer registry. Studies that directly assessed individual occupational UVR exposure of study participants found stronger associations between occupational UVR exposure and SCC than studies estimating occupational UVR exposure solely from the job description or job title. Studies adjusting for individual UVR sensitivity found stronger relationships between occupational UVR exposure and SCC than studies not adjusting for this potential confounder. (67)

Agricultural occupation was identified as a statistically significant risk factor for SCC in three studies. Gafa et al carried out a case-control study on 133 consecutive incident cases of NMSC registered by Cancer Registry of Ragusa (Sicily) and agriculture was identified as an occupational risk. Cases who had worked in agriculture for more than 10 years had an increased risk of SCC (OR 2.4). (69) Hogan et al performed a questionnaire survey of risk factors for SCC in Saskatchewan, Canada on 178 cases and

248 age, sex and location matched controls from 1982 to 1983 (70). Agricultural occupation demonstrated a relative risk of 1.49. When Marehbian et al conducted a population-based case-control study of NMSC in New Hampshire U.S.A., an elevated risk for skin cancer was observed in related agricultural occupations (OR 2.8). (71)

Only three studies considered the most important confounders of the relationship between occupational UVR exposure and SCC occurrence i.e. age, sex, individual UV sensitivity and individual non-occupational UV exposure by the study design or in data analysis. Rosso et al investigated the role of sun exposure in development of NMSC among different populations from South Europe. Incident cases and a random population sample of controls from five centres where a cancer registry was operating were interviewed. A sample of hospital-based cases and controls were selected from the other three centres for interviews. Information on life-long exposure to sunlight during different activities were gathered with a structured questionnaire arranged by life period (childhood, adolescence, adulthood, retirement) with separate sections on places of residence for more than 6 months, work, holidays and sports or other outdoor recreational activities. A statistically significant increase of risk of SCC was seen with increasing sun exposure beyond a threshold of 70,000 cumulated hours of exposure in a lifetime. Risk of SCC was significantly increased in outdoor work (OR 1.6 for more than 54,000 cumulated hours of exposure in a lifetime). When the analysis was adjusted for sex, age at interview and centres, pigmentary traits and skin characteristics, people who often burn rather than tan when exposed to sun showed a 2-fold risk increase for both BCC and SCC. Subjects with fair hair and blue eyes revealed a 4 to 8 fold increased risk for SCC. In particular, those with red hair exhibited an odds ratio of more than 16 for SCC. Outdoor work entailed the largest number of cumulated hours of exposure. Its mean and median were about 15 times higher than those of holidays or outdoor sports. A significant linear trend was observed in SCC, which confirmed that

SCC only developed in people who exposed themselves to higher doses of sunlight for a prolonged time. (72)

Aubry and MacGibbon conducted a matched case-control study to assess the relative risk associated with known and suspected risk factors of SCC in the Montreal region. Three hundred and eleven cases with a primary SCC of the skin histologically diagnosed in 1977 or 1978 in 12 hospitals were identified. A logistic regression analysis was undertaken. After standardization for age, sex, eye and hair colour-complexion, ethnic characteristics, and non-occupational sunlight exposure, occupational sunlight exposure was the only occupational variable that appeared to differ significantly between cases and controls (relative risk of 9.12), and this difference was statistically significant (P=0.02). (73)

Marehbian et al conducted a population-based case-control study of NMSC in New Hampshire U.S.A. Cases and controls completed a self-administered residence and work history questionnaire and personal interview regarding major risk factors for skin cancer. The Standardized Occupational Classification system (SOC) was used to code the reported jobs. Unconditional logistic regression models taking into account age, education, skin reaction to sun, history of painful sunburns, time spent outdoors and smoking were used to calculate the odds ratios (ORs) and confidence intervals (CIs) for men and women separately. They observed a significantly elevated risk for both BCC and SCC in groundskeepers and gardeners (OR 3.2). (71)

A US based case-control mortality study reported findings based on six thousand five hundred sixty-five cases of NSMC between 1984 and 1995. All deaths were collected from a twenty-four state database and for each case, twenty-five controls were chosen matched by a five-year age group. The usual occupation from the death certificate was

used to classify occupation as indoor, mixed indoor/outdoor, outdoor non-farmer and outdoor farmer. Estimates were adjusted for age, sex, race, occupational physical activity, socio-economic status and residential or occupational sunlight exposure. The odds ratio for NMSC was greatest in the region of the United States with highest exposure to sunlight (OR 1.23; 95% CI 1.14 to 1.33) and among workers with non-farming outdoor jobs (OR 1.30; 95% CI 1.14 to 1.47). The association with occupational exposure to sunlight was increased in both white American and African-Americans. (74)

Studies with incomplete consideration of confounders found less strong association between occupational UVR exposure and SCC occurrence, suggesting the possible presence of residual confounding. Green et al observed significant self-selection among outdoor workers, whereby men and women with olive skin colour and with a low susceptibility to sunburn were significantly more likely to report lifetime outdoor work than those with fair or medium skin colour. This suggests that selection bias has distorted the association between occupational sun exposure and skin cancer as these self-selected group of outdoor workers possess fewer of the established phenotypic risk factors for skin cancer, thus explaining the lower than expected risk of skin cancer in this study. (75)

Studies that failed to collect information on individual exposure to solar UVR at the workplace and relied exclusively on census or registry data and/or used the job description as a proxy for occupational UV light exposure may have led to underestimation of the true association between work-related UVR exposure and SCC risk. Adami et al hypothesized that the potential misclassification of exposures that are inferred from job titles and industry categories in follow-up studies is non-differential

but often substantial, which most often reduces and obscures associations. (76) Kenborg et al found decreased risks of NMSC and CMM and an increased risk of lip cancer among outdoor workers in Denmark. In this study, information on individual sun exposure was not collected. Outdoor industry was used as a proxy for exposure to the sun and duration of employment was used as proxy for length of exposure. Occupational information could only be dated back to 1964 meaning that a vast majority of the occupational history of several participants was unavailable. This form of methodology can introduce non-differential misclassification, which will tend to dilute any association and lead to an underestimated risk. (77)

Hakansson et al conducted a cohort study using data from 323,860 men participating in an occupational health service program of the Swedish construction industry. An experienced industrial hygienist assessed the exposure for 200 job tasks. Even though they did not find any excess risk for NMSC for outdoor workers, they observed an increased risk for cancer of the lip in the medium (RR 1.4) and high (1.8) exposure groups. This could be due to the sunlight exposure in Sweden being seasonal and intense only during the summertime, which yields a comparatively low cumulative exposure. Almost all cases were of the SCC type and this was consistent with previous reports of increased risks of tumours of lip among outdoor workers such as farmers. (78) Perea-Milla Lopez et al demonstrated occupational exposure a risk factor for development of lip cancer. They conducted a case-control study in the province of Granada (Andalusia, southern Spain). Cases were identified through the population-based Granada Cancer Registry with SCC of the lip diagnosed between 1987 and 1989. About 90% of cases had been engaged in fishing, agricultural and forestry work at some time in their life, whereas only 67% of the controls had been engaged likewise. Cumulative sun exposure during outdoor work was identified as a risk factor for lip cancer. (79)

Incidence rates for NMSC clearly increase with increasing UV exposure, however there is still an ongoing debate on the relevance of occupational UV exposure in outdoor occupations as a risk factor for the development of BCC. (39) Several epidemiological studies investigating the risk of occupational UV exposure to natural sunlight and BCC risk have been published in the last decades but up to 2011 there was no comprehensive systematic summary of the evidence available. Bauer et al performed a systematic literature review of cohort studies and case-control studies to provide data on occupational UV exposure and BCC occurrence. A PubMed (up to 28 January 2011) search was performed, supplemented by hand searching and consultation of experts in the field. The association between occupational UV exposure and BCC risk was presented as odds ratios (ORs). Twenty-four relevant epidemiological studies (five cohort studies, nineteen case-control studies) were identified after performing a random-effects meta-analysis and sensitivity analysis including meta-regression on study-specific covariates. Fifteen studies were performed in Europe, three studies in North America, four studies in Australia, one study in South America and one study in Europe and South America. The data source for all cohort studies was either the general population or cancer registries. None of the case-control studies identified their cases from the general population or from population-based cancer registries. Another nine studies recruited consecutive hospital patients or outpatients from dermatological practices. One study included male mountain guides only. Eleven studies showed a significant positive relationship between occupational UV exposure and the risk of BCC with odds ratios between 1.3 and 4.7. In six studies a non-significant risk increase with odds ratios between 1.2 and 1.7 was reported. Two studies did not find any effect of occupational UV exposure on BCC risk and five studies showed a non-significant risk reduction for workers in outdoor occupations with odds ratios between 0.74 and 0.9. Twenty-three studies were included in the meta-analysis. Pooled OR for the

association between outdoor work and BCC risk was 1.43 (95% CI 1.23-1.66, P=0.0001). Pooled OR (95% CI) in cohort studies (n=4, OR 1.48; 95% CI 0.83-2.66; P=0.19) and case-control studies (n-19; OR 1.43; CI 1.19-1.72; P=0.0001) did not differ significantly, but did not reach significance in cohort studies after stratification. Meta-regression analysis identified significant sources of heterogeneity between studies concerning latitude of the geographical region in which the study was conducted, and adjustment for age, sex and non-occupational UV exposure. BCC risk increased significantly with decreasing latitude. A stronger association between occupational UV exposure and BCC risk was shown in studies adjusted for sex or individual non-occupational exposure. No such influence was detected in studies adjusting for skin type / UV sensitivity or family history of cancer. Data source and measurement or quantification of occupational UV exposure did not change the association between occupational UV exposure and BCC risk. (68)

Pelucchi et al analysed data from a case-control study conducted in Italy. The study consisted of 528 subjects with newly diagnosed, histologically confirmed BCC and 512 controls admitted to the same hospitals with acute conditions. 36% of subjects with nodular BCC, 20% of cases with superficial BCC, and 27% of controls had a relevant occupational exposure to sunlight during life. The multivariate OR for occupational sun exposure was higher for nodular (OR=1.53, 95% CI 1.08-2.18) than for superficial (OR=0.71, 95% CI 0.44-1.15) clinico-pathological type. This study found an increased risk of nodular, but not superficial, clinical subtype of BCC in subjects reporting occupational sun exposures, but there was no duration-risk relation. There was a direct relation between occupational sun exposure and risk of head/neck BCC (OR 1.46) but not truncal BCC (OR 0.74) (80). This is consistent with a Puerto Rican study, where a direct relationship between UV exposure and development of NMSC was found for head/neck neoplasms only. Superficial BCC and BCC on the trunk tended to be more

uncommon in people with occupational UV exposure. (80) These findings may provide a possible explanation for the lack of association between BCC and outdoor work because other than Pelucchi et al, none of the included studies stratified on histological subtype or tumour location. (68)

The most pronounced risk increase for BCC in outdoor work was reported by Maia et al in agricultural workers. Maia et al conducted a case-control study in Brazil to investigate risk factors for development of BCC. A total of 259 cases of basal cell carcinoma diagnosed from July 1991 to July 1992 were compared with 518 controls matched to age and sex. When the risk factors were analysed by multiple conditional logistic regression, agricultural activity (OR 4.9) was one of three variables that were statistically significant. Agricultural activity has been identified as a more significant relative risk factor for BCC. It should be remembered that simply residing in the rural zone did not represent a risk factor when the BCC group was compared to the control group. It is the presence of work activity exposure to sunlight (rural workers) that was needed for a statistically significant difference in risk to be established. (81)

A study was conducted on 283 male mountain guides from Germany, Switzerland and Austria with 309 age-matched controls to evaluate the effect of UVR on professional mountain guides. Mountain guides are prototypic outdoor workers with heavy UV exposure. BCC were highly significantly more frequent in mountain guides than in the control group. Skin type, heavy sunburns and cumulative guiding days were the independent risk factors for BCC, which indicates the important of high occupational UV exposure in basal cell carcinoma formation. (82)

Hogan et al conducted the first study to associate BCC specifically with the occupation of farming. NMSC has been associated with the occupation of farming in England and the United States, but not in Finland or Sweden. Farming was identified statistically as

the most significant risk factor for BCC in this study even though the residences of controls were matched closely with the residences of the cases and this would tend to minimize the effect of rural occupations such as farming. Farming was a more important risk factor than outdoor work or number of hours worked outdoors in this study. (83)

Vlajinac et al observed that BCC were significantly more frequent in cases that were involved in farming during summer as helpers to their relatives. (84)

A study of patients with sporadic BCC and control subjects from general hospitals was conducted to assess the risk of occupational and leisure-time sun exposure, precursor lesions for skin cancer and phenotypic factors on the development of sporadic BCC in Ulm and Dresden, Germany. Their data supported the role of chronic occupational UV exposure as a risk factor for the development of sporadic BCC (OR 2.4), as indicated by a southern European study. (85)

Bauer et al revealed in their meta-analysis that there is epidemiological evidence from the studies published so far for a 40% increased risk for occupationally UV-exposed workers to develop BCCs compared with non-exposed workers. The authors in both reviews felt that the real risk is largely underestimated due to poor classification of occupation and lack of quantification of occupational and non-occupational UV exposures. Both authors, Bauer and Schmitt, concluded from their systematic appraisal and meta-analysis of the epidemiological literature that occupational UVR exposure is a substantial and robust risk factor for development of NMSC. (67, 68)

Pigmentary traits such as red hair, fair skin, lack of tanning ability and propensity to freckle have been identified as genetic risk factors for skin cancers when combined with the environmental risk factor of high ultraviolet light exposure. (122) Studies around the world have demonstrated a positive relationship between occupational sunlight exposure

and development of NMSC. While pigmentary traits are non-modifiable, the level of UV light exposure is a modifiable risk factor.

Most of the epidemiological literature to investigate the relationship between occupational sunlight exposure and NMSC has emanated from Europe, which has lower levels of UV exposure than Australia. Despite Australia having the highest incidence of skin cancer in the world, there have not been many epidemiological studies conducted to investigate this issue. An electronic literature search was performed on Medline (up to 1 January 2012, keywords used were non-melanoma/ nonmelanoma, sunlight, ultraviolet rays, occupational exposure, environmental exposure) and only three studies were identified.

The first study was performed by a group of dermatologists in Maryborough, a rural city in north-central Victoria. Two thousand, six hundred and sixty nine participants aged 40 years and older attended a population-based skin cancer survey that involved an interview and clinical examination. The study was conducted for a week at the beginning of spring each year for five years from 1982 to 1986 inclusive. Cases were followed-up annually. The interview collected information on age, sex, and country of birth, occupation and response to sunlight. Dermatologists performed the clinical examination on light-exposed area of the head and neck, forearms and dorsum of both hands. The presence of any AK, BCC, and SCC was noted and the site of the lesions marked onto grid maps that were kept and used as the basis of assessment for each annual examination. A clinical diagnosis was made in the case of typical AK. In cases where clinical differentiation was not possible or a skin cancer was suspected, a biopsy of the lesion was performed and histological examination was carried out. In subsequent examinations, all participants were questioned on whether they had undergone treatment for any lesions in the interval between examinations. Where this

was the case, permission was sought to obtain the records from the medical practitioner who had treated the person, and the nature, site and treatment of the lesions were recorded. The results showed a significantly increased incidence rate of NMSC in men, in those who worked outdoors, and in those who burn only and do not tan when exposed unprotected to strong sunlight. The difference in risk between the sexes was proposed to be likely to be caused by the greater amount of time spent outdoors by men, certainly for occupational and probably for recreational purposes. Within the Poisson mode that considered men alone, the interaction terms for outdoor work in comparison with indoor work with age was significant. The lines of incidence rates in indoor and outdoor workers only started to diverge after the age of 55 years. After this age, the rate in indoor workers remained relatively the same, compared with the rate in outdoor workers that continued to rise steeply. This may represent an indirect measure of the amount of exposure that is necessary to develop NMSC. (42)

The second study was conducted in Nambour, a typical subtropical community in Queensland, Australia by Green and Battistutta. They surveyed two thousand and ninety five residents chosen randomly from the electoral roll aged between 20 and 69 years between 1986 and 1987. The aim of the study was to gain information about skin cancer occurrence in Queensland and risk factors influencing the development of NMSC. Information was obtained about occupational and recreational sun exposure, experience of sunburns that were painful for at least 24 hour, and previous skin cancer. In December 1986, every resident was examined by dermatologists for skin cancer. Of these, 1,770 further participated in a follow-up postal survey in December 1987 to obtain details of any skin cancers treated by a doctor in the preceding two years (December 1985 to November 1987). Relative risks of BCC and SCC were estimated in multivariate analysis. Controlling for age, sex, skin colour and past history of NMSC, the relative risk (RR) of BCC associated with mainly outdoor occupations was 1.3. An

elevated risk of SCC was observed with predominantly outdoor occupations with RR of 5.5. Risk factors for BCC and SCC were similar with respect to skin and hair colour, but the risk of SCC was more strongly associated with sun exposure than was BCC. Relative risk of SCC was 3 to 5.5 times higher in persons reporting excessive sun exposure either acutely (through multiple sunburns) or chronically (through predominantly outdoor occupations and leisure activities) when compared to those who had at most a single painful sunburn, or who had indoor jobs or leisure activities, respectively. (87)

The third study was a follow-up study to the second study described above. Green et al contacted all the participants in the 1986 survey to participate in a second survey in 1992. The result of the survey did not observe an association between NMSC and occupational sun exposure. The lack of association between skin cancer and outdoor work seems paradoxical yet has been observed in many previous studies as reviewed by Kricker et al. (7) Bias that is inherent in the comparison of actinic disease in indoor and outdoor workers appears to be a more likely explanation for the paradox when assessed in these data. People who had reached their fifties and sixties were more likely than those still in their twenties and thirties to work mainly outdoors, and age is an independent predictor of skin cancer. They also found that men and women with olive skin colour and a low susceptibility to sunburn were significantly more likely to report lifetime outdoor work than those with fair or medium skin colour. This suggests that selection bias has distorted the association between occupational sun exposure and skin cancer. Outdoor workers tend to be a self-selected group with fewer of the established phenotypic risk factors for skin cancer than those in other occupations, thus explaining the lower than expected risk of skin cancer among outdoor workers. (75)

Although many outdoor workers are intensively exposed to UVR during working hours, there is still an ongoing debate about the relationship between work-related UVR

exposure and the risk of NMSC. UVR–induced skin cancer is not considered as an occupational disease in many countries. A recent article on NMSC in Australia showed a substantial increase in the number of NMSC treatments, the total Medicare Benefits Schedule (MBS) benefit and total cost of NMSC in Australia between 1997 and 201, and the authors predicted a further increase between 2010 and 2015. It will cost the Australian government $109.8 million by 2015 and NMSC will continue to be the most costly cancer in Australia. This will have implications on future medical workforce and physical infrastructure. (86) All these findings poses a significant public health impact as they highlight the need for preventative measures for individuals with high levels of work-related UV light exposure.

