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Cross-sectional study protocol to assess ultraviolet radiation exposure among military outdoor workers in Lohatla, Northern Cape Province of South Africa

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ABSTRACT

Introduction The sun is one of the primary natural sources of ultraviolet radiation (UVR) and a known human carcinogen. It has been related to melanoma and several skin cancers, such as squamous cell carcinoma and basal cell carcinoma. Non-melanoma skin cancers are prevalent in South Africa, with high reported incidence rates in both genders. Due to its diversified population, South Africa experiences extreme ultraviolet index (UVI) levels, reaching 13 in the summer (a UVI of 11+ is considered extreme). Most summer workdays expose outdoor workers to repeated UVR exposure, which can lead to health risks like sunburn, premature ageing, cataracts, and an increased risk of skin cancer. This study aims to evaluate UV radiation exposure among outdoor military workers.

Methods and analysis A cross-sectional quantitative study will occur at the Lohatla military base in Kathu, Northern Cape province of South Africa, using personal electronic dosimeters for solar UVR assessment. Additionally, a self-administered questionnaire will assist in assessing health effects and perceived exposure behaviours. The study addresses a critical public health concern, exploring significant risks associated with UVR exposure among outdoor military workers across different demographics.

Ethics and dissemination The ethical approval for this study was obtained from the Health Sciences Research Committees of the University of Free State (UFS-HSD2023/1227/2811). The confidential data will be accessed by the named researchers and stored in secure password-protected platforms. In addition, the findings will be disseminated through high-impact publications in various formats to government departments and the broader scientific community.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The cross-sectional and quantitative design using measurements and questionnaires is suitable for evaluating UV radiation exposure among military outdoor workers, providing a snapshot of the situation.
⇒ Including measurements of ambient ultraviolet radiation at each study location over five consecutive working days provides contextual information about environmental exposure, considering local variations and conditions.
⇒ Reliance on reported subjective health effects may introduce bias, as participants interpret and report their health status differently.

INTRODUCTION

UV radiation (UVR) is primarily sourced from the sun. All living things are subject to solar UV radiation when in an outside environment. Solar UVR is a proven human carcinogen connected to skin malignancies that are not melanoma, such as squamous cell carcinoma (SCC) and basal cell carcinoma (BCC).[1] According to epidemiological research, sun UVR exposure and skin cancer are related.[2] Non-melanoma skin cancers (NMSC) are among the most common cancers in South Africa, affecting both men and women equally in terms of reported incidence. Cumulative exposure to solar UVR is the primary risk factor for NMSC, particularly SCC.[3] Many health hazards, such as DNA damage, immunological suppression, premature skin ageing, skin ageing malfunction and skin cancer, are linked to excessive sun exposure.[4] Compared with the general public, outdoor workers will likely have higher cumulative sun exposure due to extended and solar solid exposure. Moreover, a correlation has been documented between outdoor employment and skin malignancies other than melanoma.[5]

One of the main risk factors for developing cataracts is sun exposure to UVR. Numerous factors, including air conditions, environmental reflection, geographical location and the anatomical position of the eye, influence ocular exposure.[6] Solar UVR mainly affects the temporal side of the eye, focusing light on the nasal portion of the cornea and lens.[7] Regular exercisers and outdoor competitors are particularly vulnerable to these harmful UVR impacts. Similarly, military personnel

are more likely to encounter these potentially detrimental consequences because they routinely spend prolonged time outdoors, frequently in high-UVR conditions.[4] Employees who labour outside are subjected to prolonged exposure to sunlight and have a more significant degree of UVR effects. The military also sticks out because, although it's not always the case, they train outside and are exposed for most of the day during drills and manoeuvres. Eventually, the UVR exposure from their outside activities will impact their health. Military operations can occur in locations with intense solar radiation, such as extremely hot weather, when soldiers may be exposed to high UV index values. Additionally, the daily patrols in the operation area without any shade aside from what their clothes provide combined with the perfect circumstances to exacerbate the effects of UVR.[8] The Army's Light Infantry is the regiment most impacted by this problem since they train in intense heat for extended periods, increasing their risk of developing skin cancer. On the other hand, military personnel assigned to mechanised units have the lowest rate because they are primarily covered, which reduces their exposure.[9] Military personnel undergo a rigorous training programme that exposes them to harsh winter conditions, where UVR is concentrated, and the sun is even more intense than in the summer.[10] The face and neck of military personnel are exposed to ultraviolet radiation even though they wear a helmet, hat, or cap to camouflage their uniforms. UVR exposure can have cumulative effects on the skin, which means that over time, it may negatively affect immune system function, skin health or eyesight.[11]

This research protocol is underpinned by a null hypothesis stating that outdoor military workers are not at risk of health-related effects from UV radiation exposure. This adds a critical dimension to the study, allowing for rigorous testing and validation of assumptions. This study aims to investigate the impact of UV radiation exposure on outdoor military workers in Lohatla, South Africa. The objectives encompass a comprehensive approach, from measuring environmental and personal UV radiation exposure to assessing related health effects among the exposed population. Furthermore, the research will explore the associations between socio-demographic factors and health effects, providing an understanding of the potential risk factors involved.

