



Solar ultraviolet radiation exposure of protection officers at a South African university

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**“NO MATTER HOW YOU FEEL, GET UP, DRESS UP, SHOW UP AND
NEVER GIVE UP” – REGINA BRETT**

PREFACE

This dissertation contains the following:

- **Chapter 1:** Introductory chapter with background, aims, objectives and hypotheses.
- **Chapter 2:** Literature review focusing on solar ultraviolet radiation, harmful and beneficial effects, factors affecting solar ultraviolet radiation exposure, protection measures, legislative requirements, and security guards' risks to solar ultraviolet radiation exposure.
- **Chapter 3:** Article – Solar ultraviolet radiation exposure of security guards at a South African university
- **Chapter 4:** Concluding chapter with a conclusion, hypotheses, limitations, recommendations, and recommendations for further studies.

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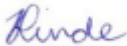

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AUTHORS CONTRIBUTIONS

NAME	CONTRIBUTION	APPROVAL
Ms M Combrink	<ul style="list-style-type: none"> • Planning of the study • Data collection • Writing all chapters • Analysis and interpretation of data 	
Ms MC Ramotsehoa	<ul style="list-style-type: none"> • Supervisor • Assisted with planning and design of study • Feedback and recommendations • Review of dissertation • Calibration of PSF badges • Analysis of data 	
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Dr DJ du Preez	<ul style="list-style-type: none"> • Assistance with calibration data and curve 	

ABSTRACT

Introduction Security guards face heightened risks of solar UVR exposure due to the predominantly outdoor nature of their work. The elevated ambient solar UVR levels in South Africa, particularly at the latitude of the study location in Potchefstroom, increase the likelihood of security guards experiencing various negative health effects associated with solar UVR exposure, ranging from sunburn to skin cancer. This study aimed to assess the personal solar UVR exposure on different anatomical areas, as well as the objective skin colour of participants, including constitutive and facultative skin. Additionally, the study investigated the behaviours and sun-related knowledge of security guards through a questionnaire and evaluated the protective capabilities of their uniform shirts.

Method Polysulphone film (PSF) badges were placed on the vertex-, on the shoulder-, under the uniform shirt and on the forearm of security guards working at a university in South Africa, North West Province, Potchefstroom, to measure solar UVR. Solar UVR exposure was monitored for eight days during both summer and winter seasons. A skin colorimeter was used to measure the Individual Topological Angle ($^{\circ}$ ITA) of facultative and constitutive skin colour of the participant group.

Results The vertex (top of the head) showed the highest exposure to solar ultraviolet radiation (UVR) during both summer (average = 1.869 J/m²) and winter (average = 1.481 J/m²). Significant differences in exposure levels were observed among various anatomical areas during both seasons, except for the forearm and under the shirt exposure during winter. Type IV (tan) was the most common constitutive skin colour, while Type V (brown) and Type VI (dark) were the predominant facultative skin colours. Only 18% of participants were familiar with what solar UVR is, while 50% reported wearing hats "sometimes" and 39% "always," indicating a need for enhanced knowledge and practices concerning sun protection. On average, uniform shirts blocked 34% of solar UVR during summer and 5% during winter, indicating that they offer some protection against solar UVR exposure for participants.

Conclusion Security guards do not receive high levels of solar UVR exposure. It is possibly due to security guards working in shaded areas such as security booths and awnings. Most security guards had constitutive skin that classified as tan or Type IV according to $^{\circ}$ ITA measurements.

Keywords Solar ultraviolet radiation, skin colour, security guards, PSF badges, sun behaviour and knowledge

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LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AOD	Aerosol optical depth
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
AS/NZS	Australian/New Zealand Standard
ASTM	American Society for Testing and Materials
BCC	Basal cell cancer
BDC	Brewer- Dobson Circulation
BSA	Body surface area
CANSA	Cancer Association of South Africa
CMM	Cutaneous malignant melanoma
DNA	Deoxyribonucleic acid
DoEL	Department of Labour and Employment
e. g	For example,
EN	European Standards
FST	Fitzpatrick skin types
GHG	Greenhouse gasses
GPF	Garment Protection Factor
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionising Radiation Protection
ISO	International Organization for Standardization

°ITA	Individual Topological Angle
MC1R	Melanocortin 1 receptor
NCR	National Cancer Registry in South Africa
NIR	Non-ionizing radiation
NMSC	Non-Melanoma Skin Cancer
NO	Nitric monoxide
NWU	North-West University
O	Symbol for oxygen
O ₂	Symbol for two bonded oxygen molecules
O ₃	Ozone (three bonded oxygen molecules)
ODS	Ozone depleting substances
OSSN	Ocular surface squamous neoplasia
PM	Particulate matter
PSF	Polysulphone film badges
ROS	Reactive oxygen species
SANS	South African National Standard
SAWS	South African National Weather Services
SCC	Squamous cell cancer
SCF	Skin Cancer Foundation
SP	Spectrophotometric testing
SPF	Sun protection factors
SZA	Solar zenith angle

TOC	Total ozone column
UPF	Ultraviolet protection factor
USA	United States of America
UV	Ultraviolet
UVA	Ultraviolet A
UVB	Ultraviolet B
UVC	Ultraviolet C
UVI	Ultraviolet Index
UVR	Ultraviolet radiation
VOC	Volatile organic compounds
WHO	World Health Organisation
ZAR	South African rand

LIST OF STANDARD UNITS

am	ante meridian
J/m ²	Joules per metre squared
MED	Minimal erythemat dose
nm	nanometres
pm	post meridian
SED	Standard erythemat dose
μW/cm ²	Micro-Watts per centimetre squared
°	Degree
°C	Degree Celsius
%	Percentage
+	Plus
-	Minus
±	Plus, or minus
<	Less than
>	greater than
≤	Less than or equal to
≥	Greater than or equal to

CHAPTER 1 INTRODUCTION

1.1 Background and problem statement

Ultraviolet radiation (UVR), generated by the sun, is one of the radiation types found in the electromagnetic spectrum consisting of three wavelength categories: Ultraviolet A (UVA) (400 - 315 nm), Ultraviolet B (UVB) (280 – 315 nm) and Ultraviolet C (UVC) (280 – 100 nm). These three wavelength categories are presented separately because they exert different energy and penetrating abilities. As a result, the UVA and UVB wavelength reaches Earth while the UVC wavelength is filtered out by the ozone layer (Jablonski, 2013). Artificial sources of the UVC, such as arc welding, are present on Earth which may also lead to exposure to this type of UVR (ICNIRP, 2010)

While the positive impacts of exposure to solar UVR on human health, such as the production of vitamin D, an essential nutrient that supports bone health, immune function, and overall well-being, are widely recognized, excessive levels of solar UVR exposure can also lead to numerous adverse health effects. (Diffey, 2020). Effects range from acute such as sunburn, to chronic like increased risk of developing different types of skin cancer and formation of cataracts in the eyes (Gallagher and Lee, 2006; Ivanov *et al.*, 2017; Peters *et al.*, 2019)

Different factors should be considered when assessing solar UVR exposure such as meteorological, occupational, and personal/individual factors because these factors clearly affect solar UVR exposure, resulting in an increase or decrease in exposure. Examples of these factors are as follows; meteorological factors such as cloud coverage and albedo, occupational factors such as type of work and area where work is performed and personal/individual factors such as skin pigmentation and behaviour (Lucas *et al.*, 2019).

When examining solar UVR exposure, geographical location is an important factor to consider due to increase in solar UVR exposure occurring in locations closer to the equator. Geographical locations closer to the equator indicates that the sun's rays have a shorter path through the atmosphere, resulting in less absorption of solar UVR. Therefore, areas with lower latitudes (less than 30°) and higher altitude (10% increase of solar UVR levels with every 1000 m increase in altitude) are more likely to receive higher solar UVR exposure (ICNIRP, 2010). South Africa lies in the southern hemisphere with a mid-latitude (22° to 34° S) (Wright *et al.*, 2019), where the geographic area of the North-West province (study location) can be described as highveld (Encyclopaedia Britannica, 2024). Some studies indicate that high levels of ambient solar UVR (Lucas *et al.*, 2016) and personal solar UVR exposure (Hadjee, 2020)

are experienced through most of the South African continent year-round, indicating that this is a prime location for high solar UVR exposure to occur (Makgabutlane and Wright, 2014).

Moreover, it's essential to acknowledge that solar UVR exposure primarily affects the skin and eyes. While the eyes have a consistent susceptibility to solar UVR exposure, different skin colours exhibit varying degrees of susceptibility. Skin colour can differ not only between populations and individuals but also across different areas of the body due to various external factors. The constitutive skin colour is determined by genetics, whereas external factors such as hormonal changes and solar UVR exposure can affect facultative skin colour. Therefore, skin colour is a crucial factor to consider as solar UVR exposure influences facultative skin colour and may contribute to the development of pathological conditions not only of the skin but also of the eyes (Lucas *et al.*, 2016).

Certain anatomical regions may experience varying levels of exposure to solar UVR. Factors influencing this exposure include working position, the specific area where work is conducted, and clothing choices. For instance, an individual working in a crouching position may receive increased solar UVR exposure on their neck, as it is more likely to be directly facing the sun. However, wearing a wide-brimmed hat can mitigate this exposure by providing shade to the neck area, thus reducing the impact of solar UVR (Backes *et al.*, 2016). Furthermore, the state of knowledge influences the perception of risk among outdoor workers affects both their attitudes and behaviours regarding exposure to solar UVR. If outdoor workers are only cognizant of the short- or long-term health effects resulting from solar UVR exposure, their assessment of the severity of these effects may be incomplete. Consequently, they may be more inclined to engage in risky behaviours rather than adopting preventive or protective measures, such as working in shaded areas or using hats and sunscreen (Rother *et al.*, 2020; Hault *et al.*, 2016). Therefore, exposure levels to solar UVR are influenced by both occupational and behavioural factors.

Over the years, many instruments were developed for measuring solar UVR exposure due to research indicating that the thinning of the ozone layer is leading to more solar UVR exposure reaching Earth (Diffey, 2020; Osman and Omar, 2016). As a result, many people have become aware of the negative health effects that may be caused by solar UVR exposure. Nevertheless, the lack of legislation regarding work environments and the personal complacency regarding health and safety cause solar UVR exposure to be overlooked. Undoubtedly, the lack of legislation and research regarding solar UVR exposure in South Africa remain a problem in the evaluation of solar UVR by occupational health professions (Wright *et al.*, 2017). However, a draft regulation for physical agents was released by the South African Department of Employment and Labour for comment in 2022, but this regulation only

defines solar UVR exposure as optical radiation and only includes an Occupational Exposure Limit (OEL) for the UVC wavelength 270 nm – 8-hours exposure of 0.1 $\mu\text{W}/\text{cm}^2$ for the skin and eyes, excluding the UVA and UVB wavelengths (Department of Employment and Labour, 2022). Additionally, the ICNIRP guidelines on protection of workers against UVR are available and state that a maximum human biologically efficient radiant exposure range for the eyes and skin should range between 1 to 1.3 standard erythemal dose (SED) or 30 J/m^2 (ICNIRP, 2010). These guidelines for protection apply to exposure to solar UVR and artificial sources of UVR (ICNIRP, 2010).

Previous studies relating to solar UVR exposure in South Africa yielded different results that may have been due to studies focusing on different occupational groups with different work activities, different geographical areas, seasons, and time of day (Makgabutlane and Wright, 2014; Nkogatse *et al.*, 2018; Hadjee, 2020; Linde *et al.*, 2020). These studies focused on different groups of workers such as general outdoor workers, car guards and farmworkers and found variation in seasonal exposure where autumn and summer seasons indicated high levels of solar UVR exposure. Further elaboration can be found in Chapter two under occupational exposure to solar UVR in South Africa. As a result, variations in data indicate that more research is needed in different provinces in South Africa. But the fact remains that South Africans are at risk to develop adverse health effects and this fact reveals the need for more research in South Africa (Rother *et al.*, 2020).

Security guards at educational institutions are exposed to various occupational stressors, including noxious exposures such as noise and extreme temperatures, as acknowledged by Jovanović *et al.* (2020). However, there is no mention of solar UVR exposure. It is important to note that solar UVR exposure should be considered, especially for day shift security guards, as their activities may put them at risk of excessive exposure to solar UVR. The duties of security guards, also known as protection officers, employed at universities' protection services or security units may include but are not limited to the following duties: traffic and access control at main access gates; protection of people and buildings within the campus, and prevention of criminal activities occurring on campus (NWU, 2021). Most of these duties may be intermittent based on duties that need to be performed on the day or dependent on where a security guard is assigned to work for the day (outdoors or indoors). Notably, Grandahl *et al.* (2017) acknowledged solar UVR exposure among outdoor workers as an occupational health problem that has been neglected for too long. Therefore, an urgent need for further research regarding different outdoor occupational groups (Hault *et al.*, 2016) is noted as well as for personal solar UVR exposure of outdoor workers in different South African

provinces other than Gauteng where research has already been conducted by Makgabutlane and Wright, (2014).

1.2 Aims and objectives.

The general aim of this study is to evaluate the occupational solar UVR exposure of protection officers at a South African university campus.

The general aim of this study was achieved through the following objectives:

- Quantification of solar UVR exposure on different anatomical sites of security guards using PSF badges during summer and winter.
- Measuring of individual typology angle (°ITA) of participants' facultative and constitutive skin using skin bioengineering methods
- Determining the amount of solar UVR penetrates uniforms' shirts of security guards using PSF badges.
- Determining the extent of security guards' knowledge of solar UVR and protective measures by making use of a questionnaire.

1.3 Hypotheses

Hypothesis 1

Hadjee, (2020) found that car guards working at a mall parking lot in Potchefstroom, North West province were exposed to higher personal levels of solar UVR in summer than in winter. Wright *et al.* (2019) calculated South Africa's average Ultraviolet Index (UVI) and found that summer UVI levels averaged around ten and winter UVI levels averaged around five, indicating that a higher level of solar UVR reaches Earth's surface during the summer months. Therefore, it was hypothesised that personal solar UVR exposure of security guards are higher during summer than winter.

Hypothesis 2

Determination of skin pigmentations is an important factor to consider (Linde *et al.*, 2020) because this will indicate the risk and reaction of the skin to solar UVR exposure. Sharma *et al.* (2018) found that the FST classification system is less accurate when used for darker skin types and objective skin phototyping tools are useful tools when determining skin colour. Therefore, it was hypothesised that there will be a difference between facultative and constitutive skin colour similar to what was found by Linde *et al.* (2020) among farmworkers in the Limpopo province.

Hypothesis 3

Studies have shown that many factors influence photoprotective abilities of clothing items such as fabric structure and type, colour, fit as well as laundering (Boothby-Schoemaker *et al.*, 2022). Additionally, it has been proven that textiles provide significant protection against solar UVR through blocking out up to 99% of solar UVB exposure (Berry *et al.*, 2022). However, conditions of protection of the shirts of officers' uniforms may be compromised due to everyday wear and tear. Therefore, it was hypothesised that some portion of the solar UVR will travel through the clothing to the skin underneath the clothing and the uniform shirt will not provide effective protection.

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CHAPTER 2 LITERATURE STUDY

2.1 Introduction

Solar ultraviolet radiation (UVR) is an ever-present factor in everyday life (Garmyn *et al.*, 2018). Therefore, exposure is difficult to avoid and may have beneficial or detrimental effects on human health (Aydogan, 2014). Exposure to solar UVR is recognised to occur in occupational settings such as agriculture and construction sectors (Linde *et al.*, 2020; Modenese *et al.*, 2020). In addition, research suggests that non-occupational exposure to solar UVR has been increasing and occurs regularly when spending leisure time outside, attending or participating in sporting events and performing subsistence or household agricultural activities (Allen *et al.*, 2020; Wright and Norval, 2021). Although most of the South African population are less vulnerable when exposed to solar UVR because of inherent protection provided by the skin's melanin content, the fact remains that all occupational groups and especially outdoor occupational groups in South Africa should be protected against solar UVR exposure (Wright *et al.*, 2017). Protective measures are necessary due to the high levels of ambient solar UVR exposure that occur in both South Africa and the rest of the African continent, all year round (Lucas *et al.*, 2016; Wright *et al.*, 2019).

The literature study in this section will be focusing on the following aspects: solar UVR and factors affecting solar UVR exposure; benefits and harmful effects of solar UVR on human health; different methods of photoprotection; national and international solar UVR legislation and guidelines; occupational solar UVR exposure, and measurements thereof as well as security guards' risks associated with solar UVR exposure.

2.2 Characteristics of solar ultraviolet radiation

The electromagnetic spectrum describes different types of radiation and their characteristics, including UVR as a form of non-ionizing radiation (Aydogan, 2014). Sunlight is the biggest natural source of UVR and is a biologically noteworthy part of radiation (Garmyn *et al.*, 2018). Artificial sources of UVR include specialised lamps and open arc processes such as sunbed lamps and arc welding (Filon *et al.*, 2018; ICNIRP, 2020). Different waveband categories exist for UVR namely Ultraviolet A (UVA) (400-315 nm), Ultraviolet B (UVB) (315-280 nm) and Ultraviolet C (UVC) (280-100 nm). Each waveband exerts different biological effects on humans because UVR penetrates skin and tissue in a wavelength-dependent manner (Makgabutlane and Wright, 2014).

The UVC waveband poses the biggest risk to human health because the UVC wavelength is the shortest with the highest amount of irradiance and photon energy (Osman and Omar, 2016). However, when solar UVR travels to Earth's atmosphere, it is widely accepted that all UVC and most of the UVB waves are usually absorbed/blocked by the ozone (O₃) layer. Nevertheless, this statement has been disputed in recent research which found that solar UVR ranging from 200- 400 nm do reach Earth's surface (Herndon *et al.*, 2018). Therefore, the whole solar UVR waveband may pass through the O₃ layer to reach Earth's surface. Hence, natural, and artificial sources of UVC on Earth may consequently lead to exposure and affect human health (Gies *et al.*, 2014a). The UVA and UVB waveband of solar UVR reaches Earth with little or no changes, where the UVA waveband (95%) is the most abundant form of solar UVR that reaches Earth's surface and UVB reaches Earth in smaller amounts (5%) (IARC, 2018).

Human exposure to solar UVR can occur on Earth's surface in three ways namely, direct, scattering/diffusion, and reflection of solar UVR. Direct exposure to solar UVR results from waves that move directly from the outer atmosphere and reach Earth's surface with little change. Scattered or diffused solar UVR are solar UVR waves that travel through the atmosphere in various directions. These solar UVR waves diffuse to become less concentrated over an area. Reflection of solar UVR on the ground is dependent on the reflection properties (albedo) of surrounding objects and reflect from surfaces and objects (Gies *et al.*, 2014a).

2.3 Beneficial effects of solar UVR on human health

The most important beneficial effect of solar UVR on human health is the role it plays in the production of vitamin D in the human body (Diffey, 2020). This lipid soluble vitamin performs many roles in the human body to maintain homeostasis. These benefits include bone mineral homeostasis, skeletal integrity, regulation of calcium and phosphorus, regulation of cells, modulation of autoimmune diseases and positive effects on cardiovascular health (Neale and Lucas, 2014). Vitamin D deficiency may lead to diseases such as bone disease (for example, osteoporosis and rickets) and muscle weakness (Neale and Lucas, 2014). Lower levels of vitamin D have been identified as a risk factor in the development and progress of some types of cancers (e.g., bladder, colon, and skin) and in contrast, higher vitamin D levels are associated with increased survival rates for patients with certain types of cancer (cutaneous malignant melanoma (CMM), lymphoma and breast). Variations in geography, skin pigmentation and sunlight exposure have been identified as factors influencing vitamin D levels in humans (Khalid *et al.*, 2017).