3. Methodology

One of the difficulties in determining whether occupational UV exposure is a risk factor in Australia is differentiating occupational UV exposure from the high level of recreational exposure. This project was a pilot study to investigate the relationship between occupational sunlight exposure and incidence of NMSC.

3.1 Study Design

This study is a case-control study aimed at investigating the relationship between occupational sunlight exposure and incidence of NMSC. We attempted to examine the role of occupational sunlight exposure in the development of NMSC in Australia, to determine if occupational sunlight exposure is a risk factor for developing NMSC. The study was conducted at Skin and Cancer Foundation in Carlton, Victoria. The Skin and Cancer Foundation is a not-for-profit, non-government funded organisation that provides specialist treatment for a wide variety of skin diseases. It is a tertiary referral centre and a large proportion of work conducted involves skin cancer diagnosis and treatment. There are skin cancer assessment clinics weekly and there is a group of plastic surgeons and dermatological surgeons who performs surgical removal of skin cancers at one of the six operating theatres within the Foundation.

In designing the study, expertise in different areas were sought. Both my supervisors are consultant dermatologists with special interest in skin cancer. Associate Professor Peter Foley is the director of Research at the Skin and Cancer Foundation. He has participated in epidemiological studies involving skin cancer i.e. First National Skin Cancer Survey, incidence and prevalence of NSMC in Maryborough Central Victoria, prevalence studies in preschool children. He is the Australasian College of Dermatologists representative at the Cancer Council Australia National Skin Cancer

Committee.

Associate Professor Rosemary Nixon is the only person with Australian qualifications in dermatology and occupational medicine. This means that she has expertise in both the occupational impact and clinical aspects of skin cancer assessment. She is the Director of Occupational Dermatology and Research Education Centre (ODREC) established at the Skin and Cancer Foundation in 2001 and has supervised Dermatology Research Fellows and registrars in research projects since 1995. She currently holds honorary appointment as Associate Professor at The University of Melbourne and Monash University.

As this project is the first pilot study in Australia to specifically look at the role of occupational sunlight exposure in the development of NMSC, there was no pre-existing template or previous studies to refer to. To design our questionnaire, we had to customise validated questionnaires used in studies to investigate the risk factors for ocular melanoma and non-Hodgkin's lymphoma in Australia to suit our project requirements. We contacted Associate Professor Claire Vajdic at University New South Wales and Dr Anne Kricker at The University of Sydney who generously shared their questionnaire with us. Associate Professor Claire Vajdic is a cancer epidemiologist leading local, national and international collaborative studies. Dr Anne Kricker has been involved in many research studies and publications involving skin cancer. Both of them developed a questionnaire to measure individual sun exposure on working days and non-working days to test the reliability and validity of a telephone questionnaire for estimating lifetime personal sun exposure in epidemiologic studies. The questionnaire was tested in two case-control studies (88, 89) and the results indicate that occupational sun exposure is substantially more accurately measured in men than women. (90) This suited our project as all our participants were men.

To calculate the sample size for our project, we consulted the expertise of a statistician Dr Sandy Clarke at The University of Melbourne Statistical Consulting Centre. Based on the odds ratio from previous studies, with a 95% confidence level and 80% power, we decided on an initial sample size of 100 cases and 200 controls.

A study protocol was constructed and a Low Risk Research application was submitted to the Ethic Committee of Research Governance Unit at St Vincent's Hospital Melbourne on 18 June 2012. Approval was granted on 2 August 2012. An email was sent to all dermatologists and dermatology registrar in Victoria informing them of the project. Flyers were placed in the waiting area of Skin and Cancer Foundation. Nurses involved with skin cancer management were informed of the project. Unfortunately, these methods yielded zero result. In the end, the only method that was successful in identifying patients were manual search of patients through all the appointment listings for all skin cancer clinics conducted at the Skin and Cancer Foundation from 1 January 2012 to 31 Dec 2013. Every patient on the appointment listings was checked against the electronic clinical records for NMSC. If a potential patient was identified, they would be contacted by phone to confirm their diagnosis and invite them for a face-to-face interview at the Skin and Cancer Foundation. All subjects had to sign a patient informed consent form (PICF) prior to commencement of interview process. The PICF outlined the aim and purpose of this project, the methods utilised to achieve the measure the effect and cause, the risks and benefits to the subject. The interview was conducted using a standardized questionnaire in a consulting room or conference room and usually took between thirty to forty minutes to complete. The author was the only interviewer on the project. (Appendix A, B C)

3.2 Study Population

Case subjects were patients who had attended the Skin Cancer Assessment Clinics at the Skin and Cancer Foundation and had been diagnosed with histopathologically confirmed NMSC either by the doctors at the Skin and Cancer Foundation or their referring dermatologist/general practitioners. If their own dermatologist or general practitioners had made the diagnosis, consent was obtained from the subject to obtain confirmation of diagnosis from their doctors. At the end of the interview process, case subjects were asked to nominate two friends with no prior history of skin cancer as control subjects. Their friends were matched to age (± 5 years) and gender, and were required to be willing to participate in the project. The control subjects were contacted by phone to assess their suitability and willingness to participate in the project. The control subjects participated in the same interview process as the case subjects.

3.3 Inclusion and Exclusion Criteria

Inclusion Criteria

- Men only
- Age 40 years and above
- Willing and able to provide informed consent
- Histological diagnosis of NMSC in case subjects
- No previous history of skin cancer in control subjects

Exclusion Criteria

- Diagnosis of CMM in case subjects
- Previous diagnosis of skin cancer in control subjects
- Subjects who have received phototherapy for treatment of dermatological condition
- Subject with an intellectual disability or mental impairment of any kind
- Subject incompetent to consent for themselves

3.4 Exposure Assessment

The questionnaire was divided into three main areas. The first part of the questionnaire gathered information on ethnic background, pigmentation, skin reaction to sun exposure, and exposure to artificial UV source for cosmetic reasons, i.e. use of sunlamps. Pigmentation was measured assessing eye and hair colour. Skin reaction to sun exposure was measured by 'splitting' the traditional Fitzpatrick's scale into two: tanning pattern and tendency to sunburn. Participants were asked what type of skin reaction they experienced when exposed to direct sunlight for the first time for an hour at midday during summer, and what type of tan developed if they were exposed repetitively.

The Fitzpatrick scale was developed in 1975 by Thomas B. Fitzpatrick, a Harvard dermatologist, as a way to classify the response of different types of skin to UVR. There are four possible answers for white skinned persons (type I, II, III, IV).

Type I	Always burns, never tans
Type II	Usually burns, then tans
Type III	May burn, tans well
Type IV	Rarely burns, tans well

Table 6. Fitzpatrick Skin Type

The second part of the questionnaire was to determine occupational sun exposure. Both case and control subjects were requested to list down all the occupations held for more than three months in their lifetime and to recall the time spent outdoor exposed to sunlight during working and non-working days, as well as any use of sun protection measures, i.e. hats and sunscreen, prior to their attendance for the interview at the Skin and Cancer Foundation. The occupational questions asked about types of occupation held for more than 3 months (paid or unpaid), start and end date of each occupation, time spent outdoors during weekdays and weekends between 9am and 5pm, body surface area covered by clothing, use of hats and sunscreen at work.

The third part of the questionnaire obtained information on recreational sun exposure. The recreational questions asked about participation in regular outdoor recreational activities between 9am and 5 pm on weekdays and weekends, types of recreational activities, use of hats and sunscreen. Participants were also asked about time spent outdoors during childhood and adolescent years. The questions obtained information on sun exposure during school days, weekend and school holidays. The duration of sun exposure was estimated by multiplying weekly exposure hours and number of years up to the age at which the first NMSC was diagnosed. The results were categorised into occupational exposure hours and recreational exposure hours.

3.5 Statistical Analysis

Conditional logistic regression models were implemented in R using the clogit package with the exact method. This is a very common approach used in matched case control studies, as it assesses the effect of the exposure while adjusting for the matching.

Subsequently, a one-way analysis of variance (ANOVA) was used to investigate the relationship of each risk factor with occupational sun exposure.

This was performed with the assistance of a statistician at The University of Melbourne Statistical Consulting Centre. The basic analyses (ANOVAs) were performed in Minitab version 16 and the conditional logistic regression was performed in R version 3 (http://cran.r-project.org/).

4. Results

4.1 Number of Cases and Controls

Approximately six thousand five hundred patients were recorded on the appointment listings used to identify potential subjects. Of these six thousand five hundred patients, less than ten percent were eligible. These cases were identified through perusing every single patient on the appointment listings for Skin Cancer Assessment Clinics and assessing each patient's suitability by looking up their electronic clinical records at the Skin and Cancer Foundation. Approximately three quarters of the cases contacted either refused to participate or did not respond to phone calls and voice messages. Seven patients did not attend on the day of interview and did not respond to follow-up phone calls and emails. One patient's mother was hospitalised on the day before the interview and he had to cancel his appointment but failed to respond when followed-up a month later. One patient had a mild degree of intellectual impairment and this was only identified on the day of interview and subsequently he was deemed unsuitable to proceed with the interview process. Two patients attended expecting a skin check despite being informed clearly over the phone and being offered the Patient Informed Consent Form to read prior to commencement of interview of the nature of the project. Both became aggressive and left the interview half way. The reasons for refusal to participate were lack of interest, too busy with commitments i.e., work / family, logistically difficult to access due to health or location of residence. After a laborious effort over a twelve months period, recruitment of one hundred case subjects was achieved. The unexpected reluctance of patients diagnosed with skin cancer to assist with the research project was a major cause of delay in completion of recruitment. Of the one hundred case subjects, only fifty-three were willing to assist with recruitment of controls. Case subjects were contacted a fortnight and a month after the interview to obtain contact details of potential control

subjects. Control subjects were contacted after verbal approval had been obtained from case subjects. Only fourteen control subjects responded positively and attended the interview. The reasons for refusal to nominate control subjects were lack of friends in the age group requested, fear of intrusion of privacy, lack of interest of family and friends, and not being interested to help.

4.2 Characteristics of Case Subjects

Our youngest patient in the group was 41 years old and the oldest was 83 years old on the day of interview. The mean age for cases was 60.4 years old. 99 of the case subjects were Caucasians or white and only one subject was of South Asian origin. This subject was of mixed British and Indian ancestry. The majority of the case subjects were of British ancestry (89%) and 10 of the case subjects were from other parts of Europe. Case subjects with blue eyes seemed to be most prevalent in the group with 61 subjects identified, followed by hazel, green, brown and grey. Fair hair (29 cases had blonde hair, 35 cases had light brown hair and 6 cases had red hair) was demonstrated in more than half of the subjects. Subjects with Fitzpatrick skin types 1, 2 and 3 represented 96% of the sample group (approximately 30% for each skin type). 71 of the subjects tended to burn after one hour of exposure at noon for the first time in summer and 30 of the subjects did not tan after repeated exposure. Only 10 patients recorded use of sunlamps for cosmetic/ recreational purpose in their lifetime.

Pigmentary Characteristics	**BCC**	**BCC+SCC**	**SCC**
Eye Colour			
Blue	49	2	10
Brown	10	1	1
Green	6	0	3
Grey	3	0	1
Hazel	14	0	0
Total	**82**	**3**	**15**
Hair Colour			
Blonde or Fair	26	1	3
Red	6	0	0
Light Brown	27	1	7
Dark Brown	18	1	3
Black	5	0	2
Total	**82**	**3**	**15**