Problem statement

UVR exposure poses significant health risks, including sunburn, premature ageing, cataracts and an increased risk of skin cancer. Outdoor workers are at a high risk of developing skin cancer due to their extreme and prolonged exposure to the sun's UV rays. This makes them a primary target for skin cancer prevention initiatives.[12] Military outdoor workers in South Africa, due to their frequent exposure to sunlight during training and operational activities, are particularly vulnerable to UVR-related health issues.[4] Despite the potential dangers, limited research exists on UVR exposure and sun safety practices, specifically among South African and Lohatla military personnel. The problem to be addressed in this study is the lack of comprehensive data and understanding of UVR exposure levels and sun safety practices among military outdoor workers in various regions of South Africa. The absence of such critical information hinders the development of evidence-based sun safety interventions and policies tailored to the unique needs of military personnel.

METHODS AND ANALYSIS

Patient and public involvement statement

This study will not involve patients; however, it will affect military outdoor workers, who can also be considered the public. The preliminary search of literature and information involved insights from military personnel's lived experiences regarding UV radiation. And all these structured the research question. The military outdoor workers will be involved as research partners in all milestones of the research project, that is, problem conceptualisation, data collection, and the distribution of study results. Moreover, the military outdoor workers (training offices and unions) will be recruited and asked to participate in the study through their representation. They will also assist with data collection in the pilot study by reviewing the research questionnaire. They will focus on the understandability and legibility of the research instruments and provide feedback in a workshop conducted by the researchers. The research results will be disseminated to all the military bases through the proper command channels until the message reaches the direct participants. Further information will be communicated as scientific papers through journal articles and conferences.

Study design

The study will be cross-sectional and quantitative to evaluate the UV radiation exposure of military outdoor workers.[13] The estimated number of Military outdoor workers permanently based in the Lohatla military base is approximately 400. Nonetheless, during the training or exercise season, the number of military outdoor workers rises noticeably and can nearly always reach 13 000 training participants from September through December.

Study area/site

The Northern Cape Province's Lohatla Military Base (Kathu) will host the study. This province makes up the Kalahari Desert's northern portion, which experiences year-round sunshine. At 1238 metres above sea level and 27°S latitude, Kathu enjoys primarily clear skies all year round.[14] As a result, this region may receive high levels of solar UVR, which increases the risk of high exposure for people who spend much time outside, such as military outdoor workers.

Study population and sampling

Military outdoor workers are employed by the South African National Defence Force (SANDF), and permission from SANDF will be sought before the study's implementation. Study participants will be recruited voluntarily from the Lohatla military base training intake for 2024 and 2025. Based on an estimate of 13 000 military personnel performing outdoor activities, a stratified random sampling technique will be used to select study participants who are volunteering and have given consent to be part of the study. Ten subgroups will be formed, each consisting of 1300 or at least a minimum of 260 participants. From the subgroups, participants will be further classified by common characteristics, and in this case, years of experience in the SANDF will be used. Furthermore, a researcher will group participants by the following years of experience: ≤2 years, >2, ≤5 years, >5 but ≤10 years and >10 years. From the years of experience category, every 10th person on the list will be selected to form part of the study. A total estimate of 1300 or a minimum of 260 military outdoor workers with various work experiences will form part of this study. Since it remains challenging to determine the association between exposure and reported health effects, the exposed group (outdoor workers) will be compared with the control group.

In this study, the control group will comprise SANDF personnel working in office spaces who are indoor cleaners and administrative personnel. A total of 500 or a minimum of 50 participants who will form part of the control group will be selected to participate in the study using purposive sampling. All these personnel (control group) will be recruited by the researcher with the help of a training officer, as they know the schedule of the unit members. This research project will encompass both male and female groups, including those who identify with other genders.