However, many beneficial health effects are independent of vitamin D production, but it is difficult to determine which effects are mediated by solar UVR alone or include vitamin D (Juzeniene and Moan, 2012). Research has found that solar UVR exposure may have effects such as enhancing moods, pain relief and UVI-Induced nitric monoxide (NO) which may lead to protection of skin and enhancing cardiovascular health (Juzeniene and Moan, 2012). Hence, phototherapy have been used as a treatment for skin diseases dating back thousands of years ago. To demonstrate, different types of therapy are used such as heliotherapy that refers to treatment that uses natural solar UVR while phototherapy uses artificial UVR as treatment. These treatment methods have been effective for certain skin diseases such as psoriasis, vitiligo, and atopic dermatitis (Juzeniene and Moan, 2012).

2.4 Harmful effect of solar UVR on human health

The skin is considered the biggest organ of the human body and provides the body with many essential physiological functions, one of which is being a protective barrier between the body and the environment. Therefore, it is very important to keep the skin in a healthy condition (Martini *et al.*, 2012). Although beneficial effects of solar UVR exposure on human health are well established, high levels of solar UVR exposure may also have many detrimental health effects (Diffey, 2020). The non-ionizing nature of solar UVR limits direct effects of solar UVR exposure to the eyes and skin of the human body and indirect effects occur for other systems such as the immune system (Paz *et al.*, 2014). Additionally, optical radiation bands such as solar- and artificial UVR, may pass through the ocular tissue to contribute to visual perception and may also lead to damaging effects of the eye and its structures. Overall, acute exposure to solar UVR has a greater effect on the skin than the eyes but chronic solar UVR exposure creates an increased risk that may lead to more detrimental health effects on both the skin and eyes (Ivanov *et al.*, 2017).

2.4.1 Mechanisms occurring in the skin and eyes leading to damaging effects

Exposure to solar UVR activates the intrinsic photoprotection of the human body, leading to increased skin pigmentation and thickening of the stratum corneum. However, after solar UVR exposure has stopped, these effects start to vanish after four to eight weeks. Due to continuous long-term solar UVR exposure of outdoor workers, the ability to return to pre-exposure conditions are inhibited (Schmalwieser *et al.*, 2021). Therefore, when the intrinsic photoprotection of the skin is not enough, solar UVR exposure may lead to damaging effects on the skin. These damaging effects can occur through direct and indirect mechanisms in the body that are very complex but can be basically / straightforwardly explained. Exposure to solar UVR can directly cause damage to deoxyribonucleic acid (DNA) because DNA can

absorb solar UVR, and this causes DNA strands to become weak and may lead to strand rupturing. Therefore, negative effects occur e.g., an increase in skin lesions. Indirect mechanisms in the body can occur via other biochromes that form reactive oxygen species (ROS) that may cause effects on cellular levels and lead to DNA modification and DNA strand breakage (Solano, 2020).

In the eyes, damage can occur via many mechanisms e.g., photothermal, photomechanical, photochemical, and photosensitisation. The photochemical mechanism is the most relevant way tissue damage is caused upon exposure to solar UVR. Photochemical damage can occur in three ways: ablation, photo-oxidative damage, and photosensitisation reaction. The underlying principle is that cellular damage occurs because of molecules that hold too much energy and interact with other molecules or tissue. First and foremost, damage can occur via ablation, this happens when high-energy UVR photons cause breakage of chemical bonds of molecules in ocular tissue. Secondly, photo-oxidative damage occurs when light interacts with chromophores in ocular tissue that may cause chemical changes in these molecules. Finally, photosensitisation occurs when oxygen and photosensitiser/ photosensitising molecules absorb UVR, leading to formation of ROS and production of other free radicals. Oxygenated products are formed, and oxidative injury occurs in the ocular tissue (Ivanov *et al.*, 2017).

2.4.2 Solar UVR effects on the skin

Exposure to solar UVR has effects on the epidermis and dermis layers of the skin as well as the tissue and cells within each layer due to solar UVR's low penetration capacity (Paz *et al.*, 2014). Exposure to UVB may cause burning sensations, irritation, blisters and reddening of skin (erythema) and may cause skin colour to darken over time in reaction to solar UVR exposure as melanocytes produce melanin causing the skin to become darker (McKnight *et al.*, 2021). The UVA waveband affects deeper skin layers, tissue and blood vessels that may lead to premature aging of the skin through weakening elastin and collagen fibres (Sample and He, 2017).

2.4.3 Skin cancer

Solar UVR is an environmentally abundant stressor that may be a contributor in rising levels of skin cancer incidents due to solar UVR's group one classification (carcinogenic to humans) since 2012 along with UVR from welding and UVR-emitting tanning devices (D'Orazio *et al.*, 2013; IARC, 2018). Therefore, solar UVR (waveband UVA, UVB and UVC) causes different types of cancer in humans when exposed such as CMM, squamous cell cancer (SCC) and

basal cell cancer (BCC) (IARC, 2018). Associations have also been observed between solar UVR exposure and cancer of the lips, conjunctival SCC and ocular CMM (IARC, 2018).

Skin cancer have two main categories namely Non-melanoma Skin Cancer (NMSC) and CMM (Martini *et al.*, 2012). The main difference between these two categories of skin cancer is which type of cells the neoplasia originates in, with NMSC neoplasia occurring in the basal, squamous and Merkel cells while CMM neoplasia only occurs in the melanocytes.

The most common type of NMSC is BCC which develops in the stratum basal and occurs on different body sites such as the face, neck, and trunk (Martini *et al.*, 2012). Basal cell cancer appears as a lump or sore on the skin that does not heal, it grows slowly but can be identified and treated because it is confined to the primary site of origin (D’Orazio *et al.*, 2013; Whiteman and Olsen, 2020). It has been noted that early childhood sun exposure, intermittent- and cumulative sun exposure could lead to the development of BCC. The other type of NMSC is SCC which is restricted to occur in areas that are exposed to solar UVR, such as the face, ears, and arms. Outdoor workers or people frequently exposed to solar UVR are more at risk to develop this type of NMSC because cumulative solar UVR exposure plays a big role in the development of SCC (Baldi *et al.*, 2014). Merkel Cell Carcinoma (MCC) is a rare and aggressive form of skin cancer but, recent research has found that this type of cancer may be caused by a virus (Merkel cell polyomavirus), but it is considered skin cancer because it forms within the Merkel cells in the epidermis of the skin (Whiteman and Olsen, 2020).

Cutaneous malignant melanoma is less common than NMSC but can be more dangerous to health because it can metastasise through the lymphatic system. Cutaneous malignant melanoma appears as an atypical mole (nevi) on the skin and raises suspicion when it changes colour, shape, and surface (how it feels). However, CMM often occurs on the back, legs, arms, and head and could spread and grow quickly. Therefore, it is important to educate people on how to evaluate if they should see a doctor regarding a suspicious mole or skin lesion (Whiteman and Olsen, 2020). A simple ABCD acronym may be used to educate people regarding atypical moles or skin lesions, where A stands for asymmetry, B stand for border, C stands for colour and D stand for diameter. If the mole or skin lesion has any change regarding any of the ABCD acronym’s components, seeing a doctor would be advisable (Martini *et al.*, 2012).

Skin cancer incidents are monitored by the National Cancer Registry in South Africa (NCR) with the most recent data analysed for 2019. The data shows that males and females classified as Asian, Black, Coloured, and White are diagnosed with BCC, SCC, and CMM (NCR, 2021). An all-population group sample of females and males shows that males have higher NMSC

and CMM rates than females in the year, 2019 (NCR, 2021). This could be due to females performing more protective behaviour than males e.g., applying sunscreen. In contrast, other research has shown that females display more risk-behaviour than men such as tanning (IARC, 2018). A study estimated that the cost of diagnosis and treatment of skin cancer in 2015 was around 92.5 million South African rand (ZAR) (Gordon *et al.*, 2016; Wright *et al.*, 2019). These statistics show that the multi-ethnic population of South Africa are all vulnerable to solar UVR related diseases or health problems and could develop NMSC or CMM, especially outdoor workers (Wright and Norval, 2021). Consequently, the cost of managing skin cancer in South Africa may be more reasonable if bigger efforts are made to support sun-protection awareness and skin cancer prevention programs (Gordon *et al.*, 2016).

2.4.4 Ocular effects of solar UVR exposure

In the eyes, solar UVR contributes to visual perception, but it may also lead to many damaging effects when excessive unprotected exposure occurs (Ivanov *et al.*, 2017). The main structures of the eyes that may be acutely or chronically affected by solar UVR exposure are the cornea, the lens, and the retina (Ivanov *et al.*, 2017). Exposure to UVB may lead to the formation of cataracts on the lens of the eye (white/cloudy areas) that may cause impairment of vision and blindness (Ivanov *et al.*, 2017). In addition, exposure to direct UVA or solar UVR from highly reflective objects may cause temporary photokeratitis (also known as welders flash or snow blindness). Photokeratitis can be described as inflammation of the corneal epithelium and symptoms like tears, pain and twitching of eyes may occur (Coroneo and Dain, 2014). The retina can also be affected by UVA exposure, leading to macular degradation that may cause blurred vision and vision loss (Backes *et al.*, 2018a). Another ocular disease with strong correlation between solar UVR exposure and disease development is climatic droplet keratopathy (CDK) that affects the corneal stroma of the eye (Backes *et al.*, 2018a).

Chronic exposure to solar UVR leads to degradation of the corneal stroma and the tissue becomes less convex and more oval with fluid build-up in this area evoking irritation of the eyes, blurred and decreased vision and light sensitivity (Yam and Kwok, 2014). Additional conditions such as pterygium can occur which can be described as hyperplasia of the bulbar conjunctiva over the cornea and may bring about symptoms including irritation of the eyes and blurred vision (Yam and Kwok, 2014). Furthermore, the formation of eyelid malignancies (BCC and SCC) can also occur on the skin of the eyes (Yam and Kwok, 2014). However, insufficient evidence exists to classify other ocular diseases including pinguecula, nuclear and posterior subcapsular cataract, ocular surface squamous neoplasia (OSSN) and ocular CMM as ocular diseases related to solar UVR exposure (Yam and Kwok, 2014).

2.4.5 Systemic effects

Systemic effects do occur for distant organs that are not directly exposed to solar UVR. As a result, these effects should also be considered when looking at solar UVR exposure (Paz *et al.*, 2014). Ultraviolet radiation-induced immunosuppression occurs when a defective immune response is triggered by UVR exposure eventually leading to loss of immunosurveillance starting in the skin and then affecting the rest of the body. Ultraviolet radiation-induced immunosuppression may play a role in the development of skin carcinogenesis through causing alterations to immune cells, molecular changes and blocking the bodies' ability to react to the development of skin. Exposure to solar UVR doses above 0.5 minimal erythemal dose (MED) has shown to cause local inflammation and systemic immunosuppression (Maglio *et al.*, 2016).

2.5 Factors affecting solar UVR exposure

Many factors should be considered when focusing on solar UVR exposure because they have a combined influence on human solar UVR exposure (Lucas *et al.*, 2019). The importance of considering factors such as meteorological, occupational, environmental, and individual factors is highlighted in other studies that found these factors to have a large effect on personal solar UVR exposure results (Hault *et al.*, 2016; Lucas *et al.*, 2019).

2.5.1 Meteorological factors

Meteorological factors refer to any factor related to the atmosphere, which may influence the amount and spectral composition of solar UVR that reach Earth (Modenese *et al.*, 2018). The solar UVR spectrum reaching Earth is photochemically active, therefore having the ability to influence components of the troposphere (Belan *et al.*, 2020). The main components of the troposphere influencing incoming solar UVR are clouds, surface albedo, aerosols, O₃ and mixtures of trace gases in the atmosphere (Belan *et al.*, 2020). The biggest factors influencing personal solar UVR exposure in the South African hemisphere, have been identified as O₃, cloud coverage and the solar zenith angle (SZA) (Makgabutlane and Wright, 2014).

Long term solar UVR analysis indicates that an increase in average zonal and annual solar UVR occurs more rapidly in the Southern hemisphere than the Northern hemisphere (Belan *et al.*, 2020). Another study made use of solar UVR modelling where findings indicate different meteorological factors influencing the amount of solar UVR that reach each hemisphere. The total ozone column (TOC) has the biggest influence in the Southern hemisphere and the TOC and aerosol optical depth (AOD) have the biggest influence in the Northern hemisphere (Lamy *et al.*, 2019). The effect of different meteorological factors depends on the physical-

geographical and climatic conditions of a region (Belan *et al.*, 2020). Therefore, it is important to consider different meteorological factors to understand personal solar UVR exposure that occurs during various times of the year (Makgabutlane and Wright, 2014).

Institutes such as the South African National Weather Services (SAWS) provide meteorological forecasts to inform the South African public of factors such as daily temperatures, the Ultraviolet Index (UVI) and expected cloud coverage (SAWS, 2022). This is important because daily temperatures are determined by incoming solar UVR leading to an increase in air temperatures and the level of solar UVR reaching Earth is indicated through UVI (Belan *et al.*, 2020).

2.5.1.1 Stratospheric ozone (O₃)

The protective shield also known as the O₃ layer, located in the stratosphere, is responsible for diverting or absorbing harmful solar UVR before it reaches Earth (Hegglin *et al.*, 2014). Ozone consists of three bonded oxygen molecules that break into a single oxygen atom and two bonded oxygen molecules (O₃ → O₂ + O), when the energy from incoming solar UVR waves is absorbed by the ozone molecules. Therefore, ozone molecules break and bind constantly to absorb or reflect incoming solar UVR (Abbasi and Abbasi, 2017).

However, changes occur in the distribution and concentration of the O₃ layer around the Earth due to O₃ depleting substances (ODSs), greenhouse gases (GHG), and the Brewer-Dobson circulation (BDC) (Bias *et al.*, 2019). These changes in the O₃ distribution and concentration that have occurred over decades, may have altered UVB radiation reaching Earth's surface, leading to an increase in solar UVR and surface climate (Bias *et al.*, 2019). Therefore, a phenomenon known as the "O₃ hole" occurred and has been monitored since the early 1970 with recent research showing a reduction in the O₃ hole (Lucas *et al.*, 2019; Diffey, 2018). Since then, protocols were put in place to ensure the recovery of the O₃ layer that may lead to a reduction in solar UVR reaching Earth's surface and lower the risks of certain solar UVR related health effects such as photo-dermatoses (Lucas *et al.*, 2019).

2.5.1.2 Cloud coverage

Clouds can be described as condensed water contained in the atmosphere and can also be referred to as attenuators of solar UVR (Bias *et al.*, 2019). The main effect of clouds is to convert direct radiation into diffused solar UVR. Clouds can scatter solar UVR towards the Earth, this is known as cloud enhancement and usually lasts for short periods. Other clouds that could reduce solar UVR exposure are heavy rain bearing clouds. Characteristics that would influence solar UVR enhancing, or blocking would include the optical depth of clouds,

macrophysically cloud features e.g., cloud height in atmosphere and microphysical structures of the water droplets and ice crystals contained in the cloud (El-Nouby and Ahmed, 2015).

Thick clouds can diminish solar UVR exposure and thin clouds can reduce solar UVR exposure, this is described by the Mie theory (Bias *et al.*, 2019; IARC, 2018). Condensed water contained in clouds can absorb some solar UVR and the rest of the solar UVR gets emitted or scattered through the water droplets. Therefore, cloud coverage is an important factor playing an important part in solar UVR exposure (Makgabutlane and Wright, 2014).

2.5.1.3 The solar zenith angle (SZA)

The SZA is the angle that occurs between the centre of the sun and a vertical plane on Earth. The SZA deviates with latitude, season, and diurnal cycle (Leal *et al.*, 2021). The SZA is smaller in summer because the sun is higher in the sky and rays are distributed over a bigger area. On the other hand, the SZA is larger in winter because the sun is positioned lower in the sky and sun rays are distributed over a smaller area (Makgabutlane and Wright, 2014). Therefore, SZA and solar UVR intensity are inversely proportional meaning a bigger SZA may lead to smaller amounts of solar UVR reaching Earth and vice versa (Leal *et al.*, 2021).

2.5.1.4 Time of day

Earth completes a diurnal cycle every 24 hours meaning that the sun is situated at different angles during the diurnal cycle of each day (El-Nouby, 2011). Therefore, the intensity of solar UVR that reaches Earth will differ during certain times of the day. For example, peak exposure time of solar UVR occurs between 10:00 – 15:00 in South Africa, where 75% of the total daily amount of solar UVR is received (CANSAs, 2010; IARC, 2018). This is due to the SZA being smaller around solar noon and the distance solar UVR waves must travel are shorter, leading to solar UVR rays traveling from a more direct angle which may cause higher exposure (El-Nouby, 2011). The World Health Organisation (WHO) recommends limiting time spent in the midday sun because solar UVR levels are higher which may lead to more damaging effects (WHO, 2017).

During solar noon (12 PM), skin exposure of 1 SED (Standard Erythemal Dose) can be reached within 5 minutes of solar UVR exposure and body sites that are uncovered by clothing such as arms and legs, can receive up to 10 SED average daily solar UVR exposure (ICNIRP, 2010). Research regarding teachers' exposure to solar UVR in an open playground environment indicates that mean daily personal solar UVR measurements on a shirt collar site, exceeds the recommended exposure limit of 30 J/m² (Joules per square meter) for outdoor workers recommended by the International Commissions of Non-Ionizing Radiation

Protection (ICNIRP) (Downs *et al.*, 2014). The teachers reported have spent time outside around 11:00 am and 1:00 pm for summer and winter seasons with a mean exposure time of 39 minutes, which would occur around solar noon (Downs *et al.*, 2014). Undoubtedly, these high exposure levels may occur often during midday and the duration as well as time of day increases outdoor workers' risk to encounter negative health effects associated with solar UVR exposure (Wright and Norval, 2021).

2.5.5.5 Season

In South Africa the summer season occurs from December until February and the winter season from June until August (Makgabutlane and Wright, 2014). Seasons are caused by the rotation of the Earth around the sun. The Earth moves around the sun causing one hemisphere to be pointing towards the sun and the other hemisphere pointing away from the sun in each season (Ghamari and Asghari, 2015). As a rule, more solar UVR reaches Earth in summer than winter. As previously mentioned, it may be due to seasonal O₃ changes and the natural chemical destruction of the O₃ layer during daylight, which would increase in summer months because of prolonged daylight period (Hegglin *et al.*, 2014). The transport of O₃ is much weaker during summer and autumn periods which may cause thinner O₃ layers, and less protection is provided against solar UVR (Hegglin *et al.*, 2014). Therefore, seasonal variations do occur and may have an influence on solar UVR exposure of outdoor workers (Modenese *et al.*, 2018).

2.5.5.6 Aerosols

Aerosols can be defined as small particles or droplets that are suspended in the air. Moreover, aerosols consist of various organic and inorganic compounds with different size distributions. Subsequently, aerosols interfere with or may cause scattering and absorption of solar UVR (Wright *et al.*, 2019). Aerosols with a dark colour have a low surface albedo and therefore can scatter solar UVR leading to a cooling effect on air temperature. On the other hand, aerosols with a brighter colour have a high surface albedo that leads to the absorption of solar UVR causing a warming effect on air temperature (Myhre *et al.*, 2013). Many aerosols may also influence clouds' optical properties and cloud formation leading to more solar UVR reaching Earth (WMO, 2022).

Air pollution is caused by numerous human activities such as vehicle emission and coal-fired power stations which release aerosols and contribute to poor air quality. Except for the effect that air pollution has on the respiratory- and cardiovascular systems, it has been noted that air pollution may also affect the skin's integrity. Aerosol exposure on the skin can occur directly

or through inhalation of substances, thus spreading particulate matter (PM) systemically or volatile organic compounds (VOCs). Therefore, aerosols lead to an increasing risk of negative health effects associated with the skin and skin cancer development (Wright *et al.*, 2019; Wright and Norval, 2021).