Table 7. Pigmentary characteristics of case subjects

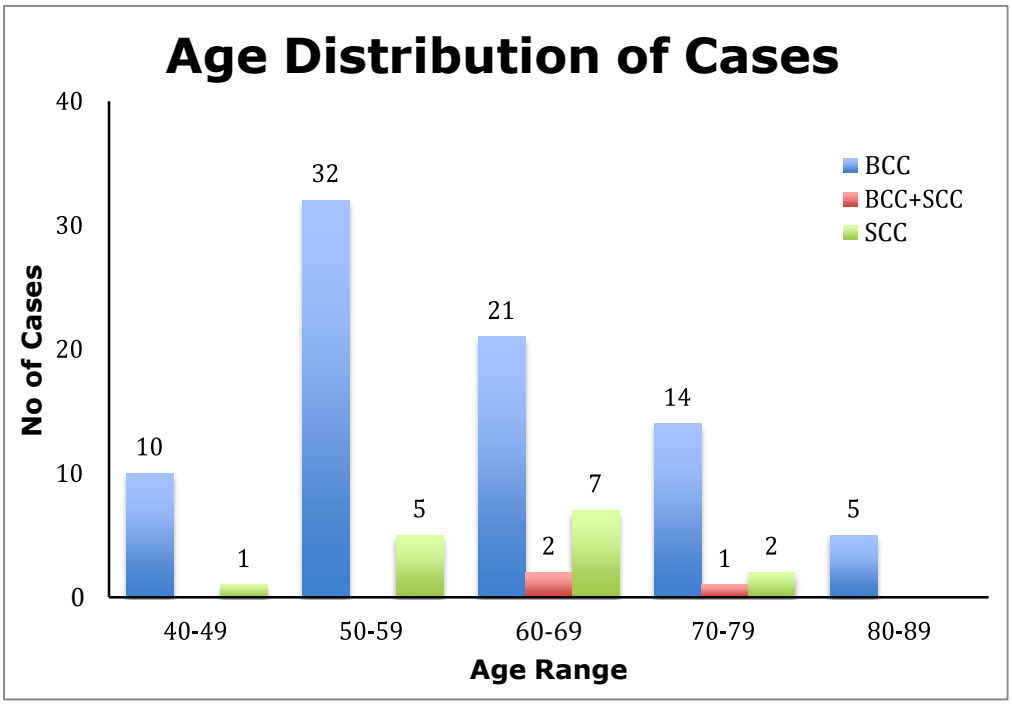


Figure 4. Distribution of Cases by Age

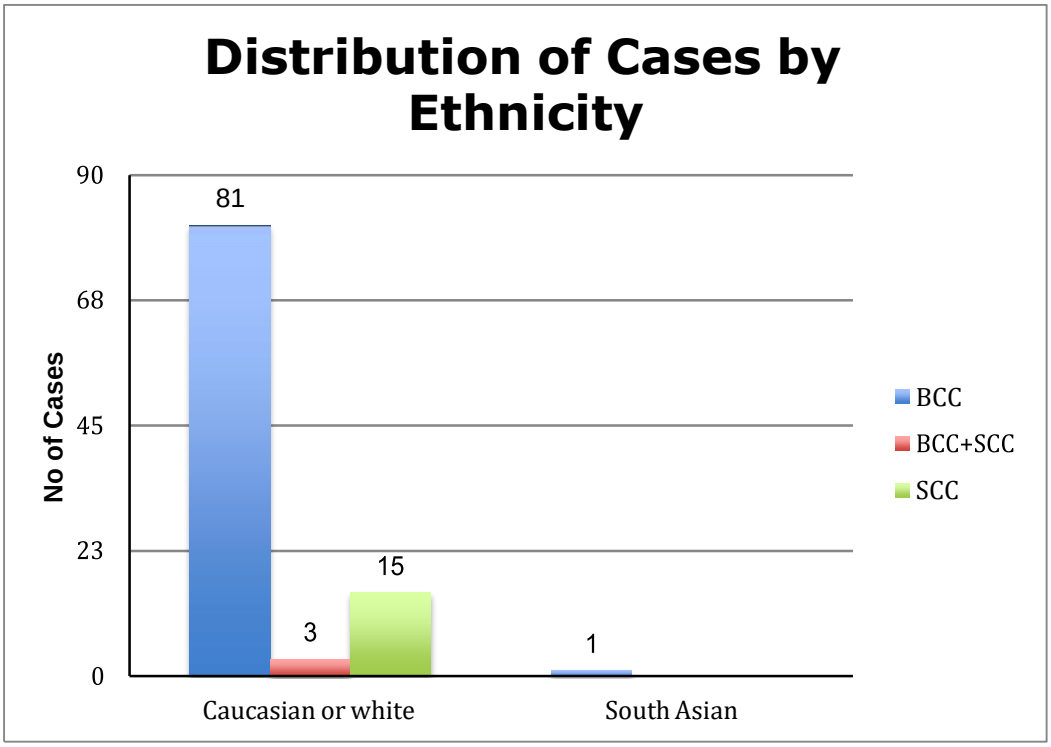


Figure 5. Distribution of Cases by Ethnicity

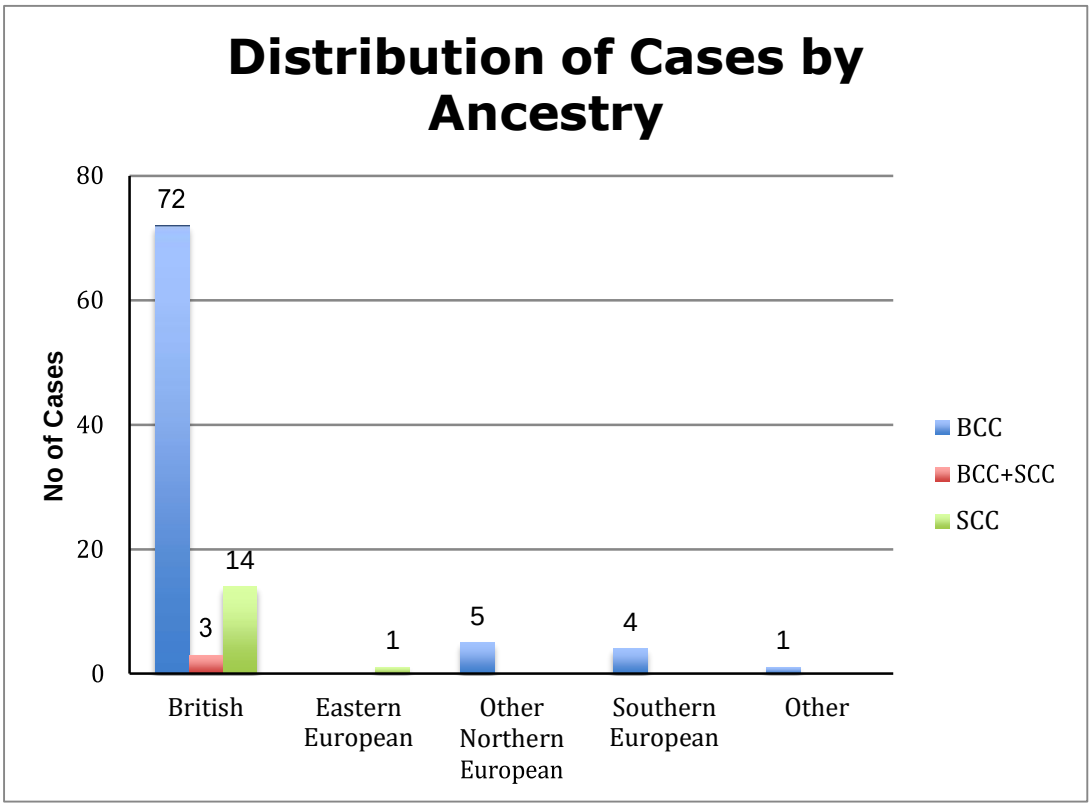


Figure 6. Distribution of Cases by Ancestry

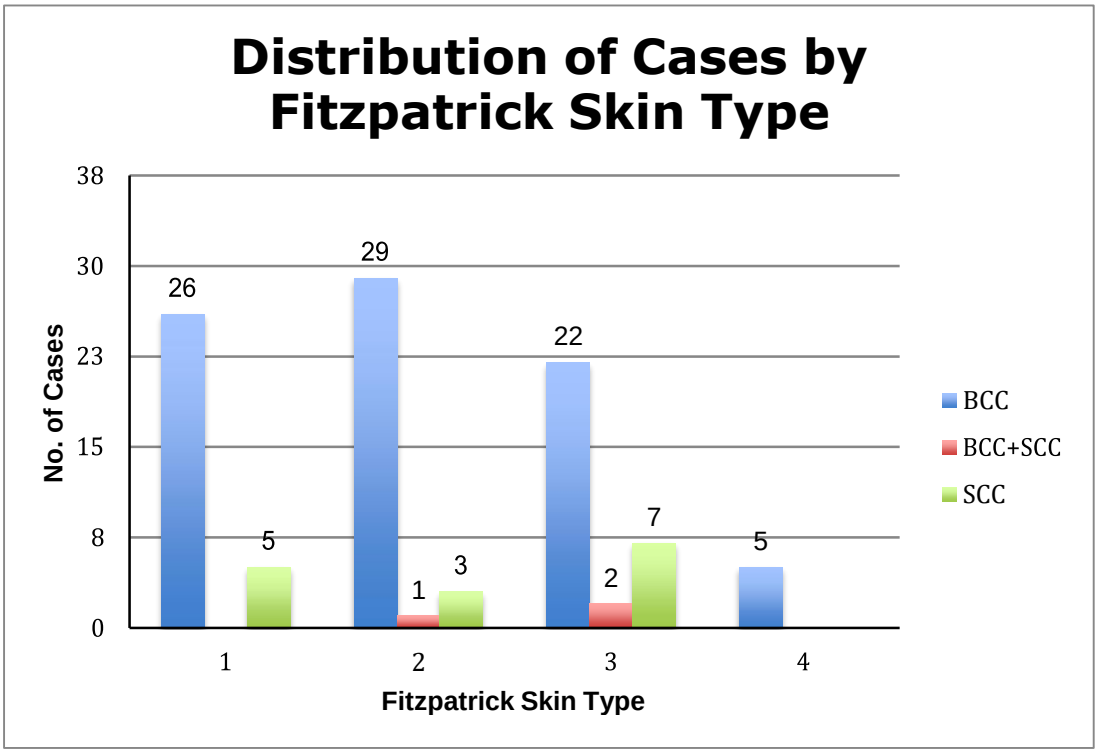


Figure 7. Distribution of Cases by Fitzpatrick Skin Type

4.3 Statistical Analysis

Conditional logistic regression models were implemented in R using the clogit package with the exact method. This is a very common approached used in matched case control studies, as it assesses the effect of the exposure while adjusting for the matching.

The following table contains the estimate of the effect of occupational exposure, in a model with occupational exposure only.

One unit is one hour of sunlight exposure. Total number of units for occupational exposure was calculated by summation of the total number of hours exposed to sunlight for each occupation. The hours of occupational exposure in each individual was variable, varying between zero and 166282 units.

	Reference	Level	OR	95% CI	*P*-value
Occupational exposure	x	x+10000	1.28	(0.79, 2.09)	0.30

Table 4. Occupational Exposure

This can be interpreted as follows: for every 10000 unit increase in occupational exposure, we estimate that the odds of being a case increase by a factor of 1.28. We are 95% confident the true odds ratio is between 0.79 and 2.09. This interval is wide and the estimate is not significantly different from 1. There is insufficient evidence to conclude that there is a relationship between occupational sun exposure and being a case.

The increment of 10000 was chosen based on the range of the data. The odds ratio can be calculated for any specified increment; the bigger the increment, the bigger the odds ratio.

The following table contains the estimate of the effect of total exposure, in a model with total exposure only. Total exposure was a summation of occupational exposure and recreational exposure.

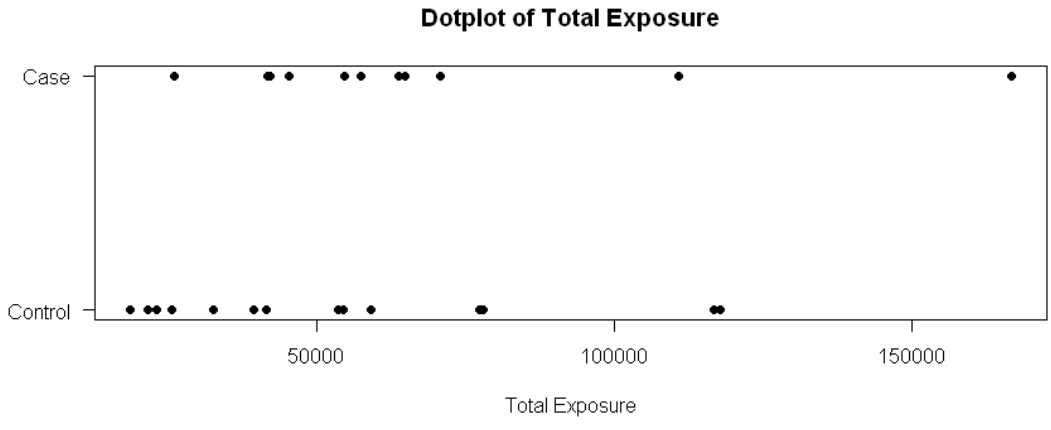
	Reference	Level	OR	95% CI	*P*-value
Total exposure	x	x+10000	1.29	(0.79, 2.11)	0.23

Table 5. Total Exposure

This can be interpreted as follows: for every 10000 unit increase in total exposure, we estimate that the odds of being a case increase by a factor of 1.29. We are 95% confident the true odds ratio is between 0.79 and 2.11. This interval is wide and the estimate is not significantly different from 1. There is insufficient evidence to conclude that there is a relationship between total sun exposure and being a case.

4.3.1 Results for matched cases and controls

Each dot represents a respondent. Both occupational and total exposure seem to be slightly higher in the cases compared to controls, but there is a good deal of overlap.



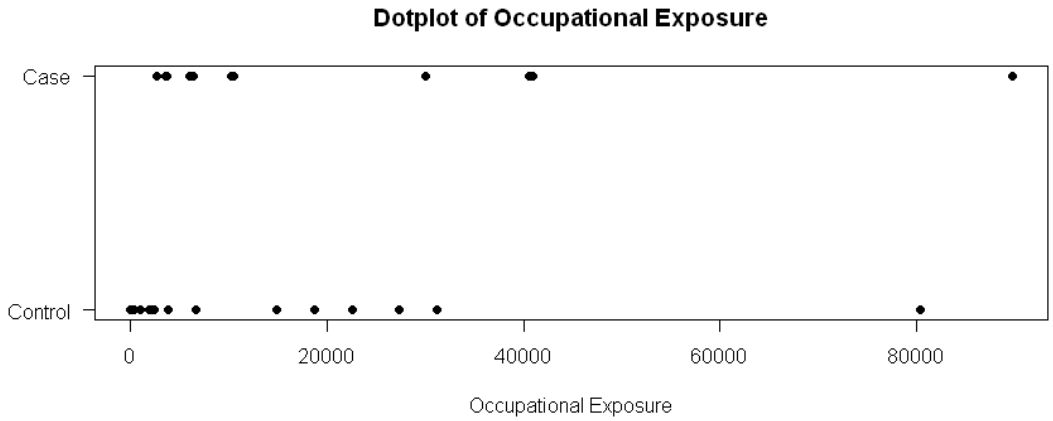


Figure 1. Dotplots of exposure for cases and controls

4.3.2 Dotplots of the difference in exposure between cases and controls.

Given the matching available, it is more appropriate to consider the differences in exposure between paired cases and controls. Each dot represents a difference between a pair. Where two controls were available for a given case, the average of those two controls has been used as the reference.

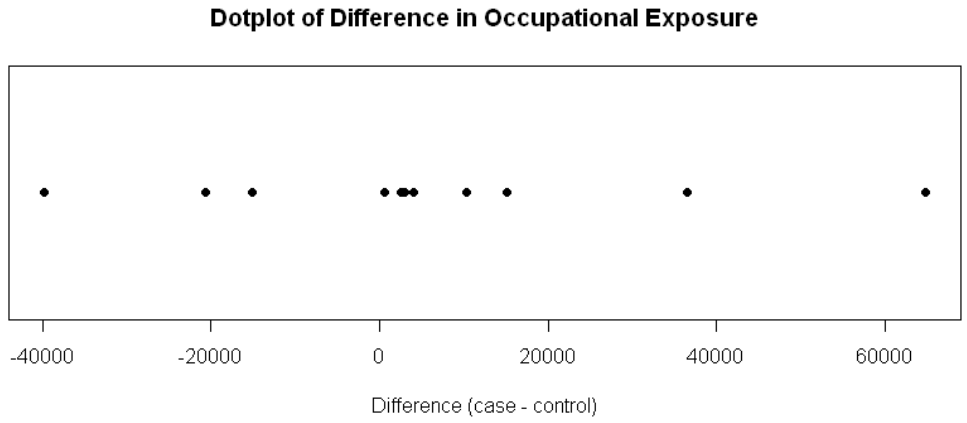


Figure 2. Dotplot of difference in occupational exposure

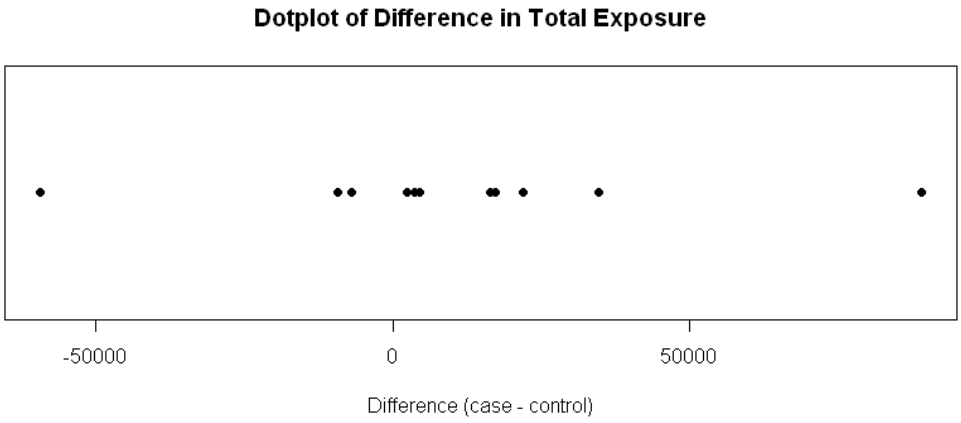


Figure 3. Dotplot of difference in total exposure

For most pairs, the cases have a greater exposure than their matched control(s). However, this result is not consistent: there were several cases which had less exposure than their matched controls.

As the results for the small sample size of the matched case-control group was not statistically significant, we performed a one-way analysis of variance (ANOVA) to compare the levels of each risk factor. Due to the skewness of the variable, the data for occupational exposure was logten transformed.

4.3.3 Fitzpatrick Skin Type

Fitzpatrick Skin Type was the only risk factor which showed a statistically significant different occupational exposure profile (with a *P*-value of 0.035) but even then the differences were minor and only between skin phototype 2 and 3. There were no significant relationships between percentage occupation exposure and the other risk factors, though Fitzpatrick Skin Type again was close to significance.

4.3.4 Summary

The preliminary statistical analysis did not show any evidence to demonstrate an association between occupational sunlight exposure and the risk factors considered. We could not identify any real pattern in the analysis. One way analysis of variance (ANOVA) was deemed sufficient in this situation and there was no need to conduct more sophisticated analyses to probe this matter further.

The statistical analyses of the data collected were not statistically significant to make any conclusion. The original idea of a case-control study evaluation could not be pursued due to the small sample size of control subjects. Hence we decided to convert the findings to an observational study by commenting on the characteristics of the case subjects.

5. Discussion

Despite Australia having the highest incidence of skin cancer in the world, there have not been many epidemiological studies to investigate the relationship between occupational sunlight exposure and NMSC. It has been estimated by the International Agency for Research on Cancer that outdoor workers have an UVR dose two to three times higher than indoor workers. (54)

5.1 Case-Control Study versus Cohort Study

We hypothesised that occupational sunlight exposure increases the risk of NMSC. To test our hypothesis, we decided to conduct an observational analytic investigation. There are two basic types of observational analytic investigation: the case-control and the cohort study. In theory, it is possible to test a hypothesis using either design strategy. In practice, however, each design offers certain unique advantages and disadvantages.

A cohort study is where a group or groups of individuals are defined on the basis of presence or absence of exposure to a suspected risk factor for a disease. At the time exposure status is defined, all potential subjects must be free from the disease under investigation, and eligible participants are then followed over a period of time to assess the occurrence of that outcome. A cohort design can provide information on the full range of health effects of a single exposure. However, they are generally very time-consuming and expensive because it involves following a large numbers of individuals for many years. Consequently, cohort studies are often conducted after a hypothesized relationship has been explored and evaluated in a case-control design. (91)

A case-control study is a type of observational analytic investigation in which subjects are selected on the basis of whether they do (cases) or do not (controls) have a particular

disease under study. The groups are then compared with respect to the proportion having a history of an exposure or characteristic of interest. Because of this design, case-control studies offer a number of advantages for evaluating the association between an exposure and a disease. This approach was begun in developed countries in the twentieth century, in part as a response to needs that accompanied the shift from acute to chronic diseases as major public health problems. Specifically, the case-control design offered a solution to the difficulties of studying diseases with long latency periods, since investigators could identify affected and unaffected individuals and then look backward in time to assess their antecedent exposures rather than having to wait a number of years for the disease to develop. Hence, case-control studies are particularly efficient in terms of both time and costs, relative to the other analytic approaches. Moreover, case-control studies select participants on the basis of their disease status and this allows investigators to identify adequate numbers of diseased and non-diseased individuals. Case-control studies allow for the evaluation of a wide range of potential aetiological exposures that might relate to a specific disease as well as the inter-relationships among these factors. This type of study design is especially useful in the early stages of the development of knowledge about a particular disease or outcome of interest. (91)

5.2 Case-Control Study Chosen for This Project

When considering the type of study design to test our hypothesis, we decided to conduct a matched case-control study to assess the role of occupational sunlight exposure in the development of NMSC. It is well established that solar UVR is a major environmental determinant in the aetiology and pathogenesis of skin cancers. Skin cancer is more common in Caucasians who have light skin and eyes, and in those who burn rather than

tan when exposed to sunlight (Fitzpatrick skin type I and II). Several studies have suggested that the lifetime cumulative sun exposure is responsible for the development of SCC while the epidemiology of BCC suggests that it is related to both acute and chronic sun exposure, providing mixed effects of cumulative and intermittent sun exposure. (7) The Skin and Cancer Foundation ran Skin Cancer Assessment Clinics on a regular basis and provided an optimum source for identification of patients with newly diagnosed NMSC. The duration of candidature for a higher research degree at The University of Melbourne was 18 months and a case-control study can be safely undertaken given time was a limiting factor.