Participants recruitment

The recruitment phase will involve the training officer's assistance in identifying volunteers interested in participating in the study. A presentation regarding the survey will be made to those who volunteered in a military unit hall. Those who voluntarily agree to participate will receive a study participant leaflet and an informed consent document to sign. Since English is the language of instruction in the SANDF, both documents and oral invites will be in English. Participants completing the self-administered questionnaire will also be asked to wear a personal UV dosimeter. The utmost care will be taken when recruiting participants to ensure that the recruitment is fair and that everyone has an equal opportunity to be selected per the criteria. Results will be disseminated to the participants through various media, such as internal newsletters, posters, research papers and internal communication through supervisors.

Research tools

Questionnaire development

Researchers will design a questionnaire with a participant study code, and its content will be pre-study validated through a pilot study. The questionnaire will be divided into three sections: Section A (demographic questions), Section B (work-related questions), which include factors such as short sleeves, shorts, or other skin covering during their outdoor work shift and Section C (health-related questions). The participants will have three months to complete the questionnaire. The questionnaire will be piloted using 13 SANDF members in Lohatla to ensure reliability. The primary purpose of the pilot is to measure the time taken to complete the questionnaire. In addition, to determine participant comprehension of the questionnaire and wording and dosimeter measurement processes. Members participating in the pilot study will be excluded from the main study.

Measuring personal UV exposure

The University of Canterbury in Christchurch, New Zealand's Department of Electrical and Computer Engineering, is the source of the electronic UVR dosimeters used in this investigation. These dosimeters can download and log data onboard and are intended to measure erythemal UVR (280–320 nm).[3] All consented participants will be asked to attach an electronic personal UV dosimeter (GENESIS-UV system) to the upper left arm, and this is regarded as a convenient body part to attach a personal electronic dosimeter.[15] Each participant will wear a UV dosimeter for 6 hours a day (5 days a week) to accurately measure their exposure when temperatures are elevated, ideally from 09:00 to 15:00 (6 hours). The selection of outdoor workers wearing the UV dosimeters will ensure a broad spectrum of job tasks.[16] After each shift, the dosimeters will be removed from the participants.

Measuring outdoor UV

To provide information on the maximum available UVR exposure for the study days, measuring the ambient (environmental) UVR available in each location during the study period is crucial. When measuring ambient UVR, UV dosimetry is more reflective of the local environment than satellite data,[17] considering local variations, clouds and aerosols. Multiple UV dosimeters will be placed in an unobstructed position at different angles at the study location to capture the variations in UVR exposure more accurately.[17] Every day after sunset, monitors will be positioned and swapped out in anticipation of the next day's ambient UVR measurements, beginning at sunrise. Every location will have its ambient UVR measured twice over five consecutive working days on the first and last days of the data collection between 3 months of summer (December 2024 and January to February 2025).

The Wet Bulb Globe Temperature (WBGT) (QuesTemp 34; QUEST Technologies, Oconomowoc, Wisconsin, USA) will be used to measure the amount of heat stress exposure. Its accuracy level is ±0.5°C between 0°C and 120°C for the dry bulb temperature and ±5% relative humidity (RH) between 20% and 95% RH. The four primary thermal factors that contribute to heat stress are combined by the WBGT

and are measured by the globe, wet bulb and dry bulb temperatures.[18] These factors are air temperature, humidity, velocity and radiation. Many international organisations use the WBGT index, the most widely used heat index worldwide for heat stress assessments, to establish heat exposure thresholds or limits for workers.[18] In most workplaces, ambient WBGT measurements during regular business hours will be taken between o9:00 and 15:00 on weekdays. Every measurement day will begin and end with a calibration of the QuesTemp. QuesTemp will be positioned at a height of 2 feet (0.6 m) for seated people and 3.5 feet (1.1 m) for standing people. A tripod mounting is used to position the device away from anything obstructing radiant heat. About 15 minutes will pass while the equipment stabilises before each location's measurements are taken. Depending on the workers' work intensities and potential hot spots in the workplace, different workplaces will have different numbers of WBGT measurement locations.[17 18] The dosimeter and WBGT metre will be calibrated before use, and pre-measurements will be conducted to ensure the instruments' functionality.

Data analysis

The data will be analysed using the statistical program SPSS IBM Corp. (IBM SPSS Statistics for Windows, V. 26.0. Armonk, New York, USA: IBM Corp). The normality of the continuous variable distribution will be assessed through formal methods such as the Shapiro-Wilk and Kolmogorov-Smirnov tests and graphical techniques like Q–Q plots and histograms. Reporting descriptive statistics will use the median, minimum and maximum.[19 20] The resultant mean values will be compared with the Threshold Limit Values (TLV) to identify overexposures.[19 20] The exposure timeline is crucial for assessing outdoor workers' UV radiation exposure and ensuring compliance with TLVs, which ACGIH sets to protect employees from harmful workplace hazards.[21] Monthly UV radiation exposure considers the total amount of UV radiation that outdoor workers are exposed to throughout a given calendar month. This timeline offers a more comprehensive understanding of the long-term impacts of UV exposure on the skin health of workers and the possible danger of developing disorders like sunburn, ageing skin and skin cancer.[22] To determine the association between socio-demographics and other variables in the questionnaire, together with reported subjective health effects, multivariate logistic regression will be used. Figure 1 summarises the research process from philosophical conceptualisation to data collection.