2.5.2 Environmental factors

Situated on the African continent, the South African region has lower latitude and high altitudes, receiving solar UVR exposure all year-round (Rother *et al.*, 2020; South African Government, 2023). These environmental conditions cannot be controlled and play a major role in solar UVR exposure risk. Undoubtedly, studies relating to solar UVR exposure measure factors that may have an influence on solar UVR exposure, indicating additional information to understand solar UVR patterns, trends and abnormalities (Turner *et al.*, 2020).

2.5.2.1 Latitude

Latitude and ambient solar UVR exposure are inversely proportional, meaning that a region with a lower latitude such as South Africa receives a higher amount of ambient solar UVR exposure than a region with a higher latitude such as a European country (e.g., France). This may be due to O₃ distribution that is influenced by circulation of air in the stratosphere, thereby transporting O₃ to higher latitudes with a thicker O₃ layer resulting in better protection against solar UVR (Hegglin *et al.*, 2014). In addition, the Southern hemisphere may experience 15% higher solar UVR than locations with the same latitude in the Northern hemisphere. This may be due to less pollution and the Earth's elliptical orbit (Gies *et al.*, 2014a).

Latitude may also play a role in the prevalence of certain diseases occurring such as pterygium, CMM and SCC due to its effect on ambient solar UVR levels. More specifically, lower latitude areas with high ambient solar UVR have indicated a higher prevalence of pterygium occurring as well as amplification of association between occupational solar UVR exposure and the risk to develop SCC. Cutaneous malignant melanoma has also been found to be more prevalent in individuals with fair skin at low latitudes (Modenese *et al.*, 2018). Therefore, latitude should be considered when evaluating solar UVR exposure, because regions with low latitude may be a risk factor for higher solar UVR exposure because of higher ambient solar UVR levels.

2.5.2.2 Altitude

Altitude determines the solar UVR intensity which is expressed through the UVI as well as ambient solar UVR levels given in SED (Diffey, 2018). Higher altitudes are associated with thinner atmospheres (less dense O₃ layer) and are closer to the sun leading to higher levels of solar UVR in these regions (Alemu and Gebre, 2020). Areas with higher altitude and thinner atmospheres experience less absorption or scattering of solar UVR. When the altitude increases with 1000 m, ambient solar UVR levels increase with 10% (WHO, 2017). Therefore, areas with higher altitudes poses a greater risk for harmful human health effects to occur because of solar UVR exposure (ICNIRP, 2010).

2.5.2.3 Albedo (surface reflection)

Albedo may affect personal solar UVR exposure through influencing the amount of solar UVR that is reflected from surfaces of objects to a person. Different surfaces have different albedo values, as illustrated in Table 1 below, (e.g., snow has the biggest albedo) with cloud coverage playing a role in albedo because albedo is determined by the spectral and angular distribution of light (Gies *et al.*, 2014a). Surfaces or objects with high albedos may lead to higher solar UVR exposure (Turner and Parisi, 2018).

Research found that solar UVR reflectance of surface materials such as concrete, contribute more to solar UVR exposure than solar UVR reflectance from green vegetation (Sivarajah *et al.*, 2020). Findings indicate that it is important to take note of objects or surfaces with high albedos such as galvanised surfaces, usually used for roofing, because facial exposure to solar UVR is enhanced by the high albedo of the galvanised surface especially on the vertex of the head, the bridge of the nose and the rear neck (Lester and Parisi, 2002). Another study measured personal solar UVR exposure of tinsmiths working on construction sites in Australia during the summer. This study recorded high personal solar UVR exposure values and noted that workers often worked around or with high reflective surfaces such as aluminium. This study also explained that the skin adapts to solar UVR exposure, but the eyes do not and for that reason a lot of workers complained about common symptoms of photokeratitis (Weber *et al.*, 2006). Except for causing higher personal solar UVR exposure through reflection, albedo of surfaces of objects may also cause acute syndromes such as photokeratitis which is usually only temporary but long-term exposure may lead to increased risk of other diseases such as formation of cataracts (Gies *et al.*, 2014a). Hence, mean albedo values of surfaces in urban settings were calculated by Turner and Parisi, (2018) as found in literature given in Table 1.

Table 1. Mean albedos of common surfaces found in an urban setting (Turner and Parisi, 2018).

Surface	Mean albedo
Bare ground	4.30
Sandy soil	3.63
Limestone	11.20
Flower bed	2.60
Lawn	2.10
Concrete	9.26
Ceramic tiles	11.48

2.5.3 Occupational factors

Solar UVR exposure is considered an occupational risk factor for outdoor workers because these workers are constantly exposed throughout their working life. Despite strong evidence indicating that solar UVR exposure may cause acute and long-term health effects, occupational solar UVR exposure risk is generally undervalued, and solar UVR protection methods are neglected by employers of outdoor workers (Modenese *et al.*, 2018).

2.5.3.1 Work environment

The location of the occupational setting plays an important role in determining solar UVR exposure because outdoor workers experience three to five times higher solar UVR exposure doses than indoor workers while working at the same latitude (ICNIRP, 2010). In 2019 there were about 14 million employed workers in South Africa with roughly 4 million of these workers engaged in outdoor jobs (Wright *et al.*, 2019). It is difficult to determine the exact amount of people working outdoors because work activities in the mining and construction industries can occur both indoors and outdoors (Wright *et al.*, 2019). In addition, South Africa has a lot of informal jobs such as subsistence farming or waste reclaimers that are not formally recorded to form part of statistics (Ledigoane and Viljoen, 2020). Therefore, it is currently unknown how many South Africans are overexposed to solar UVR daily. A limited amount of research on solar UVR exposure of different occupational groups in different occupational settings are available, undoubtedly indicating the need for more research.

2.5.3.2 Infrastructure providing physical sun protection

Shade from vegetation e.g., trees and artificial sources such as awnings can provide sun protection. However, shade structures or vegetation are not always available/feasible in every situation (Lucas *et al.*, 2016). Natural trees are a cost-effective manner to provide shade and have additional benefits through releasing oxygen (O₂) and absorbing gaseous pollutants (Zarr and Conway, 2017; Sivarajah *et al.*, 2020). However, the quality of cover provided by vegetation is determined by factors such as type and size of vegetation and should be carefully selected with specific criteria to ensure vegetation do not create additional problems such as dripping tree sap or pollen (Wolf *et al.*, 2020).

One of the factors that should be considered when implementing artificial shade structures is the type of material used for these structures because the protection abilities of these materials may decrease when it is wet, stretched or weathered (Holman *et al.*, 2018). Other factors include height, size, and shape of structures. It is also recommended that shade structures have an overhang or protection on the sides as well to decrease diffused solar UVR exposure (Holman *et al.*, 2018). Shade structures should be capable of providing protection against direct and diffused solar UVR exposure (Lucas *et al.*, 2016; Wright *et al.*, 2019).

Although shade structures are beneficial in providing protection, they are difficult to implement in most outdoor occupational settings in South Africa due to employees not being static but should be considered to provide employees with as much protection possible against solar UVR exposure (Wright and Norval, 2021). Therefore, shade structures should be incorporated in the design stage of buildings or any property to ensure an environment with shade is available for employees (Lucas *et al.*, 2019).

In addition, employers need to provide employees with an indoor area or adequately shaded area where they can have lunch or tea (Reinau *et al.*, 2013) due to the amount of solar UVR employees can receive during tea- and lunch breaks. This is important to consider because exposure during these times contribute to the total dose of solar UVR exposure per shift (Khan *et al.*, 2020). A study in Australia (Queensland) has found that personal solar UVR exposure of teachers reaches peak exposure values during meal breaks which occur outside between 11:00 am and 1:00 pm in the summer and winter season (Downs *et al.*, 2019). The study has also suggested that teachers should have meal breaks indoors on a rotation basis or in a shady area, which should be a consideration for all other outdoor workers as well, to ensure outdoor employees do not receive unnecessary solar UVR exposure (Downs *et al.*, 2019).

2.5.3.3 Work Posture

It has been acknowledged that posture and orientation of the body in relation to the sun play a key role in determining which part of the body is more likely to have higher solar UVR exposure (Schmalwieser *et al.*, 2021). Therefore, different postures may favour solar UVR exposure to certain areas on the body, specifically, those on the horizontal plane that receive more solar UVR exposure than those on the vertical plane. As an example, when standing in an upright position, the top of the head would be the horizontal plane and the upper arm on the vertical plane (Nardini *et al.*, 2014; Ioannou *et al.*, 2021). When job activities require bending over, the neck receives higher exposure while the vertex, forehead and forearm receive high solar UVR exposure during activities done while standing upright. Findings related to the most exposed area of the body could ensure that protection measures are more tailored to different work activities and occupations (Nardini *et al.*, 2014).

2.5.4 Personal/ individual factors

2.5.4.1 Behaviour and attitude

Behaviour and attitudes of people regarding solar UVR exposure could increase or decrease their level of exposure depending on factors such as predisposition as well as social and cultural norms (Lucas *et al.*, 2019; Diffey, 2018). Nevertheless, research findings have indicated that occupational health policies are unlikely to achieve their objectives because behaviour issues of target groups are not addressed (Rocholl *et al.*, 2020; Rother *et al.*, 2020). Moreover, risk perception of workers does not navigate them towards responsible protective behaviour (Rother *et al.*, 2020).

Furthermore, checking daily weather forecasts may influence a person's behaviour when spending time outside such as staying in shady areas and making use of protective measures when the UVI is high. Any person with a mobile phone that has internet access can check the daily weather forecast. However, different sun protection methods can be used, and they depend on personal preference (Lucas *et al.*, 2016). For this reason, addressing behaviour and attitudes towards solar UVR may lead to lower solar UVR exposure (Lucas *et al.*, 2019).

2.5.4.2 Use of Sunscreen

Sunscreen can be applied to the skin on a regular basis and has different sun protection factors (SPF) available. To ensure that the SPF factor indicated on sunscreen containers are achieved, two milligram of sunscreen per cubic centimetres of skin should be used (two tablespoons) (SCF, 2019a). Sunscreen products work well when used in combination with other sun protection strategies such as hats, clothing, and shade (Lucas *et al.*, 2016). In most cases, sunscreen is eliminated from the skin during perspiration due to engaging in daily

activities. Therefore, it should be reapplied regularly throughout the day (D’Orazio *et al.*, 2013). It is often difficult to remember when it is time to reapply sunscreen, however, recent technologies such as solar UVR wristbands or body stickers may solve this problem. The sticker or wristband are attached to the body and sunscreen should be applied evenly over the sticker or wristband in the same manner as the skin. When the sticker turns from white to blue or the wristband turns from white to red, sunscreen should be reapplied (Sunburn Alert, 2022). Education and training on the importance of protective measures and how to use it correctly are also a vital part of any solar UVR control measure to achieve effectiveness. There are many ways to protect against solar UVR exposure and employers should encourage outdoor workers to make use of sun protection. (Wright *et al.*, 2019).

2.5.4.3 Photoprotection provided by clothing

Most common textiles used to manufacture everyday clothing, provide a fair amount of protection against solar UVR exposure (Boothby-Shoemaker *et al.*, 2022). In addition, recent trends include swimwear and sports clothing that are formally designed using photoprotective substances such as iron oxide in the textiles, to provide more protection against solar UVR exposure (Boothby-Shoemaker *et al.*, 2022). Photoprotective clothing are available and worn by certain groups such as athletes (Aguilera *et al.*, 2014), and likewise outdoor workers should also wear clothing that provide protection against solar UVR during their work activities (Khan *et al.*, 2020; Schmalwieser *et al.*, 2021). A study found that textiles exhibit consistently higher and less variable UVB blocking compared to sunscreen. Although sunscreen remains an important photoprotective measure for places that cannot be covered with clothing e.g., face, this study showed sun-protective clothing is an important tool that should be considered to minimize solar UVR exposure (Berry *et al.*, 2022).

When the photoprotection abilities of textiles are communicated, the ultraviolet protection factor (UPF) is used and can be determined *in vitro* through laboratory evaluation (Khan *et al.*, 2020). The parameter that is measured by UPF is the solar UVR-transmission that reaches the skin through the textile used for clothing. (SCF, 2019b). To demonstrate, Table 2 contains a UPF rating with a protection category according to the percentage of solar UVR blocked. The UPF of clothing items is commonly determined and analysed with spectrophotometric testing (SP) or radiometry but *in vivo* UPF testing can also be done. However, *in vivo* testing is argued to be more expensive, more time consuming and have been criticised for not accounting coverage of body surface area (BSA) (Boothby-Shoemaker *et al.*, 2022).

Dating back a few years, some studies used *in vivo* methods to determine UPF of textiles with different dosimetry instruments, namely, VioSpor® UV biologically weighting dosimetry system

and Polysulphone film badges (PSF) (Gambichler *et al.*, 2002; Wilson and Parisi, 2006). These methods were performed in a realistic exposure situation and measurements were found to be a valid alternative method to *in vitro* testing such as SP. However, these types of studies were criticised, and more recent research decided to include BSA coverage as well (Downs and Harrison, 2018). The new method for determining the photoprotection abilities of a specific textile was adapted including UPF and BSA to calculate the Garment Protection Factor (GPF) (indicated in Table 3) (Downs and Harrison, 2018). Therefore, the GPF is designed to be used in conjunction with current Australian/New Zealand, European and U.S. standards as mentioned below. However, exploring the UPF as well as the GPF would be a better approach to determine photoprotection abilities of clothing, but broadening the scope of this study too much.

Certain textiles can transmit, scatter or absorb solar UVR waves that contact the textile, depending on the properties of the textile (Khan *et al.*, 2020). These properties include fabric structure, fabric type, colour, dryness, fit on body and laundering (Boothby-Shoemaker *et al.*, 2022). The fabric structure refers to the weave tightness and fabric thickness of a clothing item. Generally, a textile with a tighter weave and thicker fabric is less porous and provides more protection against solar UVR (Ray *et al.*, 2020; Boothby-Shoemaker *et al.*, 2022). For example, knitted fabrics provide less solar UVR protection due to the flexible nature and interlocking structure creating porosity for solar UVR to pass through. Woven fabrics provide better solar UVR protection than knitted fabrics because these fabrics have tighter weave leading to less solar UVR exposure passing through the fabric (Ray *et al.*, 2020; Rahmna *et al.*, 2022).

Different types of textiles display different levels of protection. In general, natural textiles such as cotton or silk, offers less solar UVR protection than synthetically manufactured textiles due to fibre composition (Boothby-Shoemaker *et al.*, 2022). To illustrate, textiles made of polyester may provide good solar UVR protection because these fibres have large conjugated aromatic polymer systems that may play a role in increased absorption of solar UVR (Ray *et al.*, 2020). In addition, some natural textiles have good solar UVR protection abilities such as naturally coloured cotton textiles that have higher solar UVR protection abilities than ordinary cotton and wool and may also exhibit higher solar UVR protection due to proteins on the fabric's surface (Boothby-Shoemaker *et al.*, 2022). Altogether, the selection of the type of textile would not only depend on solar UVR protection abilities but also on other factors such as thermal comfort, to ensure a person is protected against solar UVR but not uncomfortable (Ray *et al.*, 2020; Rahman *et al.*, 2022).

The colour of the clothing items can also affect the degree of photoprotection, depending on the concentration of dye, chemical composition, and type of fabric. Hence, darker colours provide more protection than lighter colours because some dyes used to colour textiles can absorb solar UVR and absorption would be enhanced when the dye concentration is higher (Boothby-Shoemaker *et al.*, 2022; Rahman *et al.*, 2022). Furthermore, bright colours reflect solar UVR better than dark colours, for example dark blue would absorb more solar UVR than light yellow reflecting more solar UVR. In addition, if the chemical composition of dyes contains metals such as copper or zinc, this may also enhance solar UVR protection abilities of textiles due to these metals acting as solar UVR blocking agents. On the other hand, different types of fabric exhibit different protection abilities according to colour, for example red dyed polyester shows better protection abilities than blue dyed polyester (Ray *et al.*, 2020; Rahman *et al.*, 2022).

Wet and dry textiles exhibit different levels of solar UVR protection. Textiles may get wet during the day due to sweating or nature of work e.g., gardening. For this reason, it is important to evaluate the protection abilities of wet and dry textiles. Hence, dry textiles provide more solar UVR protection than wet textiles because water increases solar UVR penetration through textiles (Boothby-Shoemaker *et al.*, 2022). Wetness can cause the UPF of a fabric to decrease with 30-50% because water changes the geometric arrangement of the space between fibres (Ray *et al.*, 2020; Rahman *et al.*, 2022). Therefore, when clothing is constructed to have high UPF factors, they are also developed with textile types that would dry quickly, providing more protection (Rahman *et al.*, 2022).

The way clothing fits is an important factor to consider when evaluating UPF of clothing. For this reason, clothing that is more loose-fitting on the body provides more protection against solar UVR because a bigger surface area is covered and clothing is not stretched as much, leading to smaller pores in the fabric and therefore less solar UVR passing through the fabric (Boothby-Shoemaker *et al.*, 2022). Importantly, coverage should also be considered and refers to the amount of skin that is covered by the clothing item with long-sleeved shirts providing more protection than for example, vests (Gies *et al.*, 2014b). In addition, woven fabrics have a higher cover factor than knitted fabrics due to weave construction (Ray *et al.*, 2020).

Interestingly, some studies have shown that laundering increases the UPF of clothing in various ways. In some cases, laundering may shrink the clothing, tightening the weave of the textile and leading to less solar UVR passing through the textile. Laundering causes formation of surface fuzz, increasing fabric thickness (Chen-Yu and Wong, 2017; Boothby-Shoemaker *et al.*, 2022). It has also been found that some detergents contain agents that brighten clothes,

and through washing clothes with these agents a few times, they may exhibit higher solar UVR absorbing properties (Ray *et al.*, 2020). A study investigated the effects that perspiration, weathering, and laundering have on natural lightweight cotton. Overall, laundering alone (without the effect of weathering) increase UPF and weathering decreases UPF (Chen-Yu and Wong, 2017). However, perspiration slowed down reduction in UPF. Admittedly, some factors play a big role in UPF such as colour change and humidity. However, in some instances, the colours of textiles do not change, become lighter or darker depending on other factors such as textile type. Furthermore, humidity is a contributing factor leading to decrease in UPF of textiles (Chen-Yu and Wong, 2017).

Standards are available in several countries by which the degree of protection of clothing can be determined (Boothby-Shoemaker *et al.*, 2022). In South Africa, the South African National Standard (SANS) codes are available. There is a SANS code that describes a valid method that can be used to determine solar UVR protective properties of textiles where solar spectral irradiance values and relative erythema effectiveness values can be found (SANS 6320:2003). Additionally, a European Standard (EN 13758–1 and 2) is also available containing a table that indicates protection categories and UPF rating for textiles (Khan *et al.*, 2020). The American Society for Testing and Materials (ATSM) also provides a document (ASTM D 6603–19) containing a table with guidelines for sun protective clothing and swimwear UPF rating, protection category and percentages of UVR blocked (ASTM, 2021). Other standards are also available such as the Australian/New Zealand Standard (AS/NZS 4399:1996) and an organisation known as the international testing association for applied UVR protection having their own standard (UV standard 801, 2021). Therefore, providing employees with a good level of solar UVR protection through solar UVR protective clothing may be a feasible method to reduce solar UVR exposure of outdoor workers such as security guards (Boothby-Shoemaker *et al.*, 2022; Khan *et al.*, 2020).

Table 2. ASTM standard table containing UPF rating, protection category and percentage of UVR blocked (ASTM D6603 - 19).