5.3 Challenges of Case-Control Study

The major potential problem in a case-control study relates to the fact that both the exposure and disease have already occurred at the time the participants enter into the study. As a result, this design is particularly susceptible to bias from the differential selection of either the cases or controls into the study on the basis of their exposure status as well as from differential reporting or recording of exposure information between study groups based on their disease status. This potential for bias, as well as the fact that some consider the logic of an investigation progressing temporally from the effect (disease) and to cause (antecedent exposure) as inherently flawed, has led to a degree of scepticism in the past concerning the value of case-control investigations. While this potential bias cannot be ignored, it is not a reason to avoid case-control studies. Rather it requires careful consideration of the sources from which the bias may arise in any particular investigation in order to minimize or preferably to avoid its occurrence. The logic of elucidating a potential cause from observing an effect is an approach used often in everyday life. Well-designed and conducted case-control studies

can provide valuable information on the association between an exposure and disease. Case-control studies have become the most common analytic epidemiologic study design encountered in the medical literature today due to their advantage in being able to evaluate disease that occurs many years following relevant exposures in a timely and cost-effective manner. (91)

One of the first issues to be considered in the design of a case-control study is the definition of the disease or outcome of interest. To ensure that cases selected for study represent a homogenous entity, one of the first tasks in this study was to establish strict diagnostic criteria. Once the diagnostic criteria and definition of the disease had been clearly established, the individuals with this condition could be selected from a number of sources. (91) In our study, the disease being examined was NMSC, specifically looking at SCC and BCC that had been diagnosed histologically by a pathologist. The case subjects were patients who had been treated for either SCC or BCC at the Skin and Cancer Foundation.

The next step, which is selection of controls, is perhaps the most difficult and critical issue in the design of a case-control study. Controls are necessary to allow the evaluation of whether the frequency of an exposure observed in the case group is different from that which would have been expected based on the experience of a series of comparable individuals who do not have the disease. There is no control group that is optimal for all situations. The crucial requirement is that they be comparable to the source population of the cases and that any exclusions or restrictions made in the identification of cases apply equally to the controls and vice versa. Among the specific issues to be considered in selecting controls is the source of subjects. (91) We have selected friends and relatives of case subjects as such groups share the advantage of general population controls in that they are healthy but are more likely to be cooperative

than members of the general population because of their interest in the case. The controls are matched to age (+/- 5 years) and gender. One of the main reason why we chose friends and relatives as controls was because we had hoped that they would share similar recreational activities as the case subjects and hence allow us to elucidate the role of occupation in the development of NMSC. They may also offer a degree of control of important confounding factors related to ethnic background, socioeconomic status, or environment that is not otherwise easily achieved. We decided to use only one control group. With respect to the size of the series, the control-to-case ratio was set at 2:1 to achieve the desired sample size. The power of the study increases with the increasing number of controls per case.

After the case and control series had been defined, the information on the disease (NMSC) and exposure (sunlight exposure) was obtained. Information about disease status was obtained through the electronic database at the Skin and Cancer Foundation, pathology reports issued to case subjects' dermatologist or general practitioners. Information about sunlight exposure was obtained from the study subjects themselves through a face-to-face interview at the Skin and Cancer Foundation. We were taken by surprise at the reluctance of the patients to participate in our study. We had assumed that patients with diagnosed NMSC would be more open to assist in research projects aimed at providing a better understanding of a disease that had affected them. There was significant difficulty in recruiting controls for various reasons, but they were mainly due to lack of support from case subjects. Another issue we encountered in our recruitment phase was lack of interest by dermatologists and dermatology registrars to participate in the study. Dermatologists and dermatology registrars, particularly those involved in skin cancer management can act as a good source of referral for potential case subjects. We did not foresee these as potential issues when designing the study. Hence the unexpected delay in recruitment of subjects both cases and controls.

Evaluation of the findings requires consideration of the role of bias as possible alternative explanations. The major issue in interpretation relates to the potential for a number of types of bias. There are two general classes of systematic error under which the specific types of bias can fall. The first, selection bias, refers to any error that arises in the process of identifying the study populations. The second, observation or information bias, includes any systematic error in the measurement of information on exposure. (91)

Selection bias can occur whenever the inclusion of cases or controls into the study depends in some way on the exposure of interest. Selection bias is a particular problem in case-control studies, since exposure and disease have both occurred at the time subjects are selected for study. There are a number of situations that can result in this bias. In all of these, the common element is that the relationship between the exposure and disease observed among those who participated in the study is different from that for individuals who would have been eligible to participate but were unwilling or not selected by the investigator. Concerns about the existence of selection bias are always raised when response rates are either low or unequal for cases and controls, since it is known that those who agree to participate are different from those who do not in ways that may be related to the exposure and outcome under investigation. (91) The response rate for this study was extremely low, with less than a quarter of the patients contacted expressing interest in participation. There were a small percentage of patients contacted that were keen to participate but were considered unsuitable due to presence of past history of melanoma or unable to recall the time of first diagnosis of NSMC. Controls were selected through cases. We were dependant on case subjects' willingness to nominate the control subjects. The refusal of case subjects to nominate controls that led to inability to recruit the adequate numbers of controls posed a major problem in

interpreting study results.

Observation bias, or errors in obtaining information from subjects once they have been entered into the study may also be a particular problem in a case-control design. This type of bias may arise because the participant often provides information on exposure after the onset of disease. Knowledge of the disease status may therefore influence the reporting of information by the subject or the recording or interpretation of this information by the investigator. Of particular concern is the potential for recall bias and misclassification. (91)

Recall bias relates to differences in the ways exposure information is remembered or reported by cases, who have experienced an adverse health outcome, and by controls who have not. This type of bias is especially problematic in case-control and retrospective cohort studies, since both exposure and disease have already occurred at the time participants enter into the study. One of the most common methods of gathering information particularly in a case-control investigation is by interviewing the study subjects themselves. Individuals who have experienced a disease or other adverse health outcome tend to think about the possible 'causes' of their illness and thus are likely to remember their exposure histories differently from those who are unaffected by the disease. Recall bias can lead to either an over- or underestimate of the association between exposure and disease, depending on whether the cases recall their exposure to a greater or lesser extent than the controls. Since the potential for recall bias exists in every case-control study that relies on information obtained from the participants themselves, it is important that this issue be considered carefully in the design as well as in the interpretation of published results. (91) In this study, recall bias posed a significant problem, especially in elderly patients. We are relying on their recall memory to provide us with information on sun exposure, some of which dates back to

eighty years prior. We asked our subjects to quantify the amount of time spent outdoor from the day they were born and that is a very difficult task especially for a person who has had many occupations in their lifetime or someone who has many outdoor recreational pursuits.

Another major type of observation or information bias is misclassification, which occurs whenever subjects are erroneously categorized with respect to either exposure or disease status. Since in any study, some degree of inaccuracy in reporting or recording information is inevitable, misclassification is always a potential concern. This study utilized self-reported exposure which may be subjected to substantial amounts of misclassification. (91) The potential for non-random misclassification is often a concern when the fact of either having experienced or not having experienced the outcome event (being diagnosed with NMSC) is likely to affect the accuracy with which subjects recall relevant exposures.

Another possible alternative explanation that must always be considered in assessing the presence of a valid statistical association in a given study is confounding. The concept of confounding is central to the interpretation of the findings of any epidemiologic study, most critically in observational studies but also for experimental investigations. Confounding involves the possibility that the observed association is due totally or in part to the effects of differences between the study groups other than the exposure under study that could affect their risk of developing the outcome of interest. Confounding can lead to an overestimate or underestimate of the true association between exposure and disease and can even change the direction of the observed effect. There are three methods that can be used to control confounding in the design of analytic epidemiologic studies: randomization, restriction and matching. Randomization is applicable only to intervention studies while restriction and matching

can be considered for all analytic study designs. We will discuss restriction and matching only because this was a case-control study and randomization was not applicable in this situation. (91)

Restriction is a straightforward, convenient and inexpensive means to control confounding. This is achieved by restricting the admissibility criteria for subjects and limit entrance into the study to individuals who fall within a specified category. In this study, sex is a potential confounding factor, which is why only males were recruited for this study. However, while restriction can deal effectively with the effects of a confounding variable, it does not permit evaluation of the association between exposure and disease for varying levels of factor. Restricting the study population to only men would certainly eliminate any effect of sex as a confounding factor. On the other hand, it might be of interest to know whether the existence or magnitude of the association between occupational sunlight exposure and NMSC differs between men and women. This question could not be evaluated directly because the study population is restricted to only one sex. Restriction may limit generalizability but in no way affects the validity of any observed association between the groups that were included in the study. Restriction enhances the validity by providing an estimate that is unconfounded by the restriction factors. (91)

Randomization and restriction are used to control confounding in the design stage of a study, whereas matching is a strategy that must include elements of both design and analysis. With restriction, the control of confounding is achieved by selecting into the study only individuals with certain homogenous levels of potential confounders. With matching, all levels of these factors are allowable for inclusion in the study but the particular subjects are selected in such a way that the potential confounders are distributed in an identical manner between each of the study groups. In our study, sex

and age are potential confounders. Hence for each case of NMSC, a control would be selected of the same age and sex. In this way, matching forces the distribution of these potential confounders to be identical in both study groups. Matching as a technique for the control of confounding has great intuitive appeal and has been widely used over the years. However, it also has a number of logistic and scientific disadvantages. The first disadvantage of matching is that it can be difficult, expensive and time consuming to find a comparison subject with the right set of characteristics with respect to every matching variable for each individual enrolled in a study. We were unable to recruit the expected number of controls because of various reasons which included lack of interest, fear of intrusion of privacy of control subject's medical history by case subjects, and lack of friends in the age range specified for matching. Cost of obtaining information on potential confounders and selecting matched controls can often be expensive and time-consuming to assemble a suitable study population if matching is employed. A number of potential controls may have to be excluded before finding one with the particular set of characteristics of the case. (91) For this study, I had to contact case subjects at two and four weeks post interview to obtain contact details for the controls. Not every attempt was met with success and politeness. When the contact details of controls were obtained, I had to contact the control subject to assess their suitability prior to organising an interview time for them. Despite these difficulties, there are some circumstances in which matching is desirable. Firstly, if matching were not employed in the design phase of the study, there would not be a sufficient number of individuals in the study groups who were alike with respect to these confounding factors to allow for any type of control in the analysis. Secondly, matching is useful when the case series is small like ours. Matching a number of controls to each case with respect to the potential confounders would ensure an adequate number of cases and controls for each of the subgroups so that it would be possible to evaluate efficiently

the association between exposure and disease.

5.4 Factors Influencing Choice of Study Design

Case-control studies have unique strengths and limitations that must be considered when selecting this study design to evaluate a hypothesis. We chose to conduct a case-control study because it is relatively quick and inexpensive compared to other analytic designs. It is uniquely well suited to the evaluation of diseases with long latent periods. NMSC may take years or decades to develop from the first exposure to sunlight. Case-control study also offers the opportunity to investigate multiple aetiological factors simultaneously for a single disease. It has been well established that other than solar UVR, genetic and other environmental risk factors play a role in the development of skin cancer. Unfortunately, we experienced major difficulties with recruitment of control subjects, which led to a very small sample size of paired case and control subjects. The lack of participation and interest of dermatologists in our project was rather disheartening, given skin cancer is a very common dermatological condition and there is an obvious need for more research into this area. A face-to-face interview was a deterrent for some subjects due to difficulty to access the location secondary to time or distance or both. If this study were to be extended, it may be worthwhile conducting the interview either online or via phone.

In an ideal situation, this study would have 100 cases and 200 controls matched to age and sex. All subjects will be able to provide a reliable account of sunlight exposure for both occupation and recreation. The hours spent outdoors exposed to solar UVR was adjusted to body surface area covered by clothing, use of hats and sunscreen to obtain a more accurate measurement of exposure of unprotected skin to sunlight. A multivariate analysis was performed by constructing a logistic regression model to describe the

association between occupational sunlight exposure and NMSC, as well as other variables that may have confounded or modified the effect of exposure. One advantage of this model was that these coefficients could be directly converted to an odds ratio that provided an estimate of the relative risk that was adjusted for confounding.

This project was a pilot study to investigate the role of occupational sunlight exposure in the development of NMSC. The odds ratio generated on the small sample size of matched case-control pairs was 1.29, which meant that outdoor workers has an approximately thirty percent increased risk of developing a NMSC. The question remains whether this small sample size was representative of the general population. The only way to address this issue is to recruit more control subjects. Given the original approach of using family and friends as control subject was futile, we could consider recruiting control subjects from other clinics at the Skin and Cancer Foundation, as long as the control subjects met the inclusion and exclusion criteria and were matched to age and sex.

5.5 Strengths and Limitations of This Study

The assessment for exposure to occupational sunlight in the questionnaire included documentation of location for each occupation. As explained before in the previous section, the levels of UVR were influenced by a number of factors, which included latitude. UVR levels are higher closer to the equator. This meant that a subject who had worked in a country located closed to the equator e.g. Malaysia would be exposed to higher levels of UVR than someone who worked in Melbourne. There are complex models designed by scientists at the Australian Radiation Protection and Nuclear

Agency (ARPANSA) that allow quantification of UVR levels based on latitude. However, at this stage, this calculation can only be performed on major cities around the world where the necessary parameters to quantify UVR levels are routinely collected. Quite a number of our case subjects were drafted into the army during their early adulthood and they were sent to remote areas for different periods of time. This would pose an issue when attempts are made to quantify the UVR levels.

The assessment for occupational exposure to sunlight also obtained information of body surface area covered by clothing at work. Studies have shown NMSC tend to develop in sun-exposed area. (78, 80) A subject who wears long sleeves and long pants at work is at lower risk of developing skin cancer than someone who wears short sleeves and short pants when working outdoors. Not wearing hats at work has been shown to be a risk factor for skin cancer with an odds ratio of 6.4 for SCC when compared to an odds ratio of 1.4 for basal cell carcinoma. (69) Use of sunscreen has also been associated with reducing risk of skin cancer. (92) All these factors were not taken into account when calculating the amount of time exposed to sunlight. This was a major limitation in obtaining an accurate assessment of sun exposure. When drafting the questionnaire, these questions were obtained from validated questionnaires used in skin cancer studies. When analysing our data, we contacted the authors of the questionnaires which we based our exposure assessment on to obtain the formula to calculate the amount of time exposed to sunlight, adjusting for use of protective measures and were surprised to discover that this information was not taken into consideration in their calculation of time exposed to sunlight. So why collect the information if it is not included in the analysis? A subject who uses sun protective measures i.e. wears a hat, applies sunscreen appropriately and covers sun-exposed skin with clothing would have a lower risk of developing a skin cancer than a subject who works outdoor with minimal or no

protective measures.

When obtaining information on recreational exposure to sunlight, the questionnaire only collected information up to the age of 70. The purpose of this study was to examine the role of occupational sunlight exposure in the development of NMSC. Our assumption was that subjects who spent a significant proportion of time working outdoor has an increased risk of developing NMSC. Given the retirement age is 65 in Australia (119), we assumed the role of occupational sunlight exposure loses its significance after age 65. Time spent outdoors for recreational purposes were not collected after the age of seventy years old if the subject was older than seventy years old at the time of interview. This means that the information collected will be inaccurate when calculating the hours spent exposed to sunlight during recreation for these subjects.

One of the strengths of this study was that there was only interviewer for this project. This minimised variation between interviews and reduced the potential for error due to interviewer variability. Differences in response were due to 'true variation' and not due to inconsistencies in the conduct of interviews.

Another strength of this study was the detailed information obtained on occupational exposure. Many of the studies conducted to assess the role of occupational sunlight exposure differed significantly in the specification of UV-exposed occupations. Information on occupation were obtained from cancer registry and hospital databases which do not give any information on the nature of the occupation other than the type of occupation. A civil engineer who works for VicRoads overseeing the development of new roads and maintenance of current infrastructure would spend more time outdoors working than a civil engineer who works for a town council and spends most time indoors involved in designing and planning new infrastructure. Our questionnaire was able to address this issue by clarifying the role of the subject in each occupation and

amount of time spent outdoors at each job.

5.6 Health Impact of Excessive Sunlight Exposure and Steps to Mitigate the Risk of NMSC

The Australian Work Exposure Study (AWES) showed that a significant proportion of Australian workers are still exposed to unhealthy levels of solar UVR despite solar UVR exposure established as a carcinogen. While the majority of workers used some form of sun protection, only 9% were classified as adequately protected. (126) Outdoor workers receive intense and prolonged exposure to the sun, and thus interventions that are educational and environmental are well suited to the workplace. For adults who work indoors, the workplace may also be a viable setting for educational programming.

There is strong evidence that exposure to solar UVR can have adverse effects on health, notably an increased risk of potentially fatal cancers of the skin. There is equally convincing evidence that limiting outdoor exposure, especially intense, intermittent exposures when solar UV levels are high can reduce the risk. This can be achieved without seriously compromising outdoor pursuits by avoiding direct exposure to sunlight around noon in summer, seeking shade, wearing clothing and by applying sunscreen to unprotected parts of the body.

The ideal intervention strategies to reduce UVR exposure are coordinated, sustained, community-wide approaches that combine education, mass media, and environmental and structural changes. The longest established and most studied of these programs, SunSmart in the state of Victoria in Australia, has reduced several skin cancer risk behaviours by roughly one half, although some sub-groups and behaviours present continuing challenges. SunSmart (with its predecessor Slip! Slop! Slap!) appears to

have achieved society-wide normative changes, it has good prospects for continuing to build on this success. What is less clear is whether this type of effect can be accomplished in areas with lower skin cancer rates, larger populations, or more ethnically mixed populations. (93)

5.7 Protective Behaviour and Preventative Strategies

Since 1980, Australians have been exposed to public education media campaigns raising awareness of skin cancer prevention. In the early days, it started with the slogan 'Slip! (slip on a shirt), Slop! (slop on some sunscreen), Slap! (slap on a hat)'. Over time, two new messages were added to the slogan, 'Seek! (seek shade)' and 'Slide! (slide on some sunglasses)'.

An animated seagull character with a catchy jingle was featured with the initial slogan. This campaign was able to penetrate the consciousness of Australians, reminding them of the importance of skin cancer prevention. (94) In 1987, a broadbased multifaceted programme was developed with the support of government funding (Victorian Health Promotion Foundation) called SunSmart.

The SunSmart programme tries to influence the knowledge, attitudes and intentions of individuals, along with social and cultural norms in an attempt to promote sun-protection behaviour. The programme aims to increase public awareness of the link between sun exposure and skin cancer through education, settings-based interventions, and public communication. It also attempts to change the desirability of a tan. The SunSmart programme has conducted activities across a broad range of settings including schools, community groups, leisure facilities, workplaces and child care centres.