Data management plan

Each participant opting to join the study voluntarily will undergo de-identification. Figshare, figure 1capable of storing data in various formats, will house any information

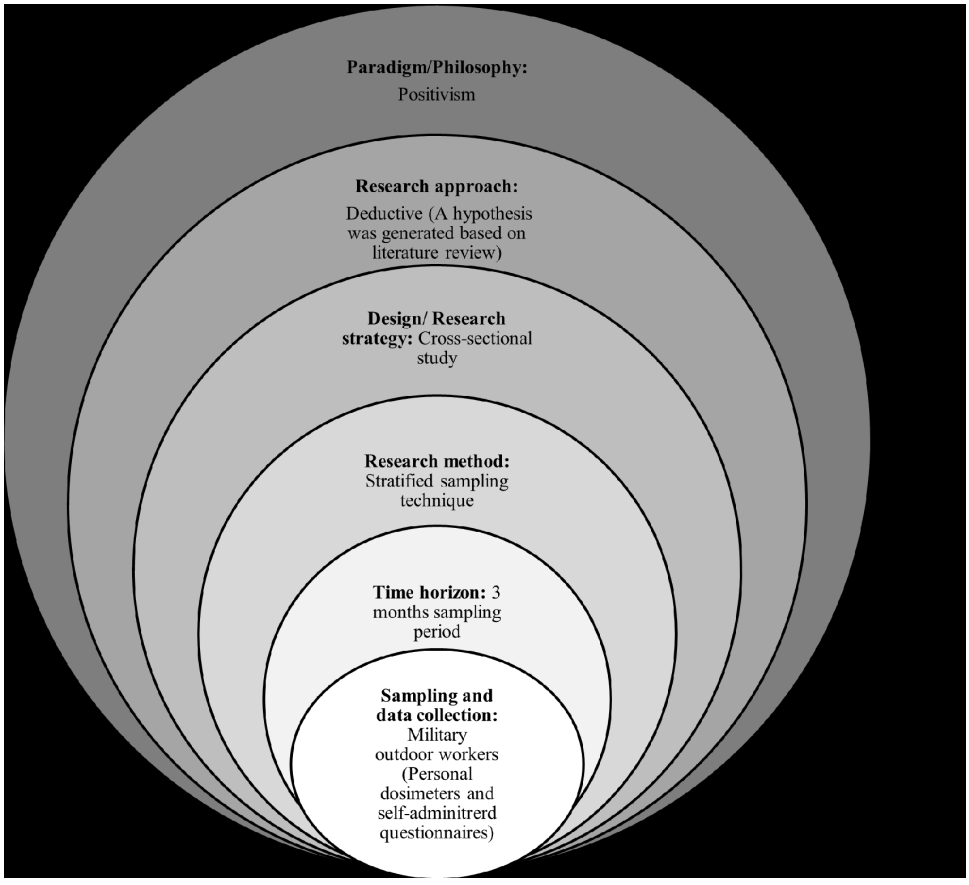

Figure 1 Summary of the research approach

linking the participant's name or research identification number with other electronic data. Data embargo, as needed for ethical clearance, is possible. Personal details will be treated confidentially, and direct identifiers will be de-identified or substituted during data analysis. Data handling will adhere to the data protection policies of the Central University of Technology and the South African National Defence Force, implementing appropriate security measures. Data retention, meeting study requirements, will last 10 years in a lockable cabinet at the military building in the researcher's office. Researchers will oversee data management throughout the project. Post-retention, the study researcher and the Military Co-Supervisor will ensure data destruction, guaranteeing permanent deletion or physical destruction to prevent recovery.

DISCUSSION

NMSCs are the most prevalent type of cancer in people with fair skin worldwide.[17] Sun UVR is the cause of NMSC in fair-skinned individuals and is also the cause of SCC and BCC. The incidence of NMSC is rising, and exposure to sunlight at work significantly raises the lifetime UVR dose.[13 17] Excessive exposure to UVR poses both acute and long-term health risks to outdoor workers.