UPF rating	Protection category	% UV radiation blocked
UPF 15 – 24	Good	93.3 – 95.9
UPF 25 – 39	Very good	96.0 – 97.4
UPF 40 – 50+	Excellent	97.5 – 98+

Table 3. Suggested GPF calculated with GPF equation suggested by Downs and Harrison, (2018).

GPF rating	Protection category
$0 \leq \text{GPF} < 3$	Comply to minimum standard
$3 \leq \text{GPF} < 6$	Good
$\text{GPF} \geq 6$	Excellent

2.5.4.4. Photoprotection provided by sunglasses

Sunglasses and hats are accessories that can be worn to provide additional protection against solar UVR exposure. Sunglasses with a solar UVR protection filter are a good way to protect the eyes against solar UVR exposure, but sunglasses are expensive and not culturally acceptable to some people (Lucas *et al.*, 2016).

In low- and middle-income countries sunglasses are imported with no or vague regulatory standards for testing the quality (Alemu and Adimassu, 2021). Non-prescription sunglasses can be bought from authorised and unauthorised vendors but should still comply with minimum requirements to sufficiently protect the eyes against solar UVR exposure. Sunglasses made from poor quality materials and providing poor protection may harm the eyes through disabling the eye's natural safety mechanisms. Harmful solar UVR may enter the eyes and cause more damage than when the eyes are left naked. A study was done in Ethiopia which found that only 73% of non-prescription sunglasses available at authorised and unauthorised vendors tested safe to use because they filtered up to 400 nm solar UVR (Alemu and Adimassu, 2021).

In South Africa, there are two SANS (South African National Standards) codes namely SANS 1644 AND SANS 50166 that describe requirements for sunglasses and personal eye protection. Both standards mention that it applies to “optical radiation” and “natural sunlight”.

The safety requirements for sunglass lenses and fashion spectacles are described in SANS1644 (SANS1644-1.3). Properties such as refractive properties, transmittance, and coloration are discussed. Specifications are discussed in SANS 50166, where design of filters, materials and field of vision are discussed. When lenses should be made for a specific hazard such as UVR filters, other standards are also applicable such as European Standards (EN) and International Organisation for Standardisation (ISO) and should be used in conjunction with the specific SANS code (SANS 50166-2). According to the ICNIRP a good design for sunglasses would include a wrap-around design with side panels that fit close to the eyes to provide ocular protection because solar UVR should be blocked from entering through the sides of the sunglasses (ICNIRP, 2010).

2.5.4.5. Photoprotection provided by hats

Environmental conditions have an influence on the effectiveness of sun protection provided by hats e.g., when the sun is in a high position during midday, the sun can reach most areas of the body and face irrespective of hats and clothing (Backes *et al.*, 2018b). When different the sun protection capabilities of various types of hats (cap, helmet, middle- and wide brimmed hat) were studied, no hat was found to provide 100% protection at any facial zone, which may be due to diffused solar UVR exposure (Backes *et al.*, 2018b). Although, wide brimmed hats were mentioned to be most effective against peak summer irradiance, no hat fits all situations and facial skin zones that are exposed should be considered when choosing hats (Backes *et al.*, 2018b). Therefore, hats should be used in combination with sunscreen e.g., when wearing a cap, the ears and neck are still exposed (D’Orazio *et al.*, 2013). Otherwise, hats should have additional sun shields and neck guards to provide better protection (Modenese *et al.*, 2018). Behavioural factors such as wearing hats and sunscreen are important to minimize solar UVR exposure of outdoor workers. Practical solutions can include tax deductions for purchasing of sunscreen and hats which are implemented in Australia for outdoor workers (Downs *et al.*, 2019).

2.5.4.6 Knowledge about solar UVR and solar UVR protection

The South African law namely the Occupational Health and Safety Act 85 of 1993 (DoEL, 1993) requires employers to identify all risks and hazards within a workplace and provide employees with training regarding these risks and hazards, to ensure that employees have knowledge on how to protect themselves. Therefore, it is vital that employees, especially those working outdoors, have a level of knowledge regarding solar UVR exposure and its effects (Hault *et al.*, 2016). A study conducted in Germany have found that employees only have knowledge regarding short term effects of solar UVR exposure such as sunburn, but this did

not include knowledge of long-term effects such as the risk to develop skin cancer (Hault *et al.*, 2016). In contrast, a South African based study found that 60% of employees (car guards) have knowledge regarding negative health effects of solar UVR exposure but only mention long term effects such as skin cancer (Nkogatse *et al.*, 2018).

Undoubtedly, educational intervention is needed for outdoor workers because there is growing evidence that education and training are effective in lowering solar UVR exposure through influencing behaviour and attitudes towards solar UVR exposure (Rocholl *et al.*, 2020). Using methods such as questionnaires may establish where employees have gaps in knowledge that could be addressed, leading to employees understanding hazards and risks better to protect themselves against these hazards and risk (Rother *et al.*, 2020).

2.6 Individual genetic or physiological factors influencing solar UVR exposure

2.6.1 Importance of skin pigmentation in solar UVR response

The skin consists of three main layers namely the epidermis, dermis, and hypodermis. Solar UVR may penetrate the epidermis (UVB) and dermis (UVA) layers of the skin that may lead to damaging effects of tissue, cells, and structures within these layers. Pigment in the epidermis and blood flow in the dermis influence the skin's colour (Martini *et al.*, 2012). The skin contains chromophores namely, haemoglobin and melanin. As a result, skin pigmentation is one of the deciding factors that influence the reaction of the bodies of various individuals to solar UVR exposure. The distribution of melanin differs in various layers of the skin, with the basal layer of the skin usually having the highest melanin content (Fajuyigbe *et al.*, 2018).

The South African population's skin pigmentations differ widely because of ethnic diversity that exist in South Africa (Lucas *et al.*, 2016). It has been found that South African skin phototypes mostly range between I and V types according to Fitzpatrick skin types (FST) (Karsten *et al.*, 2013). Therefore, a variety of responses to solar UVR exposure may be seen in one South African workforce. People who have skin phototypes that are classified as more pigmented skin (darker skin phototype) have nine-fold more melanin content than people with lighter skin phototypes. Therefore, cancer is less prevalent in people with darker skin types because there is more melanin to absorb solar UVR exposure. Nevertheless, sun protection should not be limited to high-risk populations because skin cancer diagnosis and prognosis are much more difficult with dark-skinned people than with light skinned people (Wright *et al.*, 2015; Fajuyigbe *et al.*, 2018).

2.6.3 Chromophores within the skin

The epidermis layer of the skin contains two types of pigment (carotene and melanin). Carotene is an orange-yellow pigment found in the epidermal cells and is more abundant in people with lighter skin colours (Martini *et al.*, 2012). Melanocyte (pigment producing cells) can be found in one of the epidermis layers (stratum basale / stratum germinativum) and deeper epithelial tissue. Melanocytes produce two types of melanin namely pheomelanin (red-yellow form) and eumelanin (brown-black form) (Sample and He, 2017). Melanin is also known as the natural sunscreen of the skin and determines the skin's complexion and solar UVR sensitivity. In addition, different types of skin pigmentations (skin colours) are dependent on the amount and type of melanin that are synthesised, as well as the distribution and transfer of pigment in the skin layers (Solano, 2020). Eumelanin is more effective in blocking solar UVR than pheomelanin, leading to more protection against solar UVR in people with darker skin complexions (D'Orazio *et al.*, 2013).

2.6.4 Photoadaptation in human skin to solar UVR exposure

Melanin protects the skin from harmful effects that may be caused by solar UVR (Jablonski, 2013). The physiological response of the skin against solar UVR exposure occurs through melanocytes that react to solar UVR exposure by increasing synthesis of melanin and thickening of the stratum corneum (hyperkeratosis) (D'Orazio *et al.*, 2013; Solano, 2020). Melanogenesis is the process where melanocytes manufacture melanin (both eu- and pheomelanin) from the amino acid *tyrosine* and package the melanin in intracellular vesicles called melanosomes. The melanosomes travel to the basal keratinocytes and a transfer of colour occurs, the keratinocyte and melanosomes are then destroyed by lysosomes. Melanogenesis is a slow process, therefore dark-skinned individuals have more melanin than light skinned individuals causing greater initial protection against solar UVR exposure because of endogenous melanin until more melanin is formed in reaction to solar UVR exposure (Martini *et al.*, 2012).

The Melanocortin 1 receptor (MC1R) can be found on the surface of melanocytes and can be described as a genetic locus involved in pigmentation, adaptive tanning response and skin cancer susceptibility (D'Orazio *et al.*, 2013). The MC1R binds to different hormones and molecules to transmit signals that will lead to higher levels or activity of melanogenic enzymes, therefore, enhancing production and transport of melanin. Different conditions may arise such as loss-of-signalling MC1R polymorphism as well as MC1R mutation (commonly referred to as Red Hair Colour (RHC)) that may cause a four-fold risk to develop CMM or other skin cancers. Therefore, it is important to note that the MC1R is a determinant of skin cancer risk and regulation of eumelanin due to its role in protecting skin against solar UVR. Animal models have been used to determine if melanin levels may be enhanced through targeting MC1R

signalling, which turned out successful but still requires further research (D’Orazio *et al.*, 2013).

2.6.5 Individual susceptibility to solar UVR linked health effects

Individuals that suffer from certain health problems may be more sensitive or susceptible to the negative health effects associated with solar UVR exposure. People with Albinism, photosensitivity or who are immunocompromised should be protected because these conditions are linked to increased risk of solar UVR related skin damage and developing skin cancer when exposed to solar UVR (Hernando *et al.*, 2018). Albinism can be described as a genetic condition where there is a reduced amount of melanin present in the skin, eyes, and hair (Jablonski, 2013). People living with Albinism are very sensitive to solar UVR exposure, especially their skin and eyes. Additionally, people may suffer from photosensitivity, which can be defined as an unusual reaction of the skin to solar UVR exposure (natural or artificial) (Hernando *et al.*, 2018). Photosensitivity can be caused by medication, diseases, medical conditions, and skin care products (Hernando *et al.*, 2018). Some photosensitisers can be found in the work environment e.g., textile dyes, ink used in stationery and plants near the working area. Therefore, these photosensitisers should be identified and considered to prevent photosensitivity from occurring (ICNIRP, 2010). Exposure to solar UVR may also lead to further immunosuppression, therefore making people who are already at risk e.g., HIV positive individuals, more vulnerable (Ghamari and Asghari, 2015).

2.7 Methods used to classify skin colour

The skin's colour differs across the body because of the influence of endogenous and exogenous factors. Therefore, the skin colour can be constitutive or facultative (Gupta and Sharma, 2019). Constitutive skin colour refers to skin colour on the body where the melanin level, type and distribution are genetically determined and not influenced by endogenous or exogenous factors such as hormonal factors or solar UVR exposure (Gupta and Sharma, 2019). An example of an area on the body that would be considered as constitutive skin colour would be the posterior upper side of the arm because this is usually a photo-protected area on the body (Gupta and Sharma, 2019). Facultative skin colour refers to skin where the melanin content was influenced by environmental or hormonal factors that may have changed the genetically determined melanin pattern in the skin (Gupta and Sharma, 2019). Examples of facultative skin could include the anterior side (outside) of the arm and the back of the hands (Khalid *et al.*, 2017; Linde *et al.*, 2020).

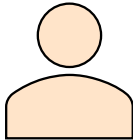
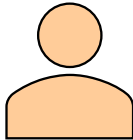
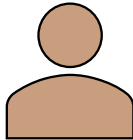
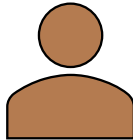
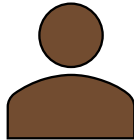

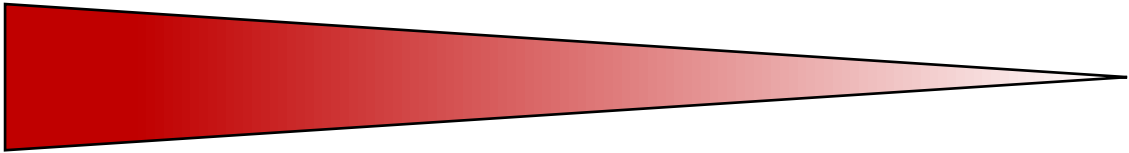
To understand exposure and implement effective sun protection programs, the determination of skin pigmentation is an important factor to consider (Linde *et al.*, 2020) because this will indicate the risk and reaction of the skin to solar UVR exposure that may help to create an effective sun protection program. (Gupta and Sharma, 2019). The FST was created to aid a person in the self-identification of their skin type and to assist a person in understanding how the skin may react to solar UVR exposure. Table 4 below illustrates the FST (Gupta and Sharma, 2019). The FST questionnaire includes questions about genetic and physical traits, sensitivity of the skin to sun exposure and intentional exposure (tanning). The FST is a subjective method used to determine personal opinions (Gupta and Sharma, 2019).

Although studies such as Eilers *et al.* (2013) and Linde *et al.* (2020) found that dermatologist-determined FST is more accurate than self-reported FST for dark-skinned populations, employing dermatologists is not reasonably feasible when considering the costs involved. These resources are in any case available when needed in some cases (Gordon *et al.*, 2016). It is recommended that the FST should only be used as a guideline because studies have found that the FST cannot adequately capture the spectrum of colour variation for the dark-skinned population and some questions may not be relevant to all populations. Therefore, modification of the FST may make it more relevant for dark-skinned populations (Sharma *et al.*, 2018). Stronger correlation is evident when people with lighter skin colours, e.g., people with European ethnicity make use of the FST. However, bias is often found in terms of overestimation of skin pigmentation in this group/population (Reeder *et al.*, 2010). Additionally, some studies have found that dark-skinned populations from African and Indian ethnicity, who participated in the FST questionnaire struggled to identify their skin colour accurately because of cultural differences and norms (Sharma *et al.*, 2018; Linde *et al.*, 2020). It was also found that the term *tanning* was confusing, perceived incorrectly or found to be irrelevant. Therefore, suitable adjustment of subjective methods should be considered (Wright *et al.*, 2015; Sharma *et al.*, 2018). Subsequently, subjective method results should be validated with objective method results or a combination of both methods (Sharma *et al.*, 2018; Wright *et al.*, 2015).

Objective methods make use of bioengineering methods or spectrophotometry. Studies have found that spectrophotometry can be used for skin typing as an objective method and are statistically significantly different from FST, especially when working with populations with darker skin types (Sharma *et al.*, 2018; Reeder *et al.*, 2010). However, when considering the cost of the equipment and operating technician, this method may be less popular to use for research or clinical applications (Eilers *et al.*, 2013). Bioengineering methods were developed to measure changes in skin and hair colour to use in cosmetic and pharmaceutical efficacy tests (Courage + Khazaka Electronic, 2021a) but these devices also benefit scientific studies

making use of dermatological research and in occupational health for skin protection (Courage + Khazaka Electronic, 2021b). Bioengineering methods used in this study include electronic wireless devices that are easy to use and provide accurate results e.g., Mexameter® MX 18 and skin-colorimeter CL 400 wireless probes (Courage + Khazaka Electronic, 2021a; b). Objective skin measurement methods could also identify erythematous sensitivity more accurately than subjective methods as found by Wright *et al.* (2015). Comparison of objective and subjective skin phototype and erythematous sensitivity can be used to ensure that these factors are determined correctly and taken into consideration when implementing sun protection programs (Reeder *et al.*, 2010).

Table 4. Illustration of the Fitzpatrick skin phototype system.

Type I	Type II	Type III	Type IV	Type V	Type VI
Very fair	Fair	Medium	Olive	Brown	Dark brown
					
Sensitive to solar UVR			Less sensitive to solar UVR		
					

2.8 South African legislation and standards related to solar UVR

An inadequacy is present in South Africa regarding evaluation of solar UVR exposure because there is no local legislation or regulations relating to solar UVR exposure. Therefore, it is difficult to determine compliance regarding solar UVR exposure after quantification (Wright *et al.*, 2017). South African legislation relating to procedures to be followed when injuries and diseases occur or originate from work activities or in the working environment (in general – non- mining industries) are documented in the Compensation for Occupational Injuries and Diseases Act (Act 130 of 1993). Although this act contains detail regarding most well-known

occupational injuries and diseases, this Act also remains outdated and neither NMSC nor CMM is listed as a reportable occupational disease in South Africa (DoEL, 2003). It has been stated that the problems regarding solar UVR exposure assessment are that optical radiation exposure is difficult to assess because exposure can occur in occupational and non-occupational settings (ILO, 2010). To be able to register NMSC and CMM as a reportable occupational disease in South Africa Wright *et al.* (2017) claims that more research regarding solar UVR exposure assessment, local epidemiology and policymaking is still needed.

2.9 International guidelines relating to solar UVR

Guidelines that are not legally binding contain suggested exposure limits for solar UVR. These guidelines are available in countries other than South Africa e.g., Australia (ARPANSA, 2006) and the United States of America (USA) (ACGIH, 2020). In addition, the ICNIRP is an international organisation that aims to protect people and the environment against the effects of NIR through making use of experts around the world using scientific data to provide guidelines for protection (ICNIRP, 2010). The ICNIRP provides guidelines for protection of workers against UVR and states in this document that a maximum human biologically efficient radiant exposure range for the eyes and skin should range between 1.0 to 1.3 SED (ICNIRP, 2010). These guidelines for protection apply to exposure to solar UVR and artificial sources of UVR (ICNIRP, 2010).

A wide range of susceptibility exist for people with different skin phototypes; however, this range of susceptibility does not exist for the eyes upon solar UVR exposure and people of all racial types are equally vulnerable to solar UVR-related eye disorders (ICNIRP, 2010). For this reason, it presents a problem in the process of deciding on an exposure limit that would be relevant to all (ICNIRP, 2010). Furthermore, it is difficult to extrapolate these guidelines to use them in South Africa because there are variations in ethnic population and skin phototypes, risk policies, risk assessment processes and available peer reviewed data in different countries and organisations (Deveau *et al.*, 2015).

2.10 Solar UVR measurement methods

Simple methods to measure solar UVR have been available since the 1970's because there was a need for data regarding solar UVR exposure because of its negative health effects and thinning of the O₃ layer (Diffey, 2020). Currently there are many methods available for measuring personal solar UVR exposure with benefits and drawbacks (Osman and Omar, 2016). The most popular measuring instruments include electronic dosimeters (Allen *et al.*, 2020), PSF badges (Diffey, 2020) and handheld UV monitoring instruments (Hadjee, 2020).

This study made use of PSF badges because of its ease of use, ability to measure a wide spectrum range and ability to attach to a participant's body (non-invasive and slight or no obstruction of movement) and can be used over multiple sites (small size) on the participant's body to be able to determine anatomical distribution of solar UVR exposure (Diffey, 2020).

2.11 Occupational exposure to solar UVR in South Africa

Previous studies relating to solar UVR exposure in South Africa have yielded different results regarding solar UVR exposure that may have been due to studies focusing on different occupational groups with different work activities, different geographical areas, seasons, and time of day. Additionally, different measuring equipment and methods were used in each study to determine solar UVR exposure which may have led to different findings. Makgabutlane and Wright (2014), have found that a general outdoor worker working in a garden and a field in Pretoria (Gauteng), was exposed to 84.11% solar UVR that reached the ground. The outdoor worker of this study experienced exposure to UVI values between 3.14 – 4.66 in sunny conditions in the autumn season. It was also found that exposure to solar UVR was the highest between 09:30 and 13:00 when measurements occurred (Makgabutlane and Wright (2014). Nkogatse *et al.*, (2018) measured solar UVR exposure of car guards during the early spring season in Potchefstroom (North West Province), with electronic dosimeters and determined that these outdoor workers received 24% of the ambient solar UVR exposure and exposure ranged from 0.005 – 0.075 SED. Exposure to solar UVR was determined to be highest between 09:00 and 15:00. Similarly, Hadjee, (2020) performed a study in Potchefstroom (North West Province) and determined that car guards experienced high levels of solar UVR exposure in summer (0.05 – 1.77 SED) and winter (0.07 – 1.03 SED) months, but exposure was determined to be higher in summer months. Another study was recently published by Linde *et al.*, (2022), who measured personal solar UVR exposure with PSF badges. The occupational exposure target group was farmworkers that worked on a Macadamia farm located in the Limpopo province. The data of this study has indicated high solar UVR exposure on farmworkers arms in autumn and the highest solar UVR exposure occurred on the top of the head during spring and summer (Linde *et al.*, 2022). Variations in data regarding peak exposure, limited outdoor occupations researched and different percentages of ambient solar UVR received indicate that more research is needed in different provinces in South Africa. But the fact remains that South Africans are at risk to develop adverse health effects and reveals the need for more research in South Africa (Rother *et al.*, 2020).