The Cancer Councils across Australia have worked very closely with the Bureau of

Meteorology to promote a solar UV index along the guidelines issued by the World Health Organization. The UV index is an international standard measurement of how strong UVR from the sun is at a particular place on a particular day. The UV index ranges from 0 to 11+ and the higher the number the greater the risk of skin and eye damage. The SunSmart UV Alert is a tool that can be used to determine when it is necessary for individuals to protect themselves from UVR and when sun protection is not required. The SunSmart UV Alert times are issued throughout the year by the Bureau of Meteorology when the UV index is forecast to reach 3 or above. The general rule of thumb for sun protection is as follows (e.g. for Victoria, Australia): from September to April, the UV index forecast for the day is usually 3 or above; at this level, UVR can damage your skin and eyes, and sun protection is required. From May to August, UVR levels are generally low (1 or 2) in Victoria. Sun protection is not needed unless you are in alpine areas or near highly reflective surfaces such as snow or water. The Bureau of Meteorology issues the UV Alert for alpine areas.

When the UV index reaches 3 and above, the following five steps are recommended for protection against sun damage. (i) Slip on some protective clothing. (ii) Slop on sun protection factor (SPF) 30+ sunscreen – make sure it is broad spectrum and water resistant. Apply 20 min before you go outdoors and re-apply every 2 hours. (iii) Slap on a hat. (iv) Seek shade. (v) Slide on some sunglasses – make sure they meet Australian Standards.

5.7.1 Slip on some protective clothing

Clothes can protect the skin against the sun's harmful UV rays. All fabrics disrupt UVR to some degree. The current recommendation is to choose clothing that covers as much

skin as possible. The UV protection factor (UPF) is a rating designation for sun-protective textiles and clothing. Unlike the SPF that in effect measures only UVB protection, the UPF measures both UVA and UVB. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) have been performing measurements on fabrics since the early 1980s.

Testing methods developed by ARPANSA were adopted by the Australian Standard: Sun Protective Clothing – Evaluation and Classification (AS/NZS 4399:1996). This standard was released in July 1996 to introduce a standardized UPF testing method and it also specifies appropriate wording to be placed on labels of clothing claiming to offer sun protection. (95)

Factors that contribute to the UPF rating of a fabric are: (i) composition of the yarns (cotton, polyester etc.); (ii) tightness of the weave or knit (tighter improves the rating); (iii) colour (darker colours are generally better); (iv) stretch (more stretch lowers the rating); (v) moisture (many fabrics have lower ratings when wet); (vi) condition (worn and faded garments may have reduced ratings); and (vii) finishing (some fabrics are treated with UV-absorbing chemicals).

Ultraviolet (UV) protection factor (UPF) ratings and protection categories are described in Table 8.

UPF rating	Protection category	%UVR blocked
15, 20	Good	93% - 95%
25, 30, 35	Very good	96% - 97%
40, 45, 50, 50+	Excellent	97% or more

Table 8. Ultraviolet (UV) protection factor (UPF) ratings and protection categories

Source: Australian Radiation Protection and Nuclear Safety Agency

5.7.2 Slop on sun protection factor 30+ sunscreen

Sunscreen has been proven to reduce risk of CMM (92) and NMSC. When using sunscreen for sun protection, members of the public are urged to remember the following. (i) Never rely solely on sunscreen alone as no sunscreen provides full protection. (ii) Choose an SPF 30+ sunscreen that is broad spectrum and water-resistant. Standards Australia has put forward a proposal that has seen a rise in the maximum SPF from 30+ to 50+. In addition, it has proposed new broad-spectrum requirements (1 ⁄3 ratio for UVA and a critical wavelength test) plus 4-hour water resistancy requirements, making a very high standard product. The draft standard has been put into effect in summer 2012. (iii) Apply sunscreen generously and evenly to clean, dry skin 20 min before going out into the sun. The average-sized adult should apply more than half a teaspoon of sunscreen (about 3 mL) to each arm and the face⁄neck (including ears), and just over one teaspoon (6 mL) to each leg, the front of the body and the back of the body. That is 35 mL of sunscreen for one full-body application. (iv) Reapply all sunscreens every 2 h, or more often when sweating. (v) Check and follow the ‘use by’ date stated on the packaging. (vi) Keep sunscreen below 30 C.

Sunscreen formulas and their components are regulated through the Therapeutic Goods Administration (TGA). In early 2009, the TGA conducted an updated review of the scientific literature in relation to the use of nanoparticulate zinc oxide and titanium dioxide in sunscreen. (96) The TGA review reached the following conclusions. (i) The potential for titanium dioxide and zinc oxide nanoparticles in sunscreens to cause adverse effects depends primarily upon the ability of the nanoparticles to reach viable skin cells. (ii) To date, the current weight of evidence suggests that titanium oxide and

zinc oxide nanoparticles do not reach viable skin cells; rather, they remain on the surface of the skin and in the outer layer (stratum corneum) of the skin that is composed of nonviable, keratinized cells. (iii) There is evidence from isolated (*in vitro*) cell experiments that zinc oxide and titanium dioxide may induce free radical formation in the presence of light and this free radical generation may cause cell damage (photogenotoxicity with zinc oxide). However, recent work suggests that the photogenotoxicity seen in these studies (with zinc oxide) may be due to UV-induced experimental artifact in an *in vitro* assay, rather than the presence of the nanoparticles. (97)

Many sunscreens tend to use 'microfine' or 'micronized' particles, which are larger than nanoparticles. Nanoparticles are smaller than 100 nm and invisible to the human eye: 1 nm = 0.000001 mm. Microfine particles are smaller than those used in conventional white zinc sunscreens, but are larger than nanoparticles – usually in the range of 100–2500 nm.

5.7.3 Slap on a hat

Broad-brimmed and bucket hats provide the most UVR protection for the face and head. Legionnaire-style hats also provide good UVR protection. Baseball caps do not protect the head and face. (98) Wearing a hat with a brim that shades the eyes can reduce UVR to the eyes by up to 50%. (99) The brim width on hats should be at least 6 cm and provide the face, neck and ears with plenty of shade. When choosing a hat, it is advised that one considers the following factors. (i) The quality of sun protection it offers. (ii) The type of fabric it is made from – a tighter fabric suture is best. (iii) The fabric's UPF label – fabric with UPF15 offers good protection while UPF50 offers excellent protection. It is important that buyers ensure the hat's overall design is effective too.

(iii) Whether it is practical (i.e. easy to keep on and does not interfere with activities). (iv)Fashion trends (so that the wearer chooses the hat over less protective ones). (vi) Safety. (vii) Ventilation (especially if the hat is used during physical activity or in warmer weather).

5.7.4 Seek shade

Shade is a practical, user-friendly form of sun protection. The most effective shade can reduce UV exposure by over 90% but this only occurs when exposure to the skin is eliminated. Typical shade, such as a tree or umbrella, can reduce UV exposure by up to 75%. This means that 25% or more of UV still reaches the skin from reflection off the sky or surrounding surfaces. Shade can be natural, man-made or a combination of both. It can be permanent, temporary or portable. As a rule of thumb, if the sky can be seen though the shade covering, the skin is less than fully protected. For the most effective UV protection, shade should be combined with protective clothing, a broad-brimmed hat, sunglasses and SPF 30+ sunscreen.

SunSmart recommends outdoor spaces to include the following. (i) Sufficient shade to protect all people when the UV index reaches 3 and above. (ii) Shade that offers at least 94% block-out of direct UV and minimizes indirect UV. (iii) A combination of built and natural shade. Built shade structures provide predictable, reliable coverage, while natural shade is aesthetically pleasing and environmentally friendly. Deciduous trees offer the added benefit of providing cool, UV-protective shade when required and dropping leaves in winter, allowing sunlight to warm and brighten outdoor spaces. (iv) Shade that is easily accessible, attractive, in good condition and regularly maintained.

5.7.5 Slide on some sunglasses

Acute effects of UVR on the eyes include photokeratitis and photoconjunctivitis. These effects are reversible, easily prevented by protective eyewear and are not associated with any long-term damage. Chronic effects of UVR include cataracts, pterygium, SCC of the cornea or conjunctiva and ocular melanoma. (18–25)

To protect the eyes from UVR, the Cancer Council Victoria recommends sunglasses that are close fitting, wrap around and cover as much of the eye as possible, meet Australian Standard 1067:2003 (Sunglasses: Category 2, 3 and 4) and are marked EPF (eye protection factor) 10. In 2003, Standards Australia issued a joint Australian/New Zealand Standard AS/NZS 1067:2003: Sunglasses and Fashion Spectacles, which set limits on the allowed transmittances of fashion spectacles and sunglasses. All sunglasses sold in Australia must be labeled according to this standard. Wearing sunglasses that meet the standard's requirement for effective sunglasses ensures the wearer's eyes have adequate protection against UVR damage.

Categories of lenses in sunglasses and labeling required are described in Table 9.

Len category	Description	Additional markings
0	Fashion spectacles - not sunglasses. Very low sunglare reduction - some UVR protection.	None
1	Fashion spectacles – not sunglasses. Limited sunglare reduction – some UVR protection.	Not suitable for driving at night
2	Sunglasses. Medium sunglare reduction and good UVR protection.	None

3	Sunglasses. High sunglare reduction and good UVR protection.	None
4	Special purpose sunglasses. Very high sunglare reduction and good UVR protection.	Must not be used when driving

Table 9. Categories of lenses in sunglasses and labeling required

Source: Australian Radiation Protection and Nuclear Safety Agency.

A market research survey was designed and implemented to establish the awareness, knowledge and attitudes of the general public to NMSC and provide an overview of the level of understanding and knowledge of preventative measures. Two thousand and one hundred Caucasian and Hispanic individuals, aged 40-75 years, from the United Kingdom, Italy, Germany, Spain, France, the United States of America and Australia were randomly selected to participate in this market research survey. In a structured telephone interview lasting approximately ten minutes, respondents answered questions on NSMC specifically actinic keratosis and basal cell carcinoma. The study demonstrated significant differences in skin cancer awareness and sun protective behaviours among the countries surveyed. The results indicated that participants in countries with higher prevalence of skin cancer demonstrated greater levels of awareness and expressed more concern about skin cancer. They were also more likely to be routinely checked by their physicians. This suggests that initiatives to educate the public in countries where NMSC is a major problem are having a demonstrable effect. (100)

5.8 Is Occupational Sunlight Exposure in Outdoor Workers a Risk Factor for NMSC?

The Global Burden of Disease study has estimated, based on 2000 data, that worldwide there were 211,921 incident cases of CMM, 65,161 deaths and a total malignant melanoma disease burden of 690,000 disability-adjusted life year (DALY). (101) It is also estimated that about 2,883,000 people developed incident SCC in 2000, with 13,534 deaths and the loss of 162,000 disability-adjusted life years. For basal cell carcinoma, it is estimated that 10 million people developed new BCC in 2000, although deaths from basal cell carcinoma are rare (estimated 3,245 worldwide in 2000) and therefore the total disease burden is lower than for malignant melanoma or SCC, at about 58,000 disability-adjusted life years lost in 2000.

Fair skinned individuals and/or those who live in areas of the world with high UV exposure from the sun disproportionately carry this global burden of cancers of the skin. With concerns about rising temperature and increased UVR through reduction of the ozone layer, it has been estimated that an elevation of temperature of 2^{o} could increase the carcinogenic effectiveness of UV light by a further 10%, although there is considerable uncertainty about this figure (102).

The global burden of disease estimates for skin cancers are not able to identify what proportion of this burden is related to work factors, as there is an absence of the necessary epidemiological data. However, estimates of the occupational contribution to cancer using a population attributable risk (PAR) approach have been performed in many countries. In Australia, it has been estimated that 192 melanomas in males in 2000 (4.3% of the total) were caused by occupation and that this was about 4.4% of the estimated total number of 4,415 work-related cancers in Australian males in that year (45). In addition, it was estimated that 28,000 NMSCs in males were caused by

occupation. Such calculations have acknowledged limitations, such as uncertainties in the numbers of exposed workers and levels of exposure, as well as uncertainties in the population attributable risks (PARs) themselves, which may not reflect the Australian situation in the case of exposures such as UV light, but these findings do help to identify this as an important problem to address.

Marks et al conducted a five-year prospective study on two thousand, six hundred and sixty nine person aged 40 years and older in Maryborough, Australia from 1982-1986. The findings showed a calculated minimal age-standardized incidence rate of 873 NMSC/100,000 population each year. The minimal incidence rate for BCC was 672 cases/ 100,000 population each year and for SCC was 201 cases/ 100,000 population each year. The rate ratio of the incidence of BCC to SCC was 3.34 to one. Occupation was one of the significant factors in determination of the risk of developing NMSC. (42) The role of occupation in the development of NMSC was reinforced in a study conducted by Green et al in Nambour, Australia between1986 and 1987. The relative risk (RR) of NMSC associated with occupational UVR exposure was increased, especially for SCC. The RR for BCC is 1.3 and for SCC is 5.5. (42)

Two national surveys were conducted in Australia to determine the incidence of NMSC. The first survey was conducted in 1985 and the second survey was conducted 5 years later in 1990. There has been a 19% increase in the incidence of medically treated NMSC between the 2 surveys. A 10% annual increase in SCC was of particular concern. The study team postulated that the increased rate of treated NMSC may have been due to education programs increasing the amount of early detection. The consistent difference in the age-incidence curves between the sexes seems to indicate that behavior change with respect to sun exposure can reduce the later incidence of NMSC. This observation underlines the importance of sun protection at any time of life in reducing the cumulative

risk of NMSCs. (43)

A more recent estimate of the contribution of occupation to cancer in the UK, based on attributable fractions for the International Agency for Research in Cancer (IARC) Group 1 and Group 2A carcinogens and using data from the CARcinogen Exposure (CAREX) database has been undertaken (103). This study estimated that 2928 NSMC registrations in 2004 were attributable to occupation, with almost all of the cases estimated to occur from three exposures; 1541 from UV light, 902 from mineral oils and 545 from polycyclic aromatic hydrocarbons. The number of NSMC was only exceeded by the estimated number of lung cancer cases attributable to occupation and was thought to be an underestimate, due to the known under-registration of NSMC in Britain.

Another approach to identify what proportion of this burden is related to work factors is to try to obtain empirical data about the extent and risk factors for skin cancers by establishing notification programs and several programs to monitor a wide range of occupational diseases, including skin cancers, have been established around the world. In the United Kingdom, The Health and Occupational Reporting (THOR) network, through its EPI-DERM program involving physician-notified occupational skin diseases, has found that about 12% of cases (n=1468) were skin neoplasms for the period 1995-2006 (104). More recent analysis of the THOR data for 1988 skin cancer notifications until 2009 showed that 99% of cases were thought to be related to sunlight/UVR, with the most frequently reported occupations being armed services personnel (37%), agricultural workers (18%) and construction workers (9%) (105). It is interesting to note that the number is considerably lower than the estimates presented in the Rushton et al (2010) study and the spectrum of work-related exposures and occupations is also very different from those estimates. A more recent analysis of the

EPI-DERM data indicates that the increased risks for skin cancers relate to roofers, those in the construction trades, labourers and painters and decorators (106).

NMSC is not usually recorded by cancer registries in Australia despite Australia having the highest incidence of skin cancer in the world. With the advancement in information technology and improved access to information, maybe a national database should be established to record all skin cancers diagnosed at all pathology laboratories in Australia. This will allow better estimation of incidence of skin cancer and development of programs to effectively reduce exposure to UVR especially in high-risk population, given skin cancer is the most expensive cancer to treat. Increased knowledge of the attitudes and intentions of susceptible individuals allows identification of at risk population and improvement in existing programs to promote sun-protection behaviours.

As 90% of NMSC may be attributed to excessive exposure to UVR, the aim of primary skin cancer prevention is to limit UVR exposure. Campaigns to prevent skin cancer are needed for outdoor workers and subjects with an increased occupational UVR exposure. There are three measures which are successful and of particular importance in the prevention of NMSC in outdoor workers. 1. Changes in behaviour regarding awareness of health and disease resulting from exposure to natural UVR. 2. Protection from direct UVR by wearing suitable clothing. 3 Regular and correct use of appropriate sunscreen. (60)

Another important public health message is that patients should promptly seek medical (dermatological) attention when they notice a suspicious or changing skin lesion. There is some evidence in the US that workers with occupational exposure to UV light are less likely than other workers to have ever had a skin examination (107). This may be due, in part, to the itinerant and seasonal nature of such work, leading to less regular

involvement in the health care system, and may be an important factor in the known underestimation of the extent of the occupational skin neoplasm burden. The detection of skin cancer at an early stage when it is most likely to be cured by simple outpatient excision is classified as secondary prevention. UVR induced skin carcinogenesis is a multistep process that provides an excellent chance for effective prevention strategies to reduce the incidence, morbidity and mortality of skin cancer and its precursor lesions. Therefore, outdoor workers should be screened for skin cancer regularly. (60)

5.9 Importance of Reducing Sunlight Exposure in Outdoor Workers

There is evidence that the pattern of sun exposure related to skin cancers is different for the different types of cancers. Malignant melanoma and BCC appear to be more related to intermittent, more intense episodes of sun exposure leading to sunburn and blistering, whereas SCC appear to be more related to chronic cumulative sun exposure (108). In Australia, which has the highest incidences of skin cancer in the world, UVR exposure of workers in the building and construction industry was found to be well in excess of the occupational UVR exposure standard developed by the International Radiation Protection Association (109). This indicates a strong need for sun protection programs, which need to be designed to take account of different patterns of sun exposure. In the case of UV exposure, the usual workplace primary prevention measures, such as elimination or substitution, are not suitable options, so the main focus needs to be on measures lower in the hierarchy of controls, such as personal protection and administrative measures.

A 2007 systematic review assessed the extent of the use of measures to reduce sun exposure among outdoor workers (110). The reviewed studies were published between 1991 and 2001 and found that measures to reduce sun exposure were variably used.