2.12 Security guards' risk of solar UVR exposure

Studies specifically mentioning security guards or security officers as well as solar UVR exposure are scarce. However, some studies have mentioned security guards or officers as part of their study focusing on the effects of shift work, workplace challenges, and coping mechanisms in the work environment (Du Toit, 2015; Bazana *et al.*, 2017). A study was undertaken in South Africa by Bazana *et al.* (2017) to determine the impact of shift work on the health and well-being of campus security guards. The study considered the effects of the working environment on performance and health of security guards. The study found that security guards complained about working conditions which included those relating to the weather that made their job difficult and that they had no shade in the working environment. It was concluded that the working environment plays a role in job performance (Bazana *et al.*, 2017).

Furthermore, security guards face a heightened risk of high solar UVR exposure due to specific activities performed throughout the day. Tasks such as foot patrols and access control, which involve monitoring premises on foot or opening and closing of access control gates, are conducted outdoors where shade may be intermittent or unavailable altogether. This parallels the responsibilities of car guards, who monitor vehicles in parking lots during daylight hours and are similarly identified as a high-risk occupational group for solar UVR exposure (Nkogotse *et al.*, 2018; Hadjee, 2020).

International studies that mentioned security guards/officers include a study done in 1992 by Wong (Cited by Schmalwieser *et al.*, 2021). This study measured personal solar UVR exposure of indoor- and outdoor worker groups, finding a four-to-five-fold difference between indoor and outdoor workers' personal solar UVR exposure. This study also found that outdoor workers' personal solar UVR exposure was more dependent on leisure time exposure than indoor workers' personal solar UVR exposure. Another study that pertinently mentioned security officers was carried out by Serrano *et al.*, (2012). This study was done in Spain and measured personal solar UVR exposure of four outdoor workers groups. The study found that security guards had higher personal solar UVR exposure on their shoulders (Serrano *et al.*, 2012). Additionally, preliminary results were presented at the ESP-IUBP (European Society for Photobiology - International Union of Photobiology) World Congress 2019, held in Barcelona, Spain. This study was done in Kenya by Schoder *et al.*, (2019), where the personal solar UVR for different outdoor occupations was measured. These outdoor occupations included taxi drivers, street vendors and guards, that would be similar to outdoor occupations found in South Africa. This study found that personal solar UVR results of these outdoor occupational groups were lower than Caucasian in Europe when evaluated in respect to skin type (Schoder *et al.*, 2019). During leisure time it is one's choice to expose yourself to solar

UVR and to what extent, outdoor workers do not have a choice and need to work in certain conditions whether they like it or not (Schmalwieser *et al.*, 2021). Therefore, further research is necessary to ensure that the conditions of outdoor workers are recognised and improved.

Protection officers (North-West University (NWU) terminology) or more commonly known as, security guards fulfil an important function in society through providing protection to people and properties (Du Toit, 2015). The duties of protection officers employed at the North-West University Protection Service include traffic and access control at main access gates, protection of people and buildings within the campus and prevention of criminal activities occurring on campus (NWU, 2021). Most of these duties may be intermittently based on duties that need to be performed during the day or dependent on where a protection officer is assigned to work for the day (outdoors or indoors) (D. Ayob personal communication, February 22, 2021). In addition, Grandahl *et al.* (2017) acknowledged solar UVR exposure among outdoor workers as an occupational health problem that has been neglected for too long. Therefore, an urgent need for further research regarding different outdoor occupational groups (Hault *et al.*, 2016) is needed as well as personal solar UVR exposure of outdoor workers in different South African provinces. Many argue that insufficient data regarding exposure - whether recreational or work related is the main reason why policy making, and classification of various skin cancers as occupational diseases are burdensome. However, the fact remains that solar UVR exposure can be quantified and therefore improved (John *et al.*, 2020).

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CHAPTER 3 ARTICLE

AUTHOR GUIDELINES

The following article will be submitted to the *Annals of Work Exposures and Health* and is therefore written in the prescribed journal format as stated on their website as part of preparing for submissions.

Annals of Work Exposures and Health is a journal dedicated to advances in exposure sciences. The journal is focused on publishing articles to help readers understand, quantify and control conditions better in work environments that may affect the health and well-being of employees in either a harmful or a beneficial way.

Language: Manuscripts must be written in English, either British or American styles and spelling are acceptable as long as one style is used consistently. Manuscripts must be written in simple and clear language and words or phrases which might be unclear should be avoided or clearly explained. Manuscripts must be written in good English, and it is recommended that language editing be done before submitting, however, this will not guarantee acceptance of manuscripts.

Brevity: The length of the paper depends on the subject. However, any submission must be brief and consistent. The number of words must be stated as a message to the editor and do not include the abstract, references, tables, and figures as part of the word count. Word count must be limited to 5000 words and justification will be needed when this amount is exceeded.

Title, abstract and keywords: The title of the manuscript must describe the major issue examined by the paper. Additionally, searchable terms or keywords must be included for readers to find a paper efficiently.

Authorship: Authorship is limited to persons who significantly contributed to the design or execution of the work described in the manuscript. All other contributors whose participation does not meet the criteria for authorship should be acknowledged in the article. Authors will be contacted to confirm their roles and after submission, no changes may be made to the authors list.

Units and symbols: SI units must be used and their equivalents in other systems may be given as well.

Tables: Tables should be numbered consecutively and given a suitable caption. Figures should be incorporated into the text with the first submission.

References: The CSE Scientific Style and Format 8th edition with name-year reference style should be used. Referencing should be in alphabetical order and all authors should be included unless there are more than 10. The accuracy of the references is the responsibility of the authors.

Reference examples:

Journal Article:

John SM, Garbe C, French LE, Takala J, Yared W, Cardone A, Gehring R, Spahn A, Stratigos A. 2021. Improved protection of outdoor workers from solar ultraviolet radiation: position statement. *Journal of the European Academy of dermatology and venereology*, :35(1):1278-1284 (DOI: 10.1111/jdv.17011)

Ethics: Upon request, the original data must be presented to the editor for inspection. The ethics committee which gave approval must be named in the paper.

Funding and potential conflict of interest: At the time of submission, the corresponding author must complete a form concerning the authorship and potential conflict of interest on behalf of co-authors.

Data Availability: Authors are required to include a statement on Data Availability in their article.

Solar ultraviolet radiation exposure of security guards at a South African university

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Keywords: Solar ultraviolet radiation, personal exposure, security guards, PSF badges, South Africa

5062 words

3.1 Abstract

Introduction Security guards face heightened risks of solar UVR exposure due to the predominantly outdoor nature of their work. The elevated ambient solar UVR levels in South Africa, particularly at the latitude of the study location in Potchefstroom, increase the likelihood of security guards experiencing various negative health effects associated with solar UVR exposure, ranging from sunburn to skin cancer. This study aimed to assess the personal solar UVR exposure on different anatomical areas, as well as the objective skin colour of participants, including constitutive and facultative skin. Additionally, the study investigated the behaviours and sun-related knowledge of security guards through a questionnaire and evaluated the protective capabilities of their uniform shirts.

Method Polysulphone film (PSF) badges were placed on the vertex-, on the shoulder-, under the uniform shirt and on the forearm of security guards working at a university in South Africa, North West Province, Potchefstroom, to measure solar UVR. Solar UVR exposure was monitored for eight days during both summer and winter seasons. A skin colorimeter was used to measure the Individual Topological Angle ($^{\circ}$ ITA) of facultative and constitutive skin colour of the participant group.

Results The vertex (top of the head) showed the highest exposure to solar ultraviolet radiation (UVR) during both summer (average = 1.869 J/m²) and winter (average = 1.481 J/m²). Significant differences in exposure levels were observed among various anatomical areas during both seasons, except for the forearm and under the shirt exposure during winter. Type IV (tan) was the most common constitutive skin colour, while Type V (brown) and Type VI (dark) were the predominant facultative skin colours. Only 18% of participants were familiar with what solar UVR is, while 50% reported wearing hats "sometimes" and 39% "always," indicating a need for enhanced knowledge and practices concerning sun protection. On average, uniform shirts blocked 34% of solar UVR during summer and 5% during winter, indicating that they offer some protection against solar UVR exposure for participants.

Conclusion Security guards do not receive high levels of solar UVR exposure. It is possibly due to security guards working in shaded areas such as security booths and awnings. Most security guards had constitutive skin that classified as tan or Type IV according to $^{\circ}$ ITA measurements.

Keywords Solar ultraviolet radiation, skin colour, security guards, PSF badges, sun behaviour and knowledge

3.2 Introduction

Solar ultraviolet radiation (UVR), an environmentally abundant stressor, is responsible for numerous health risks, due to its high energy and short wavelength properties (UVA: 315-400 nm, UVB: 315-280nm and UVC: 280-100nm) (Sadeq *et al.*, 2022). Solar UVR exposure leads to the development of many health conditions such as sunburn, cataracts, and cancer, especially affecting the skin and eyes (Sadeq *et al.*, 2022; Burattini *et al.*, 2021). Nevertheless, solar UVR is rarely emphasised as a major risk factor when compared to other work-related hazards (John *et al.*, 2020). Therefore, attention should be drawn to outdoor workers' solar UVR exposure because these workers are more susceptible to negative health effects due to spending many hours outside.

Prior research regarding personal solar UVR exposure in South Africa has been limited to certain occupations and provinces such as a groundskeeper (Pretoria, Gauteng province), car guards (Potchefstroom, North-West province) and farm workers (Limpopo province) (Makgabutlane and Wright, 2014; Nkogatse *et al.*, 2018; Linde *et al.*, 2022). Exposure measurement studies yielded varying results that may be due to differences in instruments being used, locations and seasons. Findings revealed that a groundskeeper and car guards may be exposed to 80% and 24% of the ambient solar UVR, respectively (Makgabutlane and Wright, 2014; Nkogatse *et al.*, 2018). Certain anatomical areas receive more solar UVR exposure than others due to postures adopted by the workers while working. More specifically, areas such as the nape of the neck, forehead, cheeks, forearms and top of head have been found as the most exposed anatomical areas (Nkogatse *et al.*, 2018; Nardini *et al.*, 2014; Linde *et al.*, 2022). A study by Linde *et al.*, (2022) that used PSF badges, indicated that the highest personal solar UVR exposure for autumn occurred on the arm (7.8 SED) and the highest personal solar UVR exposure for summer (13.9 SED) and spring (11.6 SED) occurred on the top of the head (Linde *et al.*, 2022). All these measurements exceeded the ICNIRP daily exposure limit of 1.0 – 1.3 SED or 30 J/m². Previous research, conducted in Valencia, Spain, indicates that security officers spend on average 9.28 hours outdoors and receive mean solar UVR exposure of 6.6 SED (Serrano *et al.*, 2012). Therefore, security guards were chosen as study population because security guards were identified as an outdoor occupation that may possibly have high solar UVR exposure during their working day.

Skin pigmentation of participants is an important factor to consider when evaluating solar UVR exposure measurements since it describes the individual sensitivity for and reaction to solar UVR exposure. The pigment produced in the skin, namely melanin, can be described as a natural

sunscreen, (McKnight *et al.*, 2021). Thus, individuals with less pigmented skin have less initial protection than individuals with more pigmented skin. It has been noted that most of the South African population have more pigmented skin, causing greater initial protection against solar UVR (Dlova *et al.*, 2018). Nevertheless, research indicates that people of all population groups are at risk to develop pathological conditions such as skin cancer (Song *et al.*, 2021) as well as pathological conditions related to the eyes. However, no range of individual susceptibility exist for the eyes (ICNIRP, 2010)

Knowledge, behaviour, and practises also play a major role in workers' solar UVR exposure. Due to higher risk of skin cancer in white population groups, education and awareness programs are mainly directed towards the white population and sunscreen is being promoted with the restricted idea of only protecting people with lighter skin against sunburn (Dlova *et al.*, 2018). As a result, white population groups are more likely to practice protective behaviour than African or Indian population groups in South Africa while those with darker skin types are unaware of risks caused by sun damage, skin cancer and benefits of sunscreen (Dlova *et al.*, 2018). Nkogatse *et al.* (2018) reported that 83% of outdoor workers (car guards) do not receive any type of sun-safety education or training, where only a few studies in South Africa considered solar UVR knowledge and behaviour of participants important enough to research (Wright and Norval, 2021). However, one of the legislative requirements in the new draft Physical Agents Regulation published in 2022, require employers to provide employees with information, instruction, and training related to solar UVR exposure as an occupational hazard, although information, instruction and training is a good start no indication of an Occupational Exposure Limit (OEL) for solar UVR exposure is given (Department of Employment and Labour, 2022)

Many argue that insufficient data regarding occupational solar UVR exposure is the main reason why policy making, and classification of various skin cancers as occupational diseases are burdensome, implying the need for improvements in solar UVR exposure quantification (John *et al.*, 2020). Therefore, the aim of this study was to evaluate personal solar UVR exposure of security guards on different anatomical sites to determine the health risk posed by solar UVR exposure to security guards. The skin colour and the level of photoprotection used by security guards were also evaluated as they are factors that influence the workers' susceptibility to solar UVR as well their risk of being exposed to high levels of solar UVR.

3.3 Materials and Methods

3.3.1 Study area and design

The following quantitative study was performed at a South African university in Potchefstroom, North West Province. Data was collected at a latitude of 26.6905° S, 27.0932° E and altitude of approximately 1400 metres. The North West Province can be described as a flat interior plateau or highveld area, that should receive higher ambient solar UVR levels due to smaller latitude values.

3.3.2 Study population

Security guards work in outdoor environments where shade may be intermittent or not available at all depending on shift assignments, which could lead to high personal solar UVR exposure. Security guards are generally responsible for access control as well as protection of people and properties. A total of 48 male and female security guards of different population groups works at the university. A group of 12 security guards are on duty per shift that starts at 6 am and ends at 6 pm.

Security guards that work indoors and outdoors were eligible to be included in the study. This was due to indoor and outdoor security guards rotating a few times daily, between the control room and foot patrol, meaning that they are all likely to receive solar UVR exposure. Only security guards who are employed fulltime at the university were eligible to participate in the study to ensure the exposure for the entire day was measured. A total of 28 security guards provided written informed consent to participate in this study during the summer and winter periods of measurement. Both winter and summer measurements were taken over a period of eight days. This study was approved by the Human Research Ethics Committee (HREC) of the North-West University (Reference number: NWU-00332-21-A1).

3.3.3 UVR dosimeters and calibration

3.3.3.1 PSF badges

Polysulphone film (PSF) badges were used for this study. These badges were prepared by mounting the PSF film in white cardboard holders to form a sturdy PSF badge by the University of Manchester, United Kingdom. PSF badges can be described as small translucent film that changes absorbance properties when exposed to solar UVR.

3.3.3.2 Calibration curve for PSF badges

PSF badges are produced in batches, therefore variation may occur, and calibration is necessary. Before calibration, the absorbance of each PSF badge (A_{pre}) were measured using a UV spectrophotometer (DLABSP-UV1000). PSF badges were marked and placed in small brown envelopes to prevent UVR exposure. A total of 48 PSF badges were prepared for calibration.

Calibration occurred at the Disaster Risk Management Offices located in Mahikeng, North West province where a UV radiometer (Model UVS-E-T; Manufacturer Kipp n Zonen) was used. Calibration was done over a period of eight hours with all the badges being placed near the radiometer. Then one badge was removed at 10-minute intervals and placed back into a marked brown envelop. The post exposure absorbance of each badge was measured (A_{post}). The difference (Δ) between pre- and post-exposure were calculated and plotted against the radiometer data. The resultant line equation ($y = a\Delta^2 + b\Delta$) obtained from the calibration curve was used to calculate the total exposure values in J/m^2 .

3.3.3.3 Solar UVR exposure data unit of measurements

The UV radiometer utilized for calibrating PSF badges (Model UVS-E-T; Manufacturer Kipp n Zonen) measured solar radiation in watts per square meter (W/m^2). Consequently, solar UVR exposure data was initially calculated in W/m^2 and subsequently converted to joules per square meter (J/m^2). The radiometer's spectrum measurement extended beyond the erythral irradiance component, and no correction factor for this instrument was available. Therefore, exposure data remained in J/m^2 , allowing for comparison to the optimal human biologically efficient radiant exposure range for both the eyes and skin of $30 J/m^2$ (ICNIRP, 2010).

3.3.4 Measurement of solar UVR exposure at anatomical positions

3.3.4.1 Preparation of PSF badges before measurements

Before measurements occur the PSF badges' absorbance (A_{pre}) were measured using the UV spectrophotometer as was the case during calibration. Each PSF badge were marked with the participants code and a corresponding alphabet letter referring to each anatomical area where the PSF badges were placed. Each badge was placed inside a marked brown envelope to protect them from exposure, and the values were recorded.

3.3.4.2 Measurement methodology

A total of four PSF badges were attached to each participant as illustrated in Figure 1. Three of the areas, namely the vertex (on the top of the head), right acromial shoulder (point of the shoulder) and the front right mid-forearm, were chosen because they may have the highest solar UVR exposure due to postures adopted by the security guards (Linde *et al.*, 2022). Additionally, the fourth PSF badge was attached under the security guards' uniform shirts to determine if any UVR could move through the fabric of their uniform shirts. The PSF badges were attached to the skin using surgical tape while the PSF badge that were placed on the top of the head were attached to a wide-brimmed hat in the summer and a beanie in the winter, which were provided by the researchers.

3.3.4.3 Procedure after measurements.

At the end of security guard's shift, PSF badges were removed and placed back into their marked brown envelopes to avoid further exposure that may cause further changes to the films. The PSF badge's post absorbance (A_{post}) was measured, and the values were recorded. The UVR doses (J/m^2) were calculated with the equation obtained during calibration for each PSF badge that was placed on the participant's body.

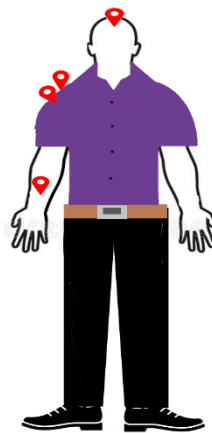


Figure 1. Placement of PSF badges on participant's body.

(Adapted from Dreamtime Design - Hladii, N- human silhouette adapted through adding clothes, shoes and PSF badge location)

3.3.5 Skin parameter measurements

The Skin-Colorimeter CL 400 wireless probe were used, to determine the objective skin colour of participants through measuring the Individual Typology Angle ($^{\circ}$ ITA) value and classifying it into a skin colour group (Courage + Khazaka Electronic, 2021). The skin was cleaned with hypoallergenic wipes and allowed to stabilise for a period of 20 minutes. Measurements were taken on two different anatomical locations: on the facultative skin (posterior side of the forearm) and constitutive skin (upper anterior side of the forearm). The probe was placed on the skin with light and constant pressure applied. Three measurements were taken in adjacent areas on the skin of each participant and an average calculated for each area. The probe was cleaned with soft tissue paper after each measurement. Table 1 below illustrates the skin colour classification groups according to the measured $^{\circ}$ ITA. Figure 2 illustrates the skin colour and how it is determined by the skin colorimeter as described by the skin-colorimeter's manual.

Table 1. Skin colour classifications according to $^{\circ}$ ITA

Skin colour phototype	$^{\circ}$ ITA range	Skin colour description
I	$^{\circ}$ ITA > 55	Very-light
II	$55 > ^{\circ}$ ITA > 41	Light
III	$41 > ^{\circ}$ ITA > 28	Intermediate
IV	$28 > ^{\circ}$ ITA > 10	Tan
V	$10 > ^{\circ}$ ITA > -30	Brown
VI	$-30 > ^{\circ}$ ITA	Dark

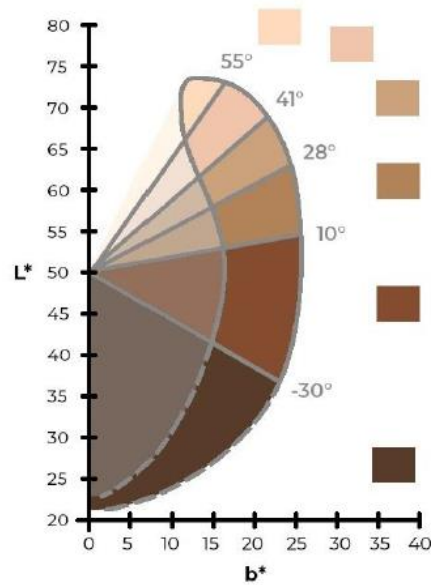


Figure 2. Skin colour according to °ITA calculated using L* lightness or brightness of skin and b* pigmentation present in the skin (Courage + Khazaka Electronic, 2021).

3.3.6 Evaluation of knowledge, attitudes, and behaviour/practises

The questionnaire used in this study was validated in previous studies such as Nkogatse *et al.*, (2018) and adapted for this study, adding questions about uniform shirts worn by security guards. The first part of the questionnaire aims at collecting biographical details, such as age and gender, as well as history of outdoor occupation. The second part of the questionnaire covers aspects related to knowledge and attitudes regarding sun exposure. The last part of the questionnaire asks questions relating to uniform shirts, worn by security guards. The questionnaires were available in English, Afrikaans, and Setswana.

3.3.7 Data analysis

All data was analysed with IBM SPSS (version 27) (IBM, 2021) and all graphs were created with GraphPad Prism (version 9) software (GraphPad, 2020). The significance level was set at $p \leq 0.05$. Further specific statistical tests were conducted on each dataset based on the distribution of the data.

3.3.7.1 Data analysis of solar UVR exposure data

Descriptive statistics were utilised for summer and winter solar UVR exposure data. All data was found to be non-normally distributed, therefore, non-parametric tests were used such as Friedman and Wilcoxon signed-rank test. The Friedman test was used to determine statical significance in

measurements between different anatomical areas within each season. The Wilcoxon signed-rank test was used to determine if mean values of two dependent groups of summer and winter measurements differ significantly from each other. Post hoc analyses with Wilcoxon signed-rank tests were conducted using a Bonferroni correction. Furthermore, the average solar UVR exposure measurements for summer and winter on anatomical areas such as the shoulder and under the shirt were utilized to determine the typical amount of solar UVR blocked by standard uniform shirts.

3.3.7.2 Data analysis of skin parameter measurement data

Descriptive statistics were done for the constitutive and facultative °ITA measurements, including the mean, median, standard deviation, minimum and maximum. The °ITA values of the constitutive and facultative skin were analysed with a Kruskal Wallis test to compare median values for constitutive and facultative skin measurements.

3.3.7.3 Data analysis of evaluation of knowledge, attitudes, and behaviour/practises of participants

Questionnaire data were analysed through descriptive statistics indicating frequency, percentage, valid percentage, and cumulative percentage. The valid percentages were reported because several questions had the option to give more than one answer.

3.4 Results

3.4.1 Personal solar ultraviolet radiation measurements for winter and summer on different anatomical sites

In both the summer and winter seasons, the vertex of the head received the highest mean exposure as well as the maximum values of solar UVR exposure (summer mean: 1.869 J/m² and maximum: 2.890 J/m²; winter mean: 1.481 J/m² and maximum: 2.230 J/m²) (Table 2). As seen in Figure 3, the mean exposure on any of the anatomical areas did not exceed the 30 J/m² as prescribed by the ICNIRP during either winter or summer (ICNIRP, 2010).

Table 2. Descriptive statistics for summer and winter solar UVR data on different anatomical sites (J/m²).

	Summer				Winter			
	Head	Shoulder	Under Shirt	Forearm	Head	Shoulder	Under Shirt	Forearm
Mean	1.869	1.622	1.064	1.753	1.481	1.110	1.052	1.060
Median	1.926	1.662	1.067	1.812	1.458	1.093	1.061	1.038
Std.	0.458	0.246	0.056	0.312	0.224	0.092	0.038	0.118
Range	1.800	0.950	0.360	1.170	1.140	0.750	0.150	0.940
Min	1.090	1.080	0.960	1.060	1.080	0.850	0.960	0.730
Max	2.890	2.030	1.320	2.230	2.230	1.600	1.120	1.660

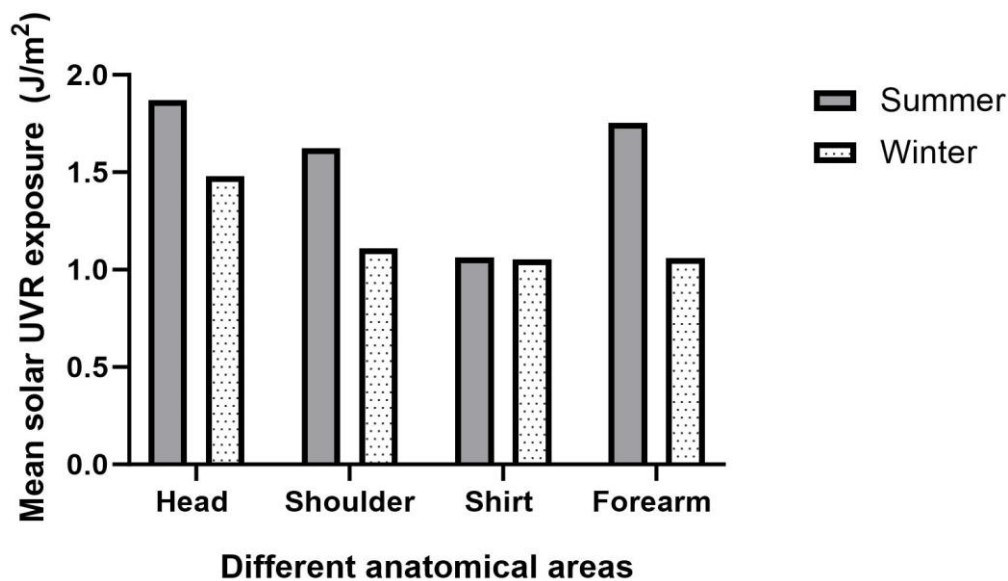


Figure 3. Mean solar UVR exposure for different anatomical areas for the summer and winter season.

Difference between solar UVR measurements in summer and winter

A non-parametric Friedman test of differences among repeated solar UVR exposure measures in winter and summer for different anatomical areas was conducted and it was found that among all anatomical areas for both winter ($X^2(2) = 166.684$, $p < 0.001$) and summer ($X^2(2) = -117.938$, $p < 0.001$) there were statistically significant differences. The comparisons between the anatomical areas during summer were all found to be statistically significant namely between shoulder and the forearm ($X^2(2) = -3.114$, $p = 0.002$), forearm and head ($X^2(2) = 2.241$, $p = 0.025$), head and under the shirt ($X^2(2) = 10.026$, $p < 0.001$) and shoulder and head ($X^2(2) = 5.355$, $p < 0.001$).

Winter data indicated that all anatomical areas had statistically significant differences with a p value of < 0.001. This was also seen when the different anatomical areas were directly compared with each other, except when comparing solar UVR exposure on the forearm and under the shirt, that was found to be not statistically significant ($\chi^2(2) = 0.987, p = 0.324$).

Comparison of summer and winter solar UVR exposure on different anatomical sites

The Wilcoxon signed-rank tests showed that there was a statistically significant difference between the solar UVR that fell on the vertex (top of the head) ($\chi^2(2) = -4.051, p = <0.001$), forearm ($\chi^2(2) = 6.193, p = <0.001$), and shoulder ($\chi^2(2) = 6.095, p = <0.001$) in the winter and summer season. However no statistical difference was found between summer and winter data for under shirt measurements ($\chi^2(2) = 1.656, p = 0.098$).

3.4.2 Skin parameter measurement data of participants

Skin photo type IV is the most commonly constitutive skin colour type found among participants with a frequency of 11. In contrast, Types V and VI were the most common facultative skin colours with a frequency of 13 for both types. As seen in Table 3, the maximum value for constitutive skin was 59.00, indicating an °ITA skin colour group of very-light colour and the maximum value for facultative skin indicating an °ITA skin colour group of a darker colour. Maximum skin colour of constitutive skin colour group and facultative skin colour group differ by between the two groups (hence about two shades darker than genetically determined).

A Kruskal-Wallis test was performed to determine the difference between the constitutive and facultative °ITA values. The differences between medians of the constitutive and facultative °ITA values found to be statistically significant, where $H(4) = 89.24, p = <0.0001$

Table 3 Descriptive statistics for constitutive and facultative skin colour based on °ITA data

Variable	Constitutive skin	Facultative skin
Mean	-6.179	-24.930
Median	-13.00	-26.00
Standard deviation	4.361	3.079
Minimum	-35.00	-42.00
Maximum	59.00	24.00

Figure 4a

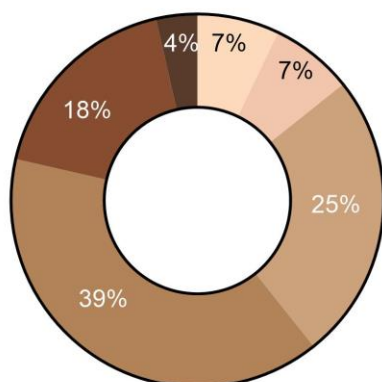


Figure 4b

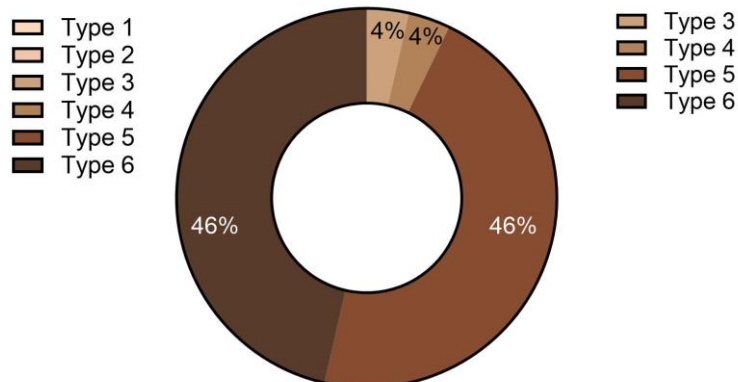


Figure 4: Constitutive (4a) vs facultative (4b) °ITA measurements of participants

As indicated by Figure 4, most participants' constitutive °ITA skin colour measurements were classified as Type IV - tan. However, the majority of facultative skin colour of participants were classified as Type V - brown and Type VI – dark.

3.4.3 Evaluation of knowledge, attitudes, and behaviour/practises of participants

As indicated in Table 4, most participants were male (89%), however a few females were included (11%). Most participants were aged between 40 – 49 years (68%) followed by the group aged between of 50 – 59 years. The most prevalent population group of participants was black (85%) but also included of populational groups of white (4%) and coloured (11%).

Table 4 Demographic characteristics of the study participants

Variable	Scale used	n (%)
Gender	Male	25 (89%)
	Female	3 (11%)
Age	Years	
	< 30	1 (4%)
	30 – 39	2 (7%)
	40 – 49	19 (68%)
	50 – 59	6 (21%)
Population group	Subjectively chosen.	
	Black	24 (85%)
	Coloured	1 (4%)
	White	3 (11%)

Most participants indicated that they spend their breaks in shady areas (79%) and 21% of participants indicated that they move around. Participants (89%) in this study indicated that they

never applied sun block while working. However, most participants wore hats while outdoors during working hours, where 50% of participants agreed that they sometimes wear hats and 39% stated that they always wear hats as shown by Table 5 results below.

Table 5 Practises and behaviour of participants when working in the sun.

Question	Scaled used	(%)
In which type of area do you spend your breaks (lunch and tea times)	Sunny area	0%
	Shady area	79%
	Semi-shaded area	0%
	I move around between different types of area	21%
Do you apply sun block while working in the sun	Never	89%
	Sometimes	11%
	Always	0%
How often do you wear a hat when outdoors during working hours	Never	11%
	Sometimes	50%
	Always	39%

As seen in Table 6, most participants (82%) indicated that they do not know what UVR was. Additionally, most of participants were not aware that sunburn causes permanent damage to the skin (67%). However, participants recognised that spending a lot of time in the sun is the most important risk factor for skin cancer (89%).

Table 6. Solar UVR knowledge of participants

Question	Scaled used	(%)
Do you know what UVR is	No	82%
	Yes	18%
Spending a lot of time in the sun is the most important risk factor for skin cancer	No	4%
	Yes	89%
	I do not know	7%
When the sun burns your skin, it causes permanent damage	No	67%
	Yes	33%

3.5 Discussion

3.5.1 Personal solar ultraviolet radiation measurements for winter and summer on different anatomical sites

Security guards received lower solar UVR exposure than what was found by other studies about other outdoor workers. It was found that security guards receive an average exposure of 1.87 J/m² on their vertex (top of head) and 1.75 J/m² on their forearm in summer. When comparing

South African security guards solar UVR exposure to international security officers solar UVR exposure in Spain, Valencia, higher solar UVR exposure (6.6 SED / 660 J/m² on the shoulder) was observed for security officers in Spain. High solar UVR exposure for these security officers may have been due to the study taking place in an open country area that may have more open spaces with less shade (Serrano *et al.*, 2012). Other South African based studies found that car guards received an average of 0.29 SED (29 J/m²) on their upper arm during spring and outdoor farmworkers receive an average of 4.9 SED (490 J/m²) and 9.1 SED (910 J/m²) on their arms during spring and summer (Nkogatse *et al.*, 2018; Linde *et al.*, 2022). Lower solar UVR exposure received by security guards may be due to security guards making use of the opportunity to work in the shade when on duty, which has been identified as a strategy for sun protection (Lucas *et al.*, 2016) (e.g., awnings and security booths at boom gates) which may lead to lower solar UVR exposure. Most participants reported that they spend their tea and lunch breaks in shaded areas, which could significantly reduce outdoor workers solar UVR exposure (Reinau *et al.*, 2013). Therefore, most security guards have lunch and teatime in their security booths or in the parade room (also known as a locker room) which may lead to lower solar UVR exposure.

The highest average exposure that security guards received were on the vertex (top of the head) in both the summer and winter season. Similar results were found by Linde *et al.*, (2022), where the highest exposure for farmworkers in summer and spring were found to be on the top of the head. In addition, Hadjee, (2021) estimated anatomical exposure to solar UVR which also indicated that the highest dose of solar UVR exposure for car guards would be on top of the head. However, other studies found that the nape of the neck was the most exposed anatomical area for car guards (estimated exposure) and farm workers (Nardini *et al.*, 2014; Nkogatse *et al.*, 2018). The reason for these differences in the most exposed anatomical area may be the different body postures or working positions adopted by the different workers during each day. Research has shown that solar UVR exposure for specific anatomical sites differed for different activities (Nardini *et al.*, 2014; Linde *et al.*, 2022). Security guards mostly sit or stand while working which would cause the top of the head to be more exposed than other anatomical sites such as the nape of the neck which would be more exposed in positions such as bending over (e.g., working in a field).

In summer, all anatomical area measurements were found to be statistically significant from each other indicating different levels of exposure. Therefore, security guards may have been sitting and standing exposing the horizontal and vertical plane. However, as found in research, the horizontal plane (e.g., top of the head) receives higher solar UVR exposure than the vertical planes (face,

neck and arms) (Milon *et al.*, 2014). Hence, it can be assumed that security guards adopted a position such as standing that would favour horizontal plane exposures to a greater extent. This working position would correspond with duties such as access control or foot patrol. The measurements under the shirt also differed statistically significantly with all other anatomical areas.

Additionally, the mean solar UVR exposure for measurements taken under the shirt was lower compared to other anatomical areas. When calculating the percentage of solar UVR blocked by the uniform shirt using the mean solar UVR exposure data for summer and winter on the shoulder and under the shirt, it was found that on average, 34% of solar UVR was blocked by the uniform shirt in summer and 5% in winter. This suggests that uniform shirts offer some level of protection against solar UVR reaching the skin they cover, as supported by previous research indicating that different fabric types can block solar UVR (Berry *et al.*, 2022).

In winter, all anatomical areas were found to be statistically significant different from each other except for the forearm and under the shirt measurements. Therefore, the forearm was shielded to the same degree as under the shirt, possibly by the body or this area was exposed less during the winter. Similarly found for summer measurements, mean winter solar UVR exposure for the under the shirt measurements had the lowest mean exposure when compared to other anatomical areas. Therefore, it may indicate that uniform shirts lower solar UVR exposure, therefore, providing some protection against solar UVR. This protection may be due to the type of fabric that the uniforms are made of.

3.5.2 Skin parameter measurements data of participants

The most frequent constitutive skin colour found in the security guards participant group was °ITA Type IV skin colour, described as tan in a population group of Black, White, and Coloured individuals in the North West province. This is in contrast with what Linde *et al.*, (2020) found for farmworkers, consisting of population groups of Black or White participants that worked on a farm in the Limpopo province. These farmworkers had constitutive skin colour that mostly classified as Fitzpatrick Skin Phototype (FST) Group 5 – brown. Furthermore, Wright *et al.*, (2015) found that most of the South African population had constitutive skin colour of °ITA Type V – Brown, out of a population group consisting of Black, Indian/Asian, White, and Coloured in Gauteng province. These differences may be due to bigger samples sizes as well as difference in anatomical area measured, where Wright *et al.*, (2015) measured on the inner forearm and Linde *et al.*, (2020)

measured on the inner upper arm as well as difference in population groups and geographical locations in South Africa.

However, the facultative skin colour's most frequent °ITA group was Types V and VI, indicating that constitutive skin colour is less pigmented than facultative skin colour. This was similar to the findings of Linde *et al.*, (2020) who found that constitutive and facultative skin colour differ statistically significantly, which could be due to protection provided by clothing such as a shirt with sleeves protecting the inner forearm from exposure to solar UVR, as well as the inner forearm being shielded due to facing the body. This difference was reinforced by the statistically significant difference between the median values of constitutive and facultative skin colour. It should also be noted that facultative skin colour may differ depending on season as well as measured area (Linde *et al.*, 2020). Some anatomical skin areas may be more exposed to solar UVR than other areas due to work position (Religi *et al.*, 2016).

Research has shown that melanin content influences the skin's abilities to absorb solar UVR. Therefore, skin with higher concentrations of melanin (darker skin colours) has higher absorbing abilities that may be due to larger melanin particles (Karsten *et al.*, 2013). Most participants had a more pigmented skin colour, which means that they have greater initial protection when solar UVR exposure occurs due to their constitutive skin colour being darker.

However, solar UVR exposure of the eyes can lead to development of disease and has no variation in sensitivity such as the skin. It has been found that different types of skin cancer (CM and SCC) have different distributions, diagnosis period and severeness of effect on the health of different skin colour populations (fair- and dark-skinned populations). These variations highlight the need to approach risk factors differently for various skin colour populations to ensure more effective diagnosis and treatment (Wright *et al.*, 2019).