For example, among Latino farm workers in California, it was common to wear long-sleeved shirts and hats, but using a sunscreen or wearing a wide-brimmed hat was much less common (111). There were also gender differences among preventive measures, with men more likely to wear hats and women more likely to use sunscreens, so it is important that such differences are considered in designing sun protection programs in workplaces.

Most of the intervention research related to reducing the impact of skin cancers in workers has concentrated on ways to reduce UV light exposure, while interventions to reduce other occupational factors have received lesser attention. The aims of the Tuscany Regional project were to study the sun protection attitude of outdoor workers; to measure solar UVR in the work environment; to describe the frequency of photoaging, precancerous lesions and skin cancers in outdoor workers; and to collect information on solar UVR exposure from incident cases of NMSC recruited from the Tuscany Cancer Registry. The clothing worn by surveyed subjects was often inadequate compared to the high level of exposure to sunlight. Among the 498 cases of NMSC, 135 (27%) were diagnosed in outdoor workers. The characterization of outdoor workers revealed unsatisfactory sun protection behaviours and highlighted the need for prevention programs. (112)

5.10 Workplace Sun Safety Interventions

The 2007 systematic review by Glanz et al assessed the evidence for the effectiveness of interventions to improve sun protection in outdoor workers (110). Most interventions studied involved various forms of educational material and/or training programs with or without skin screening examinations. The authors concluded that there were too few well designed studies with adequate documentation of changes in sun exposure (rather

than simply change in knowledge) to determine the effectiveness of skin protection programs to reduce UV light exposure in the occupational setting.

The best evidence comes from two intervention studies in the USA. The first of these was an evaluation of the Go Sun Smart (GSS) program, a worksite sun safety program largely based on the diffusion-of-innovations theory (113). The Go Sun Smart program was evaluated in a pair-matched, group-randomized, pre-test/post-test controlled design enrolling employees at 26 ski areas in Western North America. 2,119 employees completed both the pre-test and post-test surveys. Employees at the intervention ski areas were more aware of Go Sun Smart (OR = 8.27, $p < 0.05$) and reported less sunburning (adjusted OR = 1.63, $p < 0.05$) at post-test than employees at the control ski areas. A dose response relationship was found (adjusted OR = 1.46, $p < .05$) with greater observed Go Sun Smart program implementation associated with fewer episodes of sunburn among ski workers. Despite limitations, such as the short (5 month) period of follow-up, the 40% drop out at post-test, and the seasonal nature of this work not necessarily being generalisable to other occupations with more regular schedules, this study provides some evidence for short term reductions in hazardous sun exposure.

A further 2-group randomised study assessed a sun safety intervention promoting the wearing of wide-brim hats and sunscreen use among US postal workers (114). This study involved 2662 workers and had a longer period of follow-up than the ski worker study; three months, one year and two years. Intervention group workers were found to have significantly higher use of hats and sunscreen at three months and this was maintained over the two years of follow up with an OR of 2.9 (2.3-3.6) for wide-brim hat use and an OR of 2.0 (1.6-2.6) for sunscreen use at two years.

A more recent study, using a Health Belief Model, found that the use of skin cancer

videos and photos of sun damage on their own faces were associated with significant increases in sun protection behaviours and decreases in skin colour measured by a spectrophotometer in 148 male highway workers which persisted for one year after the intervention (115). This is clearly an important area of research in the future.

In Australia, a randomized controlled trial was conducted to develop and evaluate the effectiveness of a workplace intervention program designed to improve the solar protection behaviour and related knowledge and attitudes of a sample of outdoor workers in the Hunter Region, New South Wales. The results revealed a significant improvement in both the knowledge and the solar protection behaviour of the workers who participated in the intervention. This was indicated by an increase of 16% from pre- to post-test in the proportion of workers in the intervention group who used high solar protection, compared with no improvement in overall protection of workers in the control group. (116)

A graded workplace intervention program to improve sun protection and skin cancer awareness of outdoor workers was implemented and evaluated longitudinally over a period of twenty months in Israel. Twenty months after initiation of the intervention, the overall increase in frequency of sunscreen use among the complete and partial intervention groups was 2.5 fold. The mean daily occupational UVR exposure dose decreased by 33% and 18%, respectively. The rate of self-examination at least once a year in the same two groups increased by 71% and 53%, respectively. The results of this study demonstrate that an extensive and specifically designed workplace intervention program for the primary and secondary prevention of sun induced skin cancer in male outdoor workers led to significant improvement in sun protection and skin cancer awareness. The repeated double-pulse intervention combined with the provision of personal sun protective gear led to an even more conspicuous rise in the

frequency of sunscreen use in the complete intervention group compared to the first intervention. (117)

For the greatest possible impact, comprehensive workplace sun safety interventions should be aimed at both the outdoor workers and their employers. When considering a comprehensive approach to workplace safety, several issues should be considered: seasonal outdoor workers who may be at higher risk because of little organising capacity, workers belonging to a union versus non-union employees, workers in Federal agencies, and self-employed workers such as those on small farms. Appeals to employers about the importance of worker safety in the context of risk management might be successful. Employees who work primarily indoors should not be overlooked. Many receive considerable recreational exposure and exposure occurs in a much more intermittent pattern. Workplace communication also can be used to deliver sun protection advice to employees' families. These efforts should be carefully evaluated so that other occupational health and cancer prevention experts can be sure the most effective approaches are adopted and used widely, to achieve the greatest public health benefit. (110)

6. Conclusion

This pilot study sought to investigate the effect of occupational sunlight exposure on the incidence of NMSC. Unfortunately, we encountered significant barriers in subject recruitment for a tertiary dermatology referral center such as the Skin and Cancer Foundation Inc. There were some major limitations that affects the interpretation of our results (as discussed above). Among other limitations, recall bias was a major issue in this study. However, this study has successfully attempted to collect detailed information on occupational exposure, confirmed by subjects, which we believe to be a superior methodology to basing data collections on assumptions derived from job titles. In order to obtain a better understanding and quantification of the current UV exposure level amongst outdoor workers, this study needs to continue. One of the first steps is to recruit control subjects from a different pool/ source so that we can properly assess the effects of UV exposure as intended in our original study design, a case control study.

Reducing exposure to UVR contributes to the reduction of the incidence of skin cancer. This is achieved by using a combination of sun protection measures. Many risk factors are associated with the development of skin cancer, inviting the need for a multi-factorial modification approach to prevention and early detection. Such approaches need to consider cultural, socioeconomic, environmental, political and legislative impacts.

Exposure to UVR is a relevant health concern at workplace. Occupational screenings should include regular interventions aimed at enhancing a clear understanding of risk factors for individuals and finally improving the acceptance and maintenance for UV protective means at workplace. Evidence-based data confirming the benefit of sun

protective strategies are scarce, general recommendations are mainly based on the avoidance of UVR being identified as potential risk factor for NMSC in epidemiological studies. (108)

Occupational neoplasms of the skin have been recognised for more than 200 years since being first documented in chimney sweeps in 18th Century England. Since then, many other chemical and physical workplace exposures have been established as causes of malignant skin cancers, however UV light has been shown to be the most important current cause, especially for SCC. There are also some possible emerging hazards, such as shift work, which require further research to investigate their relationship with skin cancers. The increasing incidence rates of NMSC will have an impact on healthcare costs. Therefore, accurate models for determining the occupational exposure may help workers to receive compensation by the statutory accident insurance. Current methods to monitor trends in occupational skin cancers are inadequate. An effective skin protection program in the occupational setting is clearly an important priority and this will be an important focus of research in the future. In addition, it would need to be determined that screening and risk factor modification exert an influence on incidence and/or other health outcomes related to skin cancers.

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Appendix A – Participant Information and Consent Form for Case Subjects

PARTICIPANT INFORMATION AND CONSENT FORM (PICF)

Skin and Cancer Foundation Victoria

Participant Information and Consent Form
Skin and Cancer Foundation Victoria

Full Project Title: The relationship between occupational sunlight exposure and incidence of non-melanoma skin cancer

Principal Researcher: Associate Professor Peter Foley

Co-Researcher: Associate Professor Rosemary Nixon, Dr Stephanie Tan, Dr Peter Gies

1. Introduction

You are invited to take part in this research project. This is because you have been diagnosed with non-melanoma skin cancer. The research project aims to investigate the role of occupational sunlight exposure in the development of non-melanoma skin cancer.

This Participant Information and Consent Form tells you about the research project. It explains what is involved to help you decide if you want to take part.

Please read this information carefully. Ask questions about anything that you don't understand or want to know more about. Before deciding whether or not to take part, you might want to talk about it with a relative, friend or your local health worker.

Participation in this research is voluntary. If you don't wish to take part, you don't have to.

If you decide you want to take part in the research project, you may be asked to sign the consent section. By signing it you are telling us that you:

- understand what you have read;
- consent to take part in the research project;
- consent to be involved in the procedures described;
- consent to the use of your personal and health information as described.

You will be given a copy of this Participant Information and Consent Form to keep.

2. What is the purpose of this research project?

The aim of this project is to investigate the role of occupational sunlight exposure in the development of non-melanoma skin cancer in the Australian population. Ultraviolet (UV) radiation exposure from sunlight is the main environmental cause of all major forms of skin cancer. A recent review of the available epidemiological evidence by a group of German dermatologists found an increased risk of skin squamous cell carcinoma (SCC) in individuals with occupational ultraviolet light exposure. To-date, there have been only two cohort studies performed in Australia to analyse the association between occupational ultraviolet light exposure and skin cancer despite Australia having the highest incidence of skin cancer in the world. Both studies were conducted in the 1980s. This project is a case-control study, with a sample size of 300 subjects (100 cases and 200 controls). The case subjects will be recruited from the Skin Cancer Assessment Clinic at the Skin and Cancer Foundation and the controls will be two friends nominated by the case subject. The

case and control subjects will be matched to age and gender. Only male subjects are recruited. The results of this research will be used by the researcher Dr Stephanie Tan to obtain a Master of Medicine (by research) degree. This research has been funded by Skin and Cancer Foundation.

3. What does participation in this research project involve?

Male patients, age 40 years and above who have been diagnosed with their first non-melanoma skin cancer will be identified from the Skin Cancer Assessment Clinic at the Skin and Cancer Foundation and an informed consent will be obtained before any trial related procedures. You will be asked to nominate two friends with no prior history of skin cancer as controls, matched to age (± 5 years) and sex and must be willing to participate in the project. You will have a face-to-face interview with Dr Stephanie Tan in one of the consulting rooms at the Skin and Cancer Foundation. The interview process will take between 45 to 60 minutes. You will not be paid for your participation in this research, but you will be reimbursed $50 for your time.

4. What are the possible benefits?

There are no potential benefits to the participant on an individual level. However, the report generated by this project will likely reaffirm our assumptions about occupational sunlight exposure in the development of non-melanoma skin cancer in the Australian population.

5. What are the possible risks?

This project does not involve any invasive medical procedures. Hence, there is minimal level of inconvenience and/or discomfort to the participant which would be loss of time.

If you become upset or distressed as a result of your participation in the research, the researcher is able to arrange for counselling or other appropriate support. Any counselling or support will be provided by staff who are not members of the research team.

6. Do I have to take part in this research project?

Participation in any research project is voluntary. If you do not wish to take part, you do not have to. If you decide to take part and later change your mind, you are free to withdraw from the project at a later stage.

If you decide to withdraw, please notify a member of the research team. This notice will allow that person or the research supervisor to inform you if there are any special requirements linked to withdrawing.

Your decision whether to take part or not, or to take part and then withdraw, will not affect your relationship with the researchers or Skin and Cancer Foundation.

7. How will I be informed of the final results of this research project?

You will not be informed of the final results of this research project. However, we do plan to publish the results in a medical journal.

8. What will happen to information about me?

Any information obtained for the purpose of this research project that can identify you will be treated as confidential and securely stored. It will be disclosed only with your permission, or as permitted by law. The information will be retained for

15 years and stored in the research department of the Skin and Cancer Foundation. Only the researchers will have access to the information. An authorised records disposal company will be engaged for safe and secure destruction of confidential records at the end of 15 years. In any publication and/or presentation, information will be provided in such a way that you cannot be identified, except with your permission.

9. Can I access research information kept about me?

In accordance with relevant Australian and/or Victorian privacy and other relevant laws, you have the right to access the information collected and stored by the researchers about you. Please contact one of the researchers named at the end of this document if you would like to access your information.

In addition, in accordance with regulatory guidelines, the information collected in this research project will be kept for at least 15 years.

10. Is this research project approved?

The ethical aspects of this research project have been approved by the Human Research Ethics Committee of St Vincent's Hospital Melbourne.

This project will be carried out according to the *National Statement on Ethical Conduct in Human Research (2007)* produced by the National Health and Medical Research Council of Australia. This statement has been developed to protect the interests of people who agree to participate in human research studies.

11. Consent

I have read, or have had this document read to me in a language that I understand, and I understand the purposes, procedures and risks of this research project as described within it.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I freely agree to participate in this research project, as described.

I understand that I will be given a signed copy of this document to keep.

Participant's name (printed) ……

Signature Date

Declaration by researcher*: I have given a verbal explanation of the research project, its procedures and risks and I believe that the participant has understood that explanation.

Researcher's name (printed) ……

Signature Date

Note: All parties signing the consent section must date their own signature.

12. Who can I contact?

If you want any further information concerning this project or if you have any problems which may be related to your involvement in the project (for example, feelings of distress), you can contact the principal researcher on 96239400 or any of the following people:

Name: ***Dr Stephanie Tan***

Role: Co-Researcher

Telephone: 0421307383

For complaints:

If you have any complaints about any aspect of the project, the way it is being conducted or any questions about being a research participant in general, then you may contact:

Name: Executive Officer

Position: Executive Officer Research Governance Unit

Telephone: (03) 92883930

Appendix B – Participant Information and Consent Form for Control Subjects

PARTICIPANT INFORMATION AND CONSENT FORM (PICF)

Skin and Cancer Foundation Victoria

Participant Information and Consent Form
Skin and Cancer Foundation Victoria

Full Project Title: The relationship between occupational sunlight exposure and incidence of non-melanoma skin cancer

Principal Researcher: Associate Professor Peter Foley

Co-Researcher: Associate Professor Rosemary Nixon, Dr Stephanie Tan, Dr Peter Gies

1. Introduction

You are invited to take part in this research project. This is because you have been nominated by your friend who is a patient at the Skin and Cancer Foundation Victoria. The research project aims to investigate the role of occupational sunlight exposure in the development of non-melanoma skin cancer.

This Participant Information and Consent Form tells you about the research project. It explains what is involved to help you decide if you want to take part.

Please read this information carefully. Ask questions about anything that you don't understand or want to know more about. Before deciding whether or not to take part, you might want to talk about it with a relative, friend or your local health worker.

Participation in this research is voluntary. If you don't wish to take part, you don't have to.

If you decide you want to take part in the research project, you may be asked to sign the consent section. By signing it you are telling us that you:

- understand what you have read;
- consent to take part in the research project;
- consent to be involved in the procedures described;
- consent to the use of your personal and health information as described.

You will be given a copy of this Participant Information and Consent Form to keep.

2. What is the purpose of this research project?

The aim of this project is to investigate the role of occupational sunlight exposure in the development of non-melanoma skin cancer in the Australian population. Ultraviolet (UV) radiation exposure from sunlight is the main environmental cause of all major forms of skin cancer. A recent review of the available epidemiological evidence by a group of German dermatologists found an increased risk of skin squamous cell carcinoma (SCC) in individuals with occupational ultraviolet light exposure. To-date, there have been only two cohort studies performed in Australia to analyse the association between occupational ultraviolet light exposure and skin cancer despite Australia having the highest incidence of skin cancer in the world. Both studies were conducted in the 1980s. This project is a case-control study, with a sample size of 300 subjects (100 cases and 200 controls). The case subjects will be recruited from the Skin Cancer Assessment Clinic at the Skin and Cancer Foundation and the controls will be two friends nominated by the case subject. The

case and control subjects will be matched to age and gender. Only male subjects are recruited. The results of this research will be used by the researcher Dr Stephanie Tan to obtain a Master of Medicine (by research) degree. This research has been funded by Skin and Cancer Foundation.

3. What does participation in this research project involve?

Male patients, age 40 years and above who have been diagnosed with their first non-melanoma skin cancer will be identified from the Skin Cancer Assessment Clinic at the Skin and Cancer Foundation and an informed consent will be obtained before any trial related procedures. You will be asked to nominate two friends with no prior history of skin cancer as controls, matched to age (± 5 years) and sex and must be willing to participate in the project. You will have a face-to-face interview with Dr Stephanie Tan in one of the consulting rooms at the Skin and Cancer Foundation. The interview process will take between 45 to 60 minutes. You will not be paid for your participation in this research, but you will be reimbursed $50 for your time.

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There are no potential benefits to the participant on an individual level. However, the report generated by this project will likely reaffirm our assumptions about occupational sunlight exposure in the development of non-melanoma skin cancer in the Australian population.

5. What are the possible risks?

This project does not involve any invasive medical procedures. Hence, there is minimal level of inconvenience and/or discomfort to the participant which would be loss of time.

If you become upset or distressed as a result of your participation in the research, the researcher is able to arrange for counselling or other appropriate support. Any counselling or support will be provided by staff who are not members of the research team.

6. Do I have to take part in this research project?

Participation in any research project is voluntary. If you do not wish to take part, you do not have to. If you decide to take part and later change your mind, you are free to withdraw from the project at a later stage.

If you decide to withdraw, please notify a member of the research team. This notice will allow that person or the research supervisor to inform you if there are any special requirements linked to withdrawing.

Your decision whether to take part or not, or to take part and then withdraw, will not affect your relationship with the researchers or Skin and Cancer Foundation.

7. How will I be informed of the final results of this research project?

You will not be informed of the final results of this research project. However, we do plan to publish the results in a medical journal.

8. What will happen to information about me?

Any information obtained for the purpose of this research project that can identify you will be treated as confidential and securely stored. It will be disclosed only with your permission, or as permitted by law. The information will be retained for

15 years and stored in the research department of the Skin and Cancer Foundation. Only the researchers will have access to the information. An authorised records disposal company will be engaged for safe and secure destruction of confidential records at the end of 15 years. In any publication and/or presentation, information will be provided in such a way that you cannot be identified, except with your permission.

9. Can I access research information kept about me?

In accordance with relevant Australian and/or Victorian privacy and other relevant laws, you have the right to access the information collected and stored by the researchers about you. Please contact one of the researchers named at the end of this document if you would like to access your information.

In addition, in accordance with regulatory guidelines, the information collected in this research project will be kept for at least 15 years.

10. Is this research project approved?

The ethical aspects of this research project have been approved by the Human Research Ethics Committee of St Vincent's Hospital Melbourne.

This project will be carried out according to the *National Statement on Ethical Conduct in Human Research (2007)* produced by the National Health and Medical Research Council of Australia. This statement has been developed to protect the interests of people who agree to participate in human research studies.

11. Consent

I have read, or have had this document read to me in a language that I understand, and I understand the purposes, procedures and risks of this research project as described within it.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I freely agree to participate in this research project, as described.

I understand that I will be given a signed copy of this document to keep.

Participant's name (printed) ……

Signature Date

Declaration by researcher*: I have given a verbal explanation of the research project, its procedures and risks and I believe that the participant has understood that explanation.

Researcher's name (printed) ……

Signature Date

Note: All parties signing the consent section must date their own signature.

12. Who can I contact?

If you want any further information concerning this project or if you have any problems which may be related to your involvement in the project (for example, feelings of distress), you can contact the principal researcher on 96239400 or any of the following people:

Name: ***Dr Stephanie Tan***

Role: Co-Researcher

Telephone: 0421307383

For complaints:

If you have any complaints about any aspect of the project, the way it is being conducted or any questions about being a research participant in general, then you may contact:

Name: Executive Officer

Position: Executive Officer Research Governance Unit

Telephone: (03) 92333930

Appendix C – Questionnaire

Study Title:	**The relationship between occupational sunlight exposure and incidence of non-melanoma skin cancer**
Site:	**Skin and Cancer Foundation Victoria, 80 Drummond Street, Carlton 3053, Victoria**
Researchers:	**Associate Professor Peter Foley, Dr Stephanie Tan, Associate Professor Rosemary Nixon, Dr Peter Gies**
Document:	**Questionnaire Version 2- 8 May 2013**

Subject Name:	
Subject ID:	
Date of Interview:	

Personal Details

1 Date of Birth

2 Age

3 Sex

- ☐ Male
- ☐ Female

4 How would you describe your ethnic origin? (If more information is needed, add: ethnicity is how you see yourself, it is a mixture of culture, religion, skin colour, language, the origins of yourself and your family. It is not the same as nationality)

- ☐ Caucasian or white
- ☐ Indigenous Australian (Aboriginal, Torres, Straight Islander)
- ☐ South-east Asian (originated from Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar/Burma, Philippines, Singapore, Thailand, Vietnam)
- ☐ North-East Asian (originated from China, Hong Kong, Japan, Korea, Macau, Taiwan)
- ☐ South Asian (originated from Afghanistan, Bangladesh, India, Nepal, Pakistan, Sri Lanka)
- ☐ Middle Eastern (originated from Israel, Iran, Iraq, Lebanon, Turkey, Egypt or Arab)
- ☐ Pacific Islander (Pacific Island, Hawaii, New Guinea)
- ☐ Indigenous American (American Indian)
- ☐ Black American (Black person originating from USA, Canada, Puerto Rico, Caribbean)
- ☐ South American of Spanish or 'local' Indian descent (originating from Mexico, Central or South America)
- ☐ Black African (originated from North Africa, Sub-Saharan Africa, Zimbabwe or Black South African)
- ☐ Adopted
- ☐ Unknown
- ☐ Other (please specify)

(If answer 'Caucasian or white', go to question 5, otherwise go to question 6)

5 Which of the following most closely describes the part of Europe from which your ancestors came?

- ☐ British (originated from UK/Britain, England, Wales, Scotland, Ireland)
- ☐ Other Northern European (originated from Austria, Latvia, Lithuania, Estonia, Denmark, France, Germany, Luxembourg, Netherlands/Holland, Sweden, Norway, Finland, Switzerland, other Western/Northern European country)

	Southern European (originated from Greece, Italy, Portugal, Spain, former Yugoslavia, Malta, Cyprus, other Southern European country)	
	Eastern European (originated from Bulgaria, former Czechoslovakia, Hungary, Poland, Romania, Former USSR, other Eastern Europeans country)	
	Mixed (please specify)	
	Other (please specify)	
	Unknown	

Skin Types

6 What would happen to your skin if it were exposed to bright sunlight for the first time in summer, for one hour in the middle of the day, without any protection?

- [ ] Get a severe sunburn with blistering
- [ ] Have a painful sunburn for a few days followed by peeling
- [ ] Get mildly burnt followed by some tanning
- [ ] Go brown without any sunburn

7 What would happen to your skin if it was repeatedly exposed to bright sunlight in summer without any protection?

- [ ] Go very brown and deeply tanned
- [ ] Get moderately tanned
- [ ] Get mildly or occasionally tanned
- [ ] Get no suntan at all or only get freckled

Pigmentary characteristics

8 Which colour best describes the colour of your eyes?

- ☐ Grey
- ☐ Blue
- ☐ Green
- ☐ Hazel
- ☐ Brown

9 Which colour best describes your natural hair colour when you were a teenager?

- ☐ Blonde or fair
- ☐ Light brown
- ☐ Red
- ☐ Dark brown
- ☐ Black

10 Which colour best describes the colour of your skin on the inside of your upper arm, that is, your skin colour without any tanning?

- ☐ Very fair
- ☐ Fair
- ☐ Light olive
- ☐ Dark olive
- ☐ Brown
- ☐ Black

Sun Lamps

11 Have you ever used a sunlamp or sunbed for any reason?

- ☐ Never
- ☐ Yes
- ☐ Don't know

12 How old were you when you last used one? ☐

13 How old were you when you first used one? ☐

14 About how many sunlamp/sunbed sessions have you had, in total over your lifetime? ☐

15 In what types of locations have you used a sunlamp or sunbed

- ☐ Tanning salon
- ☐ Hairdressers, beauty salons
- ☐ Gymnasium-health/ fitness club/ spa
- ☐ Hospital or medical facility
- ☐ Private home
- ☐ Other (please specify) ☐
- ☐ Don't know

Occupational sunlight exposure history

16 Have you had any job for a total of 3 months or more? By "job" I mean any activity you consider to be your work, whether paid or unpaid.

	Yes
	No

17 What were these jobs? (Please record job title or type of work)

1st	
2nd	
3rd	
4th	
5th	
6th	
7th	
8th	
9th	
10th	

18.01 *I would like you to think about your 1st job*

18.01.01	In what year did you first do this?	
18.01.02	In what year did you last do this?	
18.01.03	For about how many months/years altogether did you do this job?	
18.01.04	Where did you work? (Location)	
18.01.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.01.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

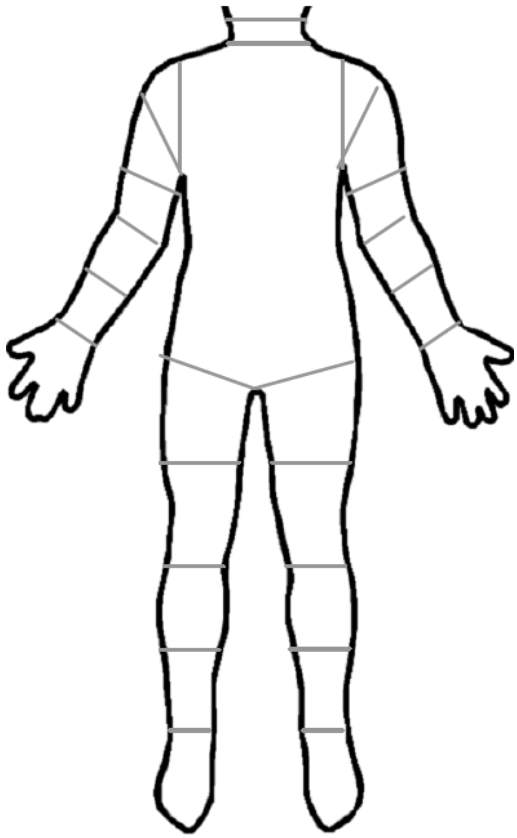
18.01.07 How often did you wear a hat?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.01.08 What type of hat do you wear when you are working outdoor?

	None		
			
			
	Other (please specify)		

18.01.09 What area of your body is covered with clothing when you are working outdoor?



18.01.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.02 *I would like you to think about your 2nd job*

18.02.01	In what year did you first do this?	
18.02.02	In what year did you last do this?	
18.02.03	For about how many months/years altogether did you do this job?	
18.02.04	Where did you work? (Location)	
18.02.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.02.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

18.02.07 How often did you wear a hat?

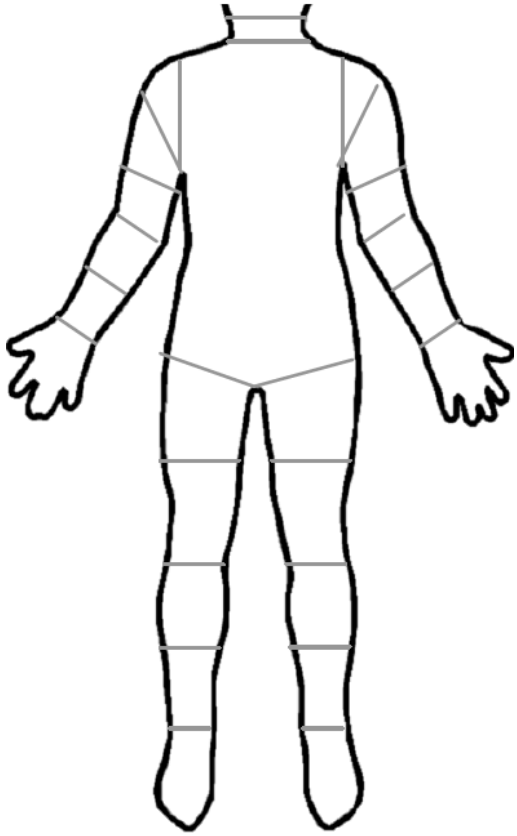
- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

18.02.08 What type of hat do you wear when you are working outdoor?

- ☐ None
- ☐ 
- ☐ 
- ☐ Other (please specify) _____

- ☐ 
- ☐ 
- ☐ 

18.02.09 What area of your body is covered with clothing when you are working outdoor?



18.02.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.03 *I would like you to think about your 3rd job*

18.03.01	In what year did you first do this?	
18.03.02	In what year did you last do this?	
18.03.03	For about how many months/years altogether did you do this job?	
18.03.04	Where did you work? (Location)	
18.03.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.03.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

18.03.07 How often did you wear a hat?

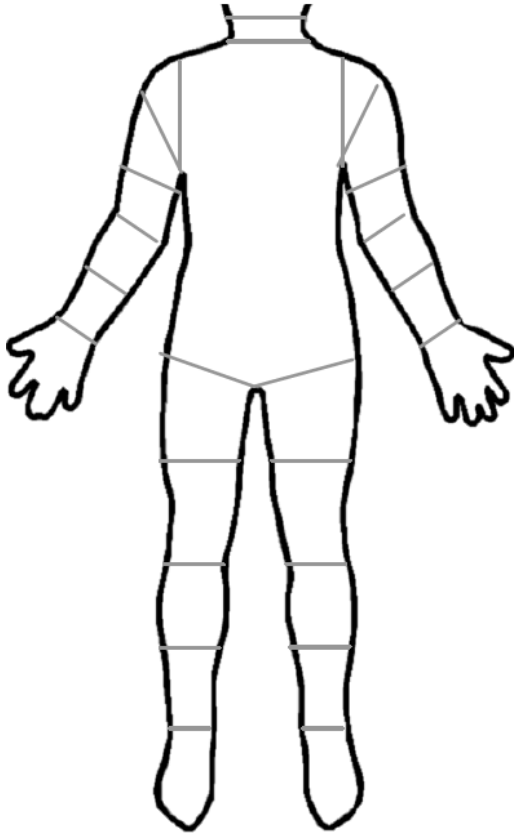
- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

18.03.08 What type of hat do you wear when you are working outdoor?

- ☐ None
- ☐ 
- ☐ 
- ☐ Other (please specify) ____

- ☐ 
- ☐ 
- ☐ 

18.03.09 What area of your body is covered with clothing when you are working outdoor?



18.03.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.04 *I would like you to think about your 4th job*

18.04.01	In what year did you first do this?	
18.04.02	In what year did you last do this?	
18.04.03	For about how many months/years altogether did you do this job?	
18.04.04	Where did you work? (Location)	
18.04.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.04.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

18.04.07 How often did you wear a hat?

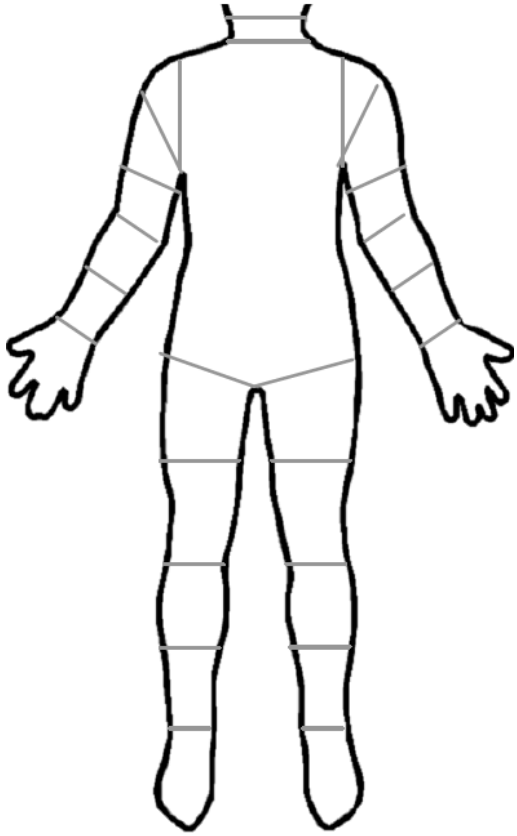
- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

18.04.08 What type of hat do you wear when you are working outdoor?

- ☐ None
- ☐ 
- ☐ 
- ☐ Other (please specify) _____

- ☐ 
- ☐ 
- ☐ 

18.04.09 What area of your body is covered with clothing when you are working outdoor?



18.04.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.05 *I would like you to think about your 5th job*

18.05.01	In what year did you first do this?	
18.05.02	In what year did you last do this?	
18.05.03	For about how many months/years altogether did you do this job?	
18.05.04	Where did you work? (Location)	
18.05.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.05.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

18.05.07 How often did you wear a hat?

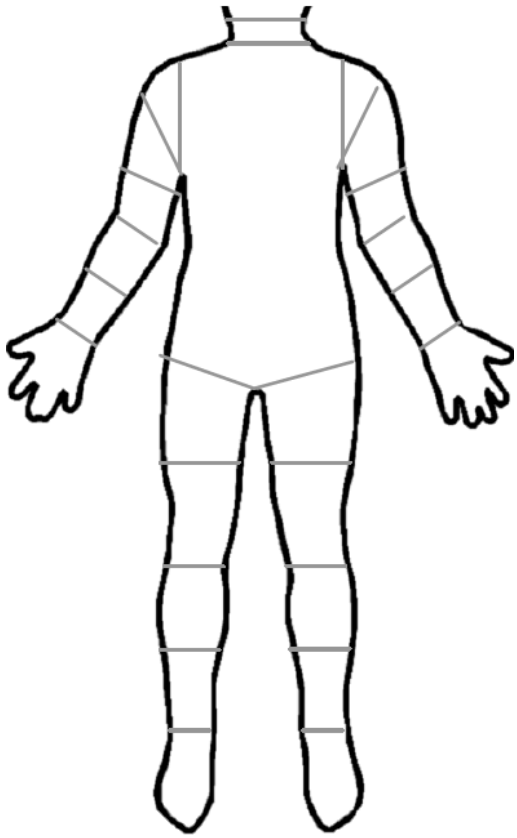
- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

18.05.08 What type of hat do you wear when you are working outdoor?

- ☐ None
- ☐ 
- ☐ 
- ☐ Other (please specify) _____

- ☐ 
- ☐ 
- ☐ 

18.05.09 What area of your body is covered with clothing when you are working outdoor?



18.05.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.06 *I would like you to think about your 6th job*

18.06.01	In what year did you first do this?	
18.06.02	In what year did you last do this?	
18.06.03	For about how many months/years altogether did you do this job?	
18.06.04	Where did you work? (Location)	
18.06.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.06.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

18.06.07 How often did you wear a hat?

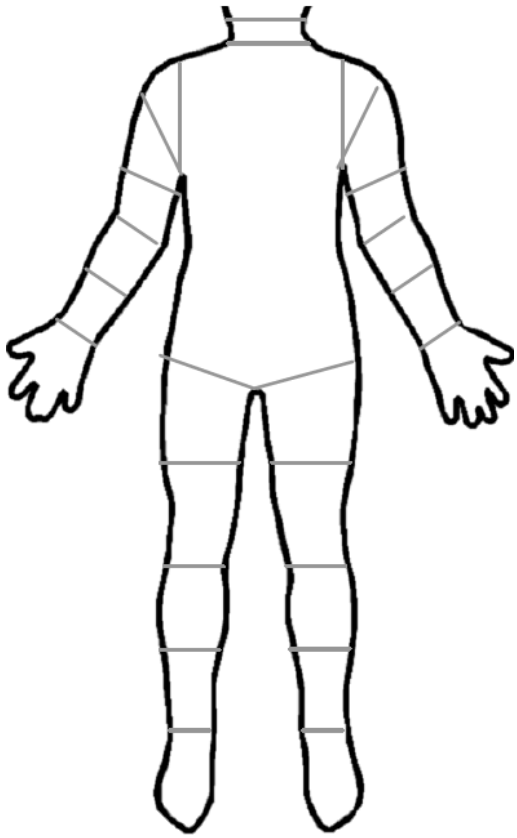
- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

18.06.08 What type of hat do you wear when you are working outdoor?

- ☐ None
- ☐ 
- ☐ 
- ☐ Other (please specify) _____

- ☐ 
- ☐ 
- ☐ 

18.06.09 What area of your body is covered with clothing when you are working outdoor?



18.06.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.07 *I would like you to think about your 7th job*

18.07.01	In what year did you first do this?	
18.07.02	In what year did you last do this?	
18.07.03	For about how many months/years altogether did you do this job?	
18.07.04	Where did you work? (Location)	
18.07.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.07.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

18.07.07 How often did you wear a hat?

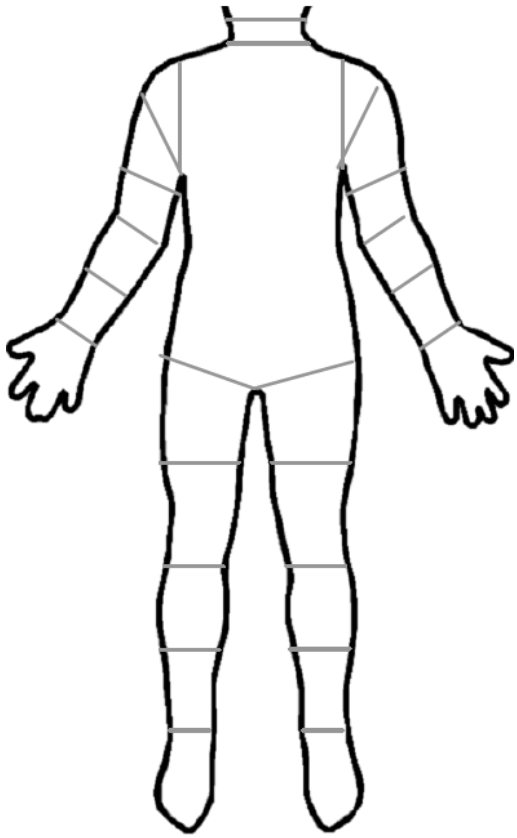
- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

18.07.08 What type of hat do you wear when you are working outdoor?

- ☐ None
- ☐ 
- ☐ 
- ☐ Other (please specify) ☐

- ☐ 
- ☐ 
- ☐ 

18.07.09 What area of your body is covered with clothing when you are working outdoor?



18.07.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.08 *I would like you to think about your 8th job*

18.08.01	In what year did you first do this?	
18.08.02	In what year did you last do this?	
18.08.03	For about how many months/years altogether did you do this job?	
18.08.04	Where did you work? (Location)	
18.08.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.08.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

18.08.07 How often did you wear a hat?

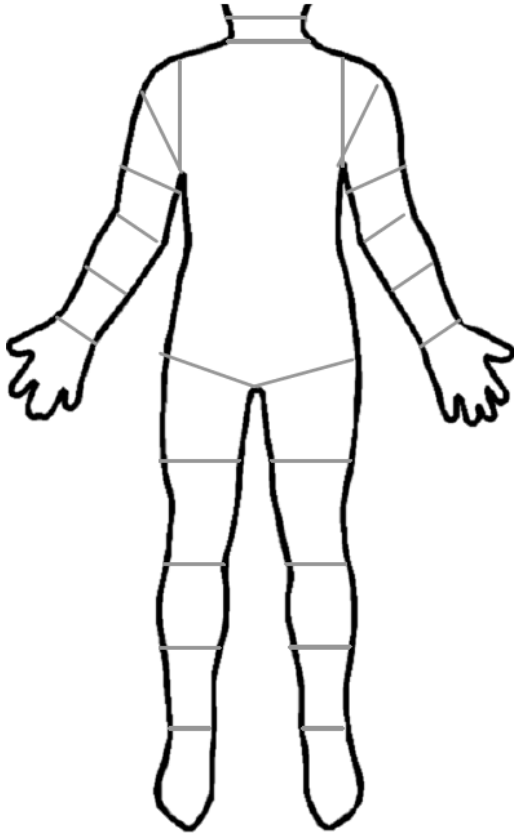
- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

18.08.08 What type of hat do you wear when you are working outdoor?

- ☐ None
- ☐ 
- ☐ 
- ☐ Other (please specify) _____

- ☐ 
- ☐ 
- ☐ 

18.08.09 What area of your body is covered with clothing when you are working outdoor?



18.08.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.09 *I would like you to think about your 9th job*

18.09.01	In what year did you first do this?	
18.09.02	In what year did you last do this?	
18.09.03	For about how many months/years altogether did you do this job?	
18.09.04	Where did you work? (Location)	
18.09.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.09.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

18.09.07 How often did you wear a hat?

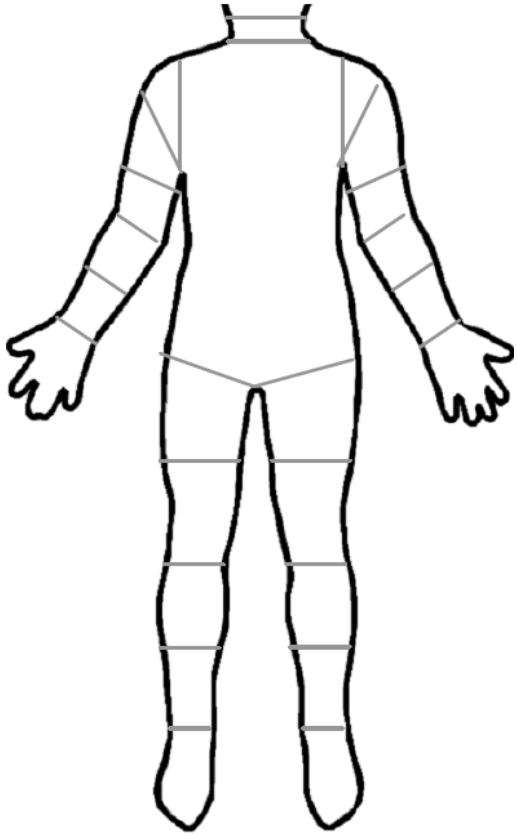
- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

18.09.08 What type of hat do you wear when you are working outdoor?

- ☐ None
- ☐ 
- ☐ 
- ☐ Other (please specify) _____

- ☐ 
- ☐ 
- ☐ 

18.09.09 What area of your body is covered with clothing when you are working outdoor?



18.09.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

18.10 *I would like you to think about your 10th job*

18.10.01	In what year did you first do this?	
18.10.02	In what year did you last do this?	
18.10.03	For about how many months/years altogether did you do this job?	
18.10.04	Where did you work? (Location)	
18.10.05	How much time did you spend outdoors between 9 am and 5 pm in this job on weekdays? By outdoors I mean outside and not under any shade	
18.10.06	How much time did you spend outdoors between 9 am and 5 pm in this job on weekends?	

18.10.07 How often did you wear a hat?

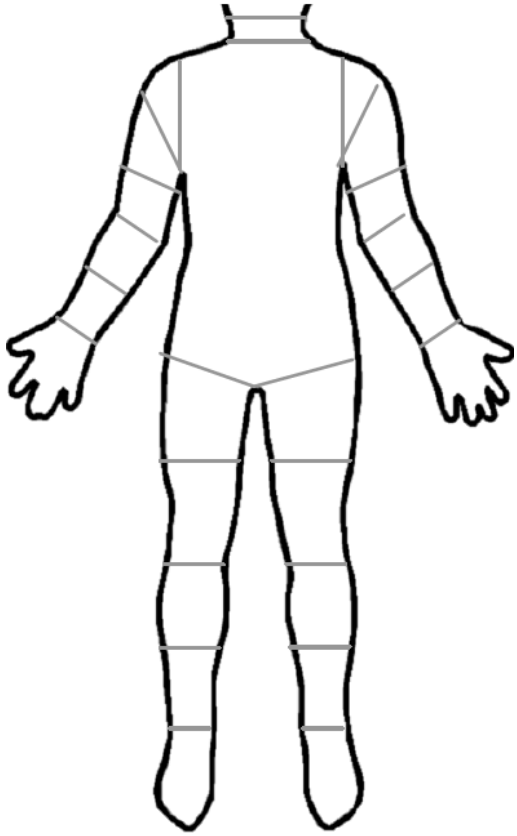
- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

18.10.08 What type of hat do you wear when you are working outdoor?

- ☐ None
- ☐ 
- ☐ 
- ☐ Other (please specify) _____

- ☐ 
- ☐ 
- ☐ 

18.10.09 What area of your body is covered with clothing when you are working outdoor?



18.10.10 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

Recreational sunlight exposure history

19.01 *In the year that you turned 10*

19.01.01	How much time did you usually spend outdoors between 9am and 5pm on school days?	
19.01.02	And between 9am and 5pm on weekends?	
19.01.03	And between 9am and 5pm on school holidays?	
19.01.04	How many weeks holiday did you take?	

19.01.05 What kind of activities did you do during your holidays?

	Beach or waterside activities i.e. swimming, surfing, walking, sunbathing or pier or beach fishing
	Any outdoor swimming pool activities i.e. swimming or sunbathing
	Any sunbathing other than at the pool or beach
	Sailing, boating, windsurfing, water skiing or fishing from a boat
	Gardening or yard work
	Walking, hiking or jogging
	Anytime spend outdoors with no special activities
	Any outdoor sports
	Other (please specify)

19.01.06 How many hours did you usually spend outdoors between 9am and 5pm during these activities?

19.01.07 How often did you wear a hat?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

19.01.08 How often did you wear sunscreen with a high protection factor?

☐	Always or almost always
☐	Not always but more than half the time
☐	About half the time
☐	Less than half the time
☐	Never or hardly ever

19.02 *In the year that you turned 20*

19.02.01	How much time did you usually spend outdoors between 9am and 5pm on school days?	
19.02.02	And between 9am and 5pm on weekends?	
19.02.03	And between 9am and 5pm on school holidays?	
19.02.04	How many weeks holiday did you take?	

19.02.05 What kind of activities did you do during your holidays?

	Beach or waterside activities i.e. swimming, surfing, walking, sunbathing or pier or beach fishing
	Any outdoor swimming pool activities i.e. swimming or sunbathing
	Any sunbathing other than at the pool or beach
	Sailing, boating, windsurfing, water skiing or fishing from a boat
	Gardening or yard work
	Walking, hiking or jogging
	Anytime spend outdoors with no special activities
	Any outdoor sports
	Other (please specify)

19.02.06 How many hours did you usually spend outdoors between 9am and 5pm during these activities?

19.02.07 How often did you wear a hat?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

19.02.08 How often did you wear sunscreen with a high protection factor?

- [ ] Always or almost always
- [ ] Not always but more than half the time
- [ ] About half the time
- [ ] Less than half the time
- [ ] Never or hardly ever

19.02.09 At what age did you leave school? (If before age 20, ask about regular outdoor leisure activities?)

19.02.09.01 On average, how many outdoor leisure activities did you regularly do between 9am and 5pm?

19.02.09.02 What kind of activities did you do?

- [ ] Beach or waterside activities i.e. swimming, surfing, walking, sunbathing or pier or beach fishing
- [ ] Any outdoor swimming pool activities i.e. swimming or sunbathing
- [ ] Any sunbathing other than at the pool or beach
- [ ] Sailing, boating, windsurfing, water skiing or fishing from a boat
- [ ] Gardening or yard work
- [ ] Walking, hiking or jogging
- [ ] Anytime spend outdoors with no special activities
- [ ] Any outdoor sports
- [ ] Other (please specify)

19.02.09.03 How many hours did you usually spend outdoors between 9am and 5pm during these activities?

19.02.09 How often did you wear a hat?

.04

☐	Always or almost always
☐	Not always but more than half the time
☐	About half the time
☐	Less than half the time
☐	Never or hardly ever

19.02.09 How often did you wear sunscreen with a high protection factor?

.05

☐	Always or almost always
☐	Not always but more than half the time
☐	About half the time
☐	Less than half the time
☐	Never or hardly ever

19.03 *In the year that you turned 30*

19.03.01 On average, how many outdoor leisure activities did you regularly do between 9am and 5pm? [ ]

19.03.02 What kind of activities did you do?

- [ ] Beach or waterside activities i.e. swimming, surfing, walking, sunbathing or pier or beach fishing
- [ ] Any outdoor swimming pool activities i.e. swimming or sunbathing
- [ ] Any sunbathing other than at the pool or beach
- [ ] Sailing, boating, windsurfing, water skiing or fishing from a boat
- [ ] Gardening or yard work
- [ ] Walking, hiking or jogging
- [ ] Anytime spend outdoors with no special activities
- [ ] Any outdoor sports
- [ ] Other (please specify) [ ]

19.03.03 How many hours did you usually spend outdoors between 9am and 5pm during these activities? [ ]

19.03.04 How often did you wear a hat?

- [ ] Always or almost always
- [ ] Not always but more than half the time
- [ ] About half the time
- [ ] Less than half the time
- [ ] Never or hardly ever

19.03.05 How often did you wear sunscreen with a high protection factor?

☐	Always or almost always
☐	Not always but more than half the time
☐	About half the time
☐	Less than half the time
☐	Never or hardly ever

19.04 *In the year that you turned 40*

19.04.01 On average, how many outdoor leisure activities did you regularly do between 9am and 5pm?

19.04.02 What kind of activities did you do?

- ☐ Beach or waterside activities i.e. swimming, surfing, walking, sunbathing or pier or beach fishing
- ☐ Any outdoor swimming pool activities i.e. swimming or sunbathing
- ☐ Any sunbathing other than at the pool or beach
- ☐ Sailing, boating, windsurfing, water skiing or fishing from a boat
- ☐ Gardening or yard work
- ☐ Walking, hiking or jogging
- ☐ Anytime spend outdoors with no special activities
- ☐ Any outdoor sports
- ☐ Other (please specify)

19.04.03 How many hours did you usually spend outdoors between 9am and 5pm during these activities?

19.04.04 How often did you wear a hat?

- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

19.04.05 How often did you wear sunscreen with a high protection factor?

	Always or almost always
	Not always but more than half the time
	About half the time
	Less than half the time
	Never or hardly ever

19.05 *In the year that you turned 50*

19.05.01 On average, how many outdoor leisure activities did you regularly do between 9am and 5pm?

19.05.02 What kind of activities did you do?

- ☐ Beach or waterside activities i.e. swimming, surfing, walking, sunbathing or pier or beach fishing
- ☐ Any outdoor swimming pool activities i.e. swimming or sunbathing
- ☐ Any sunbathing other than at the pool or beach
- ☐ Sailing, boating, windsurfing, water skiing or fishing from a boat
- ☐ Gardening or yard work
- ☐ Walking, hiking or jogging
- ☐ Anytime spend outdoors with no special activities
- ☐ Any outdoor sports
- ☐ Other (please specify)

19.05.03 How many hours did you usually spend outdoors between 9am and 5pm during these activities?

19.05.04 How often did you wear a hat?

- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

19.05.05 How often did you wear sunscreen with a high protection factor?

☐	Always or almost always
☐	Not always but more than half the time
☐	About half the time
☐	Less than half the time
☐	Never or hardly ever

19.06 *In the year that you turned 60*

19.06.01 On average, how many outdoor leisure activities did you regularly do between 9am and 5pm? [ ]

19.06.02 What kind of activities did you do?

- [ ] Beach or waterside activities i.e. swimming, surfing, walking, sunbathing or pier or beach fishing
- [ ] Any outdoor swimming pool activities i.e. swimming or sunbathing
- [ ] Any sunbathing other than at the pool or beach
- [ ] Sailing, boating, windsurfing, water skiing or fishing from a boat
- [ ] Gardening or yard work
- [ ] Walking, hiking or jogging
- [ ] Anytime spend outdoors with no special activities
- [ ] Any outdoor sports
- [ ] Other (please specify) [ ]

19.06.03 How many hours did you usually spend outdoors between 9am and 5pm during these activities? [ ]

19.06.04 How often did you wear a hat?

- [ ] Always or almost always
- [ ] Not always but more than half the time
- [ ] About half the time
- [ ] Less than half the time
- [ ] Never or hardly ever

19.06.05 How often did you wear sunscreen with a high protection factor?

☐	Always or almost always
☐	Not always but more than half the time
☐	About half the time
☐	Less than half the time
☐	Never or hardly ever

19.07 *In the year that you turned 70*

19.07.01 On average, how many outdoor leisure activities did you regularly do between 9am and 5pm? ☐

19.07.02 What kind of activities did you do?

- ☐ Beach or waterside activities i.e. swimming, surfing, walking, sunbathing or pier or beach fishing
- ☐ Any outdoor swimming pool activities i.e. swimming or sunbathing
- ☐ Any sunbathing other than at the pool or beach
- ☐ Sailing, boating, windsurfing, water skiing or fishing from a boat
- ☐ Gardening or yard work
- ☐ Walking, hiking or jogging
- ☐ Anytime spend outdoors with no special activities
- ☐ Any outdoor sports
- ☐ Other (please specify) ☐

19.07.03 How many hours did you usually spend outdoors between 9am and 5pm during these activities? ☐

19.07.04 How often did you wear a hat?

- ☐ Always or almost always
- ☐ Not always but more than half the time
- ☐ About half the time
- ☐ Less than half the time
- ☐ Never or hardly ever

19.07.05 How often did you wear sunscreen with a high protection factor?

☐	Always or almost always
☐	Not always but more than half the time
☐	About half the time
☐	Less than half the time
☐	Never or hardly ever

20 Have you ever been treated by a doctor for skin cancer?

- [ ] Yes
- [ ] No

21 What was the type of skin cancer?

- [ ] Basal cell carcinoma
- [ ] Squamous cell carcinoma
- [ ] Melanoma