3.5.3 Evaluation of knowledge, and behaviour/practises of participants

Most participants indicated responsible practices and behaviours when working in the sun. Most participants indicated that they spend their tea and lunch breaks in shaded areas (79%) which would cause employees to be exposed to direct solar UVR to a lesser extent. Most participants (89%) also agreed that spending a lot of time in the sun as the most important risk factor for skin cancer. Therefore, most participants were aware that spending time in the sun is a risk factor for skin cancer and therefore preferred to spend tea and lunch times in shaded areas for protection against solar UVR.

In contrast, 89% of participants reported not to wear sunscreen while working in the sun. Recent research investigated drivers for sun protection in Black South Africans, and it was found that sunscreen was a preferred protection method for people classified in the higher income ranges while people from the lower income ranges preferred to make use of shaded areas, umbrellas, and hats (Diffey *et al.*, 2020). However, the case can be made that income ranges should not matter when it comes to occupational control measures such as personal protective equipment because according to the Occupational Health and Safety Act no deduction may be made from employees' remuneration for required items regarding health and safety (DoEL, 1993). Additionally, research has shown that people with darker skin colours do not like the white residue or white cast effect left on their skin after applying sunscreen, therefore, indicating a need for more culturally acceptable protective measures against solar UVR exposure (Song *et al.*, 2021).

Half of the participants confirmed that they sometimes wore hats when working outdoors and 39% of participants confirmed that they always wear hats when working outdoors. Therefore, employees are intermittently protected against solar UVR for one of the highest exposed anatomical areas. This behaviour can be linked to the level of knowledge of employees because only 18% of the participants acknowledged that they knew what solar UVR is. According to Diffey *et al.*, (2020), sun protection is dependent on whether persons were aware of skin cancer or not. Therefore, practises and behaviour are influenced by a person's knowledge of solar UVR exposure. Therefore, lack of knowledge of what UVR is, may cause employees to practise irresponsible behaviour and give in to practises such as wearing a hat to a lesser extent, sometimes versus always.

Research has shown that knowledge is an effective way to changing workers' behaviour and practises when working outdoors. When people are made aware of a risk and the consequences, they are more likely to act and behave in a way to reduce the risk. Therefore, knowledge is the most important component in lowering solar UVR exposure. However, a small number of participants knew what solar UVR was and only 33% of participants agreed that sunburn causes permanent damage to the skin. Similar results were found where only 31.2% of a combined population group of Black, White, and Indian participants knew that sunburn is a form of skin damage (Dlova *et al.*, 2018). Therefore, it is evident that there is a lack of knowledge related to solar UVR exposure among security guards. Moreover, recent research indicated that the general South African population also lacks knowledge related to solar UVR exposure (Dlova *et al.*, 2018).

3.6 Conclusion

Participants received solar UVR exposure that was lower than the ICNIRP exposure limit of 30 J/m² (ICNIRP, 2010). However, participants are still potentially at risk because as shown by Nkogatse *et al.*, (2018), a study also performed in Potchefstroom (North West province), participants were exposed to 0.24 SED around 12:10 pm (24 J/m²). High solar UVR exposure values can be reached within 10-minute time intervals. This is a result of meteorological factors that change constantly, which influences solar UVR exposure by enhancing or decreasing exposure such as stratospheric ozone, cloud coverage, solar zenith angle (SZA), season and aerosols (Belan *et al.*, 2020). Therefore, changes in meteorological conditions may lead to peaks in solar UVR exposure and security guards may still be at risk to develop pathological conditions related to the skin and eyes. Overall, the study population do have more pigmented skin types which would cause greater initial protection against solar UVR exposure. However, the NCR found that all population groups with different ethnicities (Asian, Black, Coloured and White) were included in diagnosis statistics of SCC, BCC as well as CMM (NCR, 2019).

The study population practiced some good protective behaviours such as wearing hats and spending tea and lunch breaks mostly in the shade. However, very few participants wore sunscreen when working outdoors and research showed that sunscreen and clothing work better when used in combination with each other (Lucas *et al.*, 2016). Participants indicated low awareness to basic knowledge regarding solar UVR, which may indicate that participants are not aware of the risks involved when excess solar UVR exposure occurs. Although solar UVR exposure was found to be lower for security guards at a university in Potchefstroom, North West province, this may not be the same for security guards at other workplaces in different geographical locations or occupational settings. Therefore, security guards cannot be declared “safe” when it comes to solar UVR exposure and additional research is needed to understand occupational solar UVR exposure for this group of outdoor employees.

3.7 Funding

Funding for this project was provided by the Occupational Hygiene and Health Research Initiative (OHHRI) at the North-West University.

3.8 Disclaimer

The authors of this study declare no conflict of interest.

3.9 Data Availability

All data generated and analysed during this study are available on request to ensure protection of privacy of the participants. Data may be made available upon reasonable request from the corresponding author.

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CHAPTER 4 CONCLUDING CHAPTER.

4.1 Final Conclusion

Solar UVR exposure can be described as an “invisible risk” and outdoor workers are at risk due to occupational exposure. Recent research estimates that around 1.6 billion workers are occupationally exposed to solar UVR worldwide (Pega *et al.*, 2023), where an estimated 4 million or more of these workers are in South Africa (Wright *et al.*, 2019). Given the increase in SCC, BCC and CMM rates for all population groups in South Africa, solar UVR exposure monitoring is essential for outdoor workers to ensure adequate protection and prevention of conditions such as sunburn, skin cancer and cataracts.

The primary aim of this study was to quantify personal solar UVR exposure on different anatomical areas (vertex, shoulder, under shirt and forearm) of security guards during summer and winter. Additional aims such as objectively determining skin colour of constitutive and facultative skin as well as establishing state of knowledge and behaviour of security guards were also included in this study. The primary aim was achieved by using PSF badges attached to different anatomical areas during their working day as mentioned above. An additional PSF badge was placed under the uniform shirts of security guards to determine if uniform shirts effectively blocked solar UVR exposure. Skin colour was measured using a skin colorimeter to objectively determine skin colour of constructive and facultative skin. A questionnaire was used to gather information from participants such as demographics as well as knowledge and practises.

While high levels of solar UVR exposure among security guards were anticipated as an outcome of this study, this expectation was not met. Further research should be undertaken to ascertain if protection officer’s occupation poses a lower risk of solar UVR exposure overall. Nevertheless, measured solar UVR exposure data used to quantify solar UVR exposure of protection officers on different anatomical areas indicated that summer and winter solar UVR exposure differed significantly from each other and the most exposed anatomical area for summer and winter is the vertex (top of the head). Furthermore, all anatomical area measurements for summer and winter differed significantly except for measurement taken under the shirt and on the forearm in winter. This may be due to the forearm and under the shirt areas being shielded to the same degree or less exposed occurred for these areas during the winter season. Statistical difference in summer and winter data on different anatomical areas may result from different positions favoured during work as well as different planes (horizontal or vertical).

Additionally, objective skin measurements were taken on security guards constitutive (upper inner arm) and facultative skin (lower forearm) with a skin colorimeter to determine the most prevalent skin colour within the group to analyse how the skin of this population would react to solar UVR exposure and what level of protection is provided by their skin alone. These measures were analysed and used to determine if participants would have greater or less initial protection against solar UVR exposure. The constitutive and facultative skin colour measurements differed significantly, with constitutive skin colour measurements being a lot lighter or less pigmented than facultative skin colour. Therefore, security guards' high levels of melanin in the skin as shown by darker skin colours, indicate that participants are protected against solar UVR exposure.

Workers' knowledge, attitudes, and behaviour were also evaluated using a questionnaire. Security guards answered questions regarding their knowledge of solar UVR as well as behaviour while spending time outdoors while at work. Questionnaires give valuable insights into personal solar UVR exposure of employees, and it has been noted that risk behaviour are dependent on workers' knowledge regarding solar UVR and related health effects (Hault *et al.*, 2016; Diffey *et al.*, 2020). As seen from the results of this study, participants spend tea and lunch breaks in shady areas which may lead to lower solar UVR exposure which indicate that they are taking some measures to protect against the effect of solar UVR. However, overall participants had limited knowledge regarding solar UVR. Therefore, they do not realise the extent of exposure for example on their heads and faces. This may explain the reason why participants only sometimes wore their hats and therefore, running the risk of unprotected solar UVR exposure.

4.2 Hypotheses

The study had three hypotheses formulated.

Hypothesis 1

Personal solar UVR exposure of security guards are higher during summer than winter.

Study findings indicate that there was a statistically significant difference between summer and winter solar UVR exposure. As a rule, more solar UVR exposure reaches Earth in summer than in winter. However, solar UVR exposure still occurs in winter as well. However, metrological conditions may play significant roles in solar UVR exposure and may influence these exposures resulting in possible dangerous exposures (Wright *et al.*, 2019). As a result, security guards may still need to make use of protective measures, especially in summer months. Therefore, this hypothesis is accepted.

Hypothesis 2

Constitutive and facultative skin colour measurements will differ significantly from each other.

The study's findings suggest that the °ITA measurements for constitutive and facultative skin differed significantly, indicating that constitutive skin colour is inherently less pigmented than facultative skin colour. This distinction arises because facultative skin colour is influenced by external factors such as exposure to solar UVR. Additionally, employees, with constitutive skin colour exhibit greater inherent protection due to the presence of melanin in the skin. Melanin serves as a natural protective mechanism against solar UVR. This hypothesis is accepted.

Hypothesis 3

Some portion of the UVR travels through the clothing to the skin underneath the clothing.

The study findings reveal that, on average, 34% of solar UVR was blocked by the uniform shirt during summer, and 5% during winter. This suggests that clothing offers a degree of protection against solar UVR exposure. Consequently, the hypothesis proposing that clothing provides protection against solar UVR exposure is supported by these results and is accepted.

4.3 Limitations

- Quick weather changes may have affected solar UVR exposure measurements.
- Limited number of participants were included in the study.
- After the study had commenced with all approvals and ethical clearance done, the researcher noticed that other groups working along with security guards at the university such as traffic officers, could also have been included in the study.
- There was a need for participants to be given wide brimmed hats during summer and beanies during winter for the attachment of PSF badges on the head. However, the wide brimmed hats may have blocked some solar UVR exposure on the shoulders as observed in Backes *et al.* (2018).

4.4 Recommendations

Although the solar UVR exposure of security guards were low, being cumulatively exposed to solar UVR is a risk factor for the development of many pathological conditions such as cataracts and hyperpigmentation (Baldi *et al.*, 2014). Therefore, protection measures should be put in place to prevent occurrence of the above-mentioned pathological conditions and to maintain the current low exposures due to cumulative nature of security guards' exposure.

Protection against solar UVR exposure for mobile workers such as security guards, poses a challenge and requires a proper understanding of the occupational environment as well as participants' preferences, to ensure that control measures are relevant and practical. When considering control measures, it is always preferable to start the process at the top section of the hierarchy of control, namely elimination, substitution, or engineering control. However, previously mentioned types of controls not always viable and sometimes very costly such as engineering controls for example implementing awnings. Therefore, a combination of other controls such as administrative controls and PPE are mostly used.

Administrative controls such as shift rotation, which is already in place, should be maintained to lower solar UVR exposure such as rotation of employees in control room, security booths and foot patrol. Another administrative control measure can include training on solar UVR and its effects. These training sessions can be presented by Occupational Hygiene students to security guards. This would be very beneficial for both parties because students learn soft skills and protection officers gain knowledge regarding solar UVR. However, training should be preferably refreshed every year and security guards should have information posters put up in their workplace to remind them of solar UVR exposure and its effects. Additionally, security guards should be required to go for medical surveillance on a yearly basis like most other occupations.

Last resort measures or also known as personal protective equipment (PPE) can also be considered. Very practical solutions could include providing security guards with uniforms made from fabric that have ultraviolet protection factors (UPF), seeing that security guards are required to wear uniforms. Protection officers can also be provided with wide-brimmed hats as well as sunglasses. Wide-brimmed hats would cover a bigger area of the participant's upper body such as the head and neck, which are both proven to be highly exposed areas. Sunglasses with a verified UV protecting rating could be provided to security guards. Nevertheless, PPE, such as sunglasses and sunscreen, may not align with social norms for all employees and may also contradict uniform policies (Dlova *et al.*, 2018). Participants were given wide-brimmed hats during the study and participants enquired if their caps could be replaced with the wide-brimmed hats from their supervisors because all the participants preferred the wide brimmed hats.

4.5 Recommendations for future studies

- A study should be conducted on the effectiveness of training in knowledge, behaviour and practices related to solar UVR. Participants can be divided into two groups. For example, one group should receive training on solar UVR exposure and its effects while another

group receives no training. The knowledge, behaviour, and practises of these two groups should be compared to determine if training could be an effective intervention or not. As past research suggests, sun-safety education could prove effective in enhancing outdoor worker sun protection (Reinau *et al.*, 2013).

- A study should be conducted to determine the solar UVR exposure through normal uniform clothes versus uniform clothes made from fabric with an UPF to determine if clothes with ultraviolet protection factor are effective against occupational solar UVR exposure of outdoor workers.

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LANGUAGE EDITING STATEMENT

I, Jannetje Levina De Kock,
hereby declare that the dissertation submitted in partial fulfilment of the
requirements for the degree Master of Health Sciences in Occupational
Hygiene (OHHRI)
at the North-West
University with the title

**Solar ultraviolet radiation exposure of protection
officers at a South African university**

by

Megan Combrink
28728432

- has been edited for language correctness and spelling.
- has been edited for consistency (repetition, long sentences, logical flow)

No changes have been made to the document's substance and structure (nature of academic content and argument in the discipline, chapter and section structure and headings, order and balance of content, referencing style and quality).

J L DE KOCK

ANNEXURE 2 – QUESTIONNAIRE ON SUN EXPOSURE OF OUTDOOR WORKERS



Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: <http://www.nwu.ac.za>

Created: January 2018

Adapted: June 2021

QUESTIONNAIRE ON SUN EXPOSURE OF OUTDOOR WORKERS

Dear Participant,

These questionnaires intend to measure the different aspects related to your exposure to the sun during work and off-duty time. These aspects include your history of working outdoors, your practices/behaviour in terms of the protective measures you use, attitude and knowledge about the sun in general, as well as your Fitzpatrick skin phototype. The results of the questionnaires will help us to have a better understanding of gaps that exist as well as assist us in formulating recommendations towards protecting your health and overall well-being.

We will appreciate it if you could complete the questionnaire by following instructions given for each question or group of questions. As you complete the questionnaires, please do the following:

- a) Read each question/statement carefully and mark the answer that is true for you,
- b) Clearly indicate your answer by making a cross (X) in the box with the option that is true for you,
- c) Answer as honestly as you possibly can,
- d) Answer only one question at a time,
- e) Answer all questions,
- f) Ask for help whenever you need it and

g) Do not think too much about the questions.

If the person is not able to read the questionnaire, then a researcher will help the participant to fill in the questionnaire by reading the questions to him/her and writing down the answers.

Yours sincerely

Ms K Linde, Ms CM Ramotsehoa and Ms M Combrink

karlien.linde@gmail.com, Cynthia.ramotsehoa@nwu.ac.za, megancombrink0616@gmail.com

Participant code: _____

A: Participant questionnaire on the amount of sun received and practices during

This questionnaire contains 5 parts and a total of 37 questions or statements. The aim of this questionnaire is to determine your history of outdoor work, practices and training you may have received. Please read each one carefully and answer as truthfully as you possibly can. Instructions are given for each question or a group of questions to assist you with answering them.





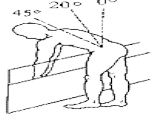
PART 1: BIOGRAPHICAL DATA/ PERSONAL INFORMATION. Mark the correct box with and X.

Work site:				Date:			
Gender	Male		Female		Age (Years)		
Ethnicity	White		Black		Indian		Coloured
In which job category are you?							
What is your highest level of education?				No schooling		Other:	
Do you know your HIV status?							
Negative		Positive		I do not know		I do not want to tell	

PART 2: THIS SECTION IS ABOUT THE WORK (JOB) YOU DID BEFORE YOU STARTED WORKING AT THE UNIVERSITY. Make a cross (X) in the box with the answer that is true for you.

A1) Did the work you do before you started working at the university involve working outside in the sun?	No	Yes
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If your answer to A1 above is Yes, then continue with Question A2 to A7, otherwise go to Question A8.

A2) How long (in years or months) did you work in the past outdoor job?					
A3) How many days of the week did you work in your previous outdoor job?					
A4) How many hours a day did you work outside in your previous job?					
A5) Which body position(s) did you adopt the most in your previous job? (Mark with an X all that are true for you)					
Sitting	Standing	Lying down	Crouching	Bending forward	
					

A6) Did you receive sun safety education and training in your previous job? If your answer is Yes, indicate the number of times you received training

No	Yes	Once	
		Two or more times	

A7) If you received sun safety education and training, which of the following aspects did your training cover in your previous outdoor job? (Make a cross (X) on all that are true for you)





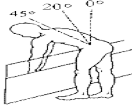
How to use sunblock	Importance of covering your skin with clothes that have long sleeves	Importance of eye protection	Importance of staying in the shade (under a tree or shelter)	Importance of skin checks
---------------------	--	------------------------------	--	---------------------------

PART 3: THIS SECTION IS ABOUT THE JOB YOU ARE DOING NOW AT THE UNIVERSITY. Make a cross (X) on the box with the answer that is true for you.

A8) How long (in years or months) have you been in the outdoor job you hold now?					
A9) How many days a week do you work in the outdoor job you hold now?					
A10) How many hours a day do you work outside in the outdoor job you hold now?					

For question A11 to A15 you are required to make a cross (X) in the box with the answer that is true for you.

A11) Which body positions do you adopt the most in the job you hold now? (Make a (X) cross on all that are true for you)

Sitting	Standing	Lying down	Crouching	Bending forward
				

A12) Do you use welding equipment during any of your work activities in the job you hold now?

Never	Sometimes	Always
-------	-----------	--------

A13) Did you receive sun safety education and training in job you hold now? If your answer is Yes, please indicate the number of times you received training

No	Yes	Once	
		Two or more times	

If you did not receive training, skip A14.

A14) if you did receive training, which of the following aspects did the training in your current job cover? (tick all applicable)

How to use sunblock creams	Importance of covering your skin with long sleeved clothes	Importance of eye-protection	Importance of staying in the shade whenever possible	Importance of skin checks	Health effects of prolonged exposure to the sun
----------------------------	--	------------------------------	--	---------------------------	---

A15) Do you work in the shade (under a tree or shelter where it is available) in the job you hold now?

	No	Yes
--	----	-----

A16) If your answer to A15 is yes, please write down the number of hours you work in the shade every day in the job you hold now?

PART 4: THIS SECTION IS ABOUT YOUR PERSONAL PRACTICES (OR YOUR BEHAVIOUR) WHEN YOU ARE AT WORK. Make a cross (X) on the box with the answer that is true for you.

A17) In which type of area do you spend your breaks (lunch and tea times)?

Sunny (Not covered)	Shady (Covered)	Semi-shady (Tree)	I move around between different types of areas
---------------------	-----------------	-------------------	--

A18) Do you apply sunblock while working in the sun?

Never	Sometimes	Always
-------	-----------	--------

A19) If you do apply sunscreen, on which parts of your body do you apply sunscreen while in the sun? Please choose all are true for you.

Face	Neck	Arms	Legs
------	------	------	------

A20) How often do you reapply sunscreen when outdoors during working hours?

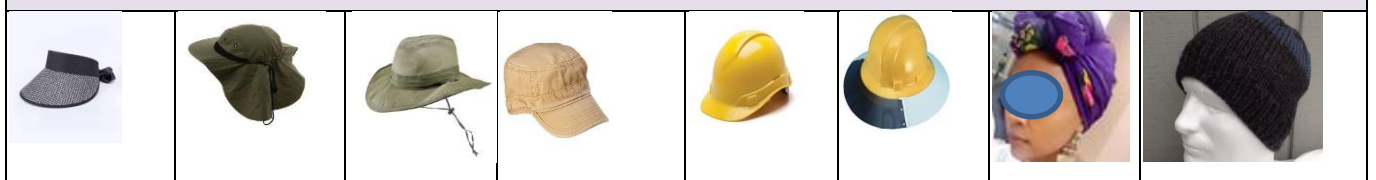
Never	Every 5 hours	Every 2 hours	Every 1 hour	More than once per hour
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A21) How often do you wear a hat when outdoors during working hours?








Never	Sometimes	Always
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If your answer to A21 above is Never skip A22.

A22) Make a cross in the box with the type(s) of hat you wear when outdoors during working hours? (Mark all that are true for you)



A23) Which type of clothes do you wear most of the time when you are at work? (Mark all that are true for you with an X)

T-shirt		Shirt		Coveralls		
Short sleeve	Long sleeve	Short sleeve	Long sleeve	No sleeves, long pants	Short sleeves, long pants	Long sleeves, long pants
						

A24) How often would you wear less clothing so that you are able to get some sun on your skin while at work?






Never	Sometimes	Always
-------	-----------	--------

A25) How often do you wear eye-protection (sunglasses) when outside during working hours?

Never	Sometimes	Always
-------	-----------	--------

If your answer to A25 is Never, then skip A26.

A26) Mark the type of eye-protection you wear when you are at work.

Non-Prescription sunglasses with UVA and UVB lenses	Prescription sunglasses with tinted lenses	Prescription sunglasses with plain lenses (no tinting)	Goggles	Wrap-around goggles
				

PART 5: THIS SECTION IS ABOUT YOUR PERSONAL PRACTICES (YOUR BEHAVIOUR) DURING OFF-DUTY TIME. Make a cross (X) on the box with the answer that is true for you.

A27) How many hours do you spend in the sun per day during your off-duty time?

A28) Do you apply sunblock (sunscreen) when outdoors during your off-duty time?

Never	Sometimes	Always
-------	-----------	--------

A290) On which parts of your body do you apply sunscreen when outdoors during your off-duty time? Please mark all that apply to you with an X.

Face	Neck	Arms	Legs
------	------	------	------

A30) How often do you reapply your sunblock (sunscreen) when outdoors during your off-duty time?

Never	Sometimes	Always
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A31) If you do reapply sunblock (sunscreen), how many hours do you wait before you reapply during your off-duty time?

A32) What is the Sun Protection Factor (SPF) of the sunblock (sunscreen) you use during your off-duty time?

I do not know	15	Greater than 30	Greater than 50
---------------	----	-----------------	-----------------

A33) Which type of clothing do you wear when outdoors during your off-duty time? Mark all that are true for you with an X

T-shirt		Shirt		Coveralls		
Short sleeve	Long sleeve	Short sleeve	Long sleeve	Long sleeves, long pants	No sleeves, long pants	Short sleeves, long pants
						

A34) Which type(s) of hat(s) do you wear most of the time during your off-duty time? Mark all that are true for you with an X



A36) How often do you wear eye-protection (sunglasses) when outdoors in your off-duty time?

Never	Sometimes	Always
-------	-----------	--------

A37) if you wear eye protection, which type of eye-protection do you wear when outdoors in your off-duty time

Non-Prescription sunglasses with UVA and UVB and tinted lenses	Non-prescription sunglasses with UVA and UVB lenses	Prescription lenses with no tinting	Goggles	Wrap-around goggles
				

A38) Do you use any product or substance to lighten your skin?

Never	Rarely	Sometimes	Usually	Always
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A39) If you have ever used one more product or substance to lighten your skin, please name all the products or substances

B: Knowledge and attitudes of outdoor workers regarding the sun

This questionnaire, containing 4 parts and 36 questions/statements, aims to determine how much you know about the sun and your attitudes towards the sun. Please read each question/statement carefully and mark the box with the answer that is true for you.

PART 1: THIS PART IS ABOUT YOUR GENERAL KNOWLEDGE ABOUT THE SUN AND ITS HEALTH EFFECTS. Make a cross (X) on the box with the answer that is true for you.

B1) Have you received any information about the sun and its health effects?				No	Yes
B2) Where did you receive the information about the sun and its health effects? (Write down your answer)					
B3) Do you know what ultraviolet radiation is?				No	Yes
B4) Do you know the meaning of the Ultraviolet index (UVI)?				No	Yes
B5) What time of the day is the sun the hottest? (Mark the first box if you do not know or write down your answer in the second box)					
I do not know		Answer:			
B6) It is good to spend a little time in the sun every day			No	Yes	I do not know
B7) Spending a lot of time in the sun is the most important risk factor for skin cancer			No	Yes	I do not know
B8) How is your health affected when you work in the sun for a long time? (Mark the first box if you do not know or write down your answer in the second box)					
I don't know		Answer:			
B9) Do people with darker skin colour suffer from health effects caused by the sun?					
No		Yes		I do not know	
B10) Do people with darker skin burn as easily as people with lighter skin?					
No		Yes		I do not know	
B11) When the sun burns you skin it causes a permanent damage.					
No		Yes			

PART 2: THIS PART IS ABOUT YOUR KNOWLEDGE OF THE WAYS OF PROTECTING YOURSELF AGAINST THE SUN. Make a cross (X) on the box with the answer that is true for you.

<i>B12) Do you know what a sunblock's (sunscreen's) sun protection factor (SPF) means?</i>		
No	Yes	I have heard of it, but I do not know what it means
<i>B13) Do people with lighter colour skin have to use sunblock (sunscreen)?</i>		
No	Yes	I do not know

<i>B14) Do people with dark skin colour have to use sunblock (sunscreen)?</i>		
No	Yes	I do not know
<i>B15) What type of clothing prevents more of the sun from reaching the skin surface?</i>		
Lighter coloured clothing	Darker coloured clothing	I do not know

PART 3: THIS PART IS ABOUT YOUR ATTITUDES WHEN SPENDING TIME IN THE SUN. Make a cross (X) on the box with the answer that is true for you.

<i>B16) Do you look at the ultraviolet index (UVI) when planning to go outside?</i>	No	Yes
<i>B17) Would you change your plans to go outside if you knew that the ultraviolet index (UVI) level was?</i>	No	Yes
<i>B18) Do you worry about sun when working outside?</i>	No	Yes
<i>B19) I spend too much time in the sun.</i>	No	Yes
<i>B20) I stay for a long time in the sun to darken my skin.</i>	No	Yes
<i>B21) Somebody that has a darker skin is more attractive.</i>	No	Yes
<i>B22) I enjoy spending time in the sun.</i>	No	Yes
<i>B23) I think I am at risk of skin cancer.</i>		
No	Yes	I do not know

PART 4: THIS PART IS ABOUT YOUR ATTITUDES TOWARDS WAYS OF PROTECTING YOURSELF AGAINST THE SUN. Make a cross (X) on the box with the answer that is true for you.

<i>B24) Protecting yourself against the sun is important when you are driving or in a car/taxi as a passenger.</i>	No	Yes
<i>B25) It is important to work or stand in the shade (where there is no sun such as under a tree or shelter when it is available) when it is hot.</i>		
No	Yes	I do not know

If your answer to B25 is Yes, then answer B26 below

<i>B26) Why do you work in the shade when it is available (where there is no sun such as under a tree, shelter or indoor areas)?</i>		
Somebody tells me to work there	It is cooler	It protects me from the sun
<i>B27) It is important to protect your skin with clothes that have long sleeves</i>		
No	Yes	I do not know

<i>If your answer to B27 is Yes, then answer B28 below</i>		
<i>B28) Why do you wear clothes with long sleeves when working outside in the sun?</i>		
Somebody tells me to wear clothes with long sleeves	I look good in long sleeved clothing	It protects my skin from the sun
<i>B29) It is important to wear sunglasses to protect my eyes from the sun</i>		
No	Yes	I do not know
<i>If your answer to B29 is Yes, then answer B30 below, otherwise go to B31.</i>		
<i>B30) Why do you wear sunglasses when you are outside in the sun?</i>		
Somebody tells me to wear it	I look good in sunglasses	It protects my eyes from the sun
<i>B31) It is important to wear a hat when you are outside in the sun</i>		
No	Yes	I do not know
<i>If your answer to B31 is Yes, then answer B32 below</i>		
<i>B32) Why do you wear a hat when you are outside in the sun?</i>		
Somebody tells me to wear it	I look good in a hat	It protects my head and face from the sun
<i>B33) It is important to apply sunblock whenever you go outside in the sun.</i>		
No	Yes	I do not know
<i>If your answer to B33 is Yes, then answer B34 below. If your answer to B33 is No or I do not know, then go to B35 and B36.</i>		
<i>B34) You apply sunblock when outside in the sun because.....(Mark the answer that is true for you)</i>		
Somebody tells me to apply sunblock	Sunblock protects my skin from being burned by the sun.	
<i>B35) Sunblock is too expensive</i>	No	Yes
<i>B36) I do not have time to apply sunblock</i>	No	Yes

C: Fitzpatrick skin phototype questionnaire.

This questionnaire, containing 2 parts and 9 questions/statements, aims to determine your skin colour according to the Fitzpatrick skin phototype classification system. Please read each question/statement carefully and mark the box with the answer that is true for you.

PART 1: THIS PART IS ABOUT YOUR PHYSICAL FEATURES Make a cross (X) on the box with the answer that is true for you.

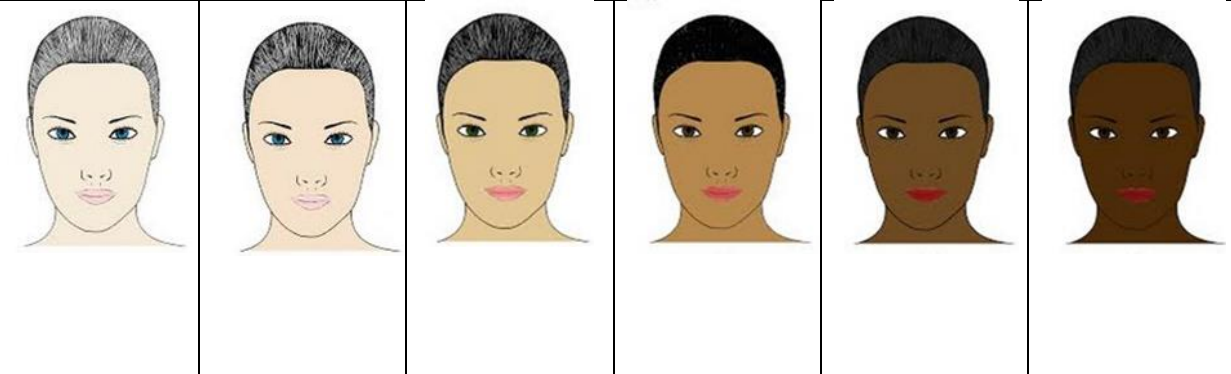
C1. What is your eye colour?

Green	Blue	Hazel/light brown	Dark brown	Black
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C2. What is your natural hair colour?

Red	Blonde	Dark blonde/light brown	Dark brown	Black
-----	--------	-------------------------	------------	-------

C3. Which of the following is the closest to the colour of your skin that is not exposed to sun?



C4) How many freckles do you have on your unexposed skin

None	One or two	Few	Several	Many
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PART 2: THIS PART IS ABOUT THE REACTION OF YOUR SKIN TO SUN EXPOSURE Make a cross (X) on the box with the answer that is true for you.

C5) What happens to your skin if you spend a lot of time in the sun?

Nothing	My skin turns brown/ I tan	My skin turns red, but it is not painful	My skin turns red, and it is painful	I burn blisters and it is painful
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C6) How many freckles do you have on your skin that is not exposed to sun?

None	Few	Average	Several	Many
------	-----	---------	---------	------

C7) Do you turn brown/darker or tan after spending a lot of time in the sun?

Never	Rarely	Sometimes	Usually	Always
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C8) How brown/darker does your skin get when spending time in the sun?

Does not get brown/tan	Light tan	Medium tan	Dark tan	Deep dark brown
<i>C9) How long does your brown /darker colour/ or tan last after spending a lot of time in the sun?</i>				
No time. I do not tan	For a few days	For a few weeks	For a few months	For longer than a few months

D: Questions relating to uniforms worn by protection officers.

Part 1: Factors relating to fit and colour of uniform shirt.

1.1 Were you allowed to fit the uniform shirt before you chose a size?	<p>a. Yes</p> <ul style="list-style-type: none"> ● I tried on a sample uniform size before choosing the size uniform I want. 	<p>b. Yes</p> <ul style="list-style-type: none"> ● But I was absent or not working on the day uniforms were fitted. 	c. No.											
<p>Answer question 1.2 if your answer at 1.1 was b. YES or c. No Skip question 1.2 if your answer at 1.1 was a. YES.</p>														
1.2 Were you allowed to choose a size for your uniform shirt?	<p>a. Yes</p> <ul style="list-style-type: none"> ● Specific information was available, and I was able to make an informed choice about my size. ● For example: <table border="1" style="margin-left: 20px;"> <thead> <tr> <th>Shirt size</th> <th>Chest (cm)</th> <th>Waist (cm)</th> </tr> </thead> <tbody> <tr> <td>Small</td> <td>104</td> <td>92</td> </tr> <tr> <td>Medium</td> <td>110</td> <td>98</td> </tr> </tbody> </table>	Shirt size	Chest (cm)	Waist (cm)	Small	104	92	Medium	110	98	<p>b. Yes</p> <ul style="list-style-type: none"> ● But no extra information was available for me to make an informed choice. ● For example: Choose a uniform shirt size and write it next to your name on the list (S, M, L, XL or XXL). <table border="1" style="margin-left: 20px;"> <tr> <td>N, Nkosi</td> <td>Small</td> </tr> </table>	N, Nkosi	Small	c. No.
Shirt size	Chest (cm)	Waist (cm)												
Small	104	92												
Medium	110	98												
N, Nkosi	Small													
<p>Part 2: Quantity and age of uniform shirts.</p>														

2.1 How many uniform shirts do you receive from the NWU protection services?	One uniform shirt for each day.	Two uniform shirts.	One uniform shirt.	
2.2 How often do you receive a new uniform shirt from the NWU protection services?	Once a year.	Once every six months.	When the NWU changes the design or colour of uniforms. (intervals differ)	
2.3 When do you receive new uniform shirts?	In the beginning of the year.	In the middle of the year.	At the end of the year.	Intervals differ each year.
Part 3: Personal practices relating to your uniform shirt.				
3.1 How often do you wash your uniform shirt?	After each time I wore it for a shift.	After every second shift.	Less often (e.g., once a week).	
3.2 Where do you leave your uniform shirt to dry?	In the sun.	In my house.	In the tumble dryer.	
3.3 Do you iron your uniform shirt?	Yes, always.	Yes, regularly but not every time.	No.	
3.4 Do you notice colour loss of your uniform shirt?	Yes (Indicate how often below by circling an option). <ul style="list-style-type: none"> ● After every wash. ● After about every 5th wash. ● After about every 10th wash. 		No.	

<p>3.5 Do you ever try to dye or bleach your uniform shirt?</p>	<p>Yes.</p>	<p>No.</p>
<p>3.6 Did your uniform shirt wear out in any manner or not?</p>	<p>No</p> <ul style="list-style-type: none"> ● The shirt did not wear out and no damage occurred. 	<p>Yes</p> <ul style="list-style-type: none"> ● The uniform shirt shrunk. ● The uniform shirts stretched. ● The uniform shirt material became thinner.

ANNEXURE 3 – ETHICS APPROVAL LETTER OF STUDY



Private Bag X1290, Potchefstroom
South Africa 2520
Tel: 086 016 9898
Web: <http://www.nwu.ac.za/>

North-West University Health Research Ethics
Committee (NWU-HREC)

Tel: 018 299-1206
Email: Ethics-HRECApply@nwu.ac.za (for human
studies)

17 May 2022

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the North-West University Health Research Ethics Committee (NWU-HREC) on 17/05/2022, the NWU-HREC hereby approves your study as indicated below. This implies that the NWU-HREC grants its permission that, provided the general conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Solar ultraviolet radiation exposure of protection officers at a South African university																															
Principal Investigator/Study Supervisor/Researcher: Ms MC Ramotsehoa																															
Student: M Combrink - 28728432																															
Ethics number:	<table border="1"><tr><td>N</td><td>W</td><td>U</td><td>-</td><td>0</td><td>0</td><td>3</td><td>3</td><td>3</td><td>-</td><td>2</td><td>1</td><td>-</td><td>A</td><td>1</td></tr><tr><td colspan="3">Institution</td><td colspan="6">Study Number</td><td colspan="2">Year</td><td colspan="4">Status</td></tr></table>	N	W	U	-	0	0	3	3	3	-	2	1	-	A	1	Institution			Study Number						Year		Status			
N	W	U	-	0	0	3	3	3	-	2	1	-	A	1																	
Institution			Study Number						Year		Status																				
<u>Status:</u> S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation																															
Application Type: Single study	Risk: <table border="1"><tr><td>Minimal</td></tr></table>	Minimal																													
Minimal																															
Commencement date: 17/05/2022																															
Expiry date: 31/05/2023																															
Approval of the study is provided for a year, after which continuation of the study is dependent on receipt and review of an annual monitoring report and the concomitant issuing of a letter of continuation. A monitoring report is due at the end of May annually until completion of the study.																															

General conditions:
<i>While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:</i>
<ul style="list-style-type: none">• <i>The principal investigator/study supervisor/researcher must report in the prescribed format to the NWU-HREC:</i><ul style="list-style-type: none">- <i>Annually on the monitoring of the study, whereby a letter of continuation will be provided annually, and upon completion of the study; and</i>- <i>without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.</i>• <i>The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the principal investigator/study supervisor/researcher must apply for approval of these amendments at the NWU-HREC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.</i>• <i>Annually a number of studies may be randomly selected for active monitoring.</i>• <i>The date of approval indicates the first date that the study may be started.</i>• <i>In the interest of ethical responsibility, the NWU-HREC reserves the right to:</i><ul style="list-style-type: none">- <i>request access to any information or data at any time during the course or after completion of the study;</i>- <i>to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;</i>

- *withdraw or postpone approval if:*
 - *any unethical principles or practices of the study are revealed or suspected;*
 - *it becomes apparent that any relevant information was withheld from the NWU-HREC or that information has been false or misrepresented;*
 - *submission of the annual monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and/or*
 - *new institutional rules, national legislation or international conventions deem it necessary.*
- *NWU-HREC can be contacted for further information via Ethics-HRECApply@nwu.ac.za or 018 299 1206*

Special conditions of the research approval due to the COVID-19 pandemic:

Please note: Due to the nature of the study i.e. (face-to-face collection of quantitative data via questionnaires and physical measurements of protection officers at a South African University), this study will be able to proceed during the current alert level, following receipt of the approval letter. No additional COVID-19 restrictions have been placed on the study other than that indicated under the COVID-19 risk mitigation strategy as indicated in the application. The researcher must, however, ensure that before proceeding with the study that all research team members have reviewed the North-West University COVID-19 Occupational Health and Safety Standard Operating Procedure.

The NWU-HREC would like to remain at your service and wishes you well with your study. Please do not hesitate to contact the NWU-HREC for any further enquiries or requests for assistance.

Yours sincerely,



Digitally signed by
Prof Petra Bester
Date: 2022.05.17
14:18:55 +02'00'

Chairperson NWU-HREC

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20 August 2019
File Reference: 9.1.5.4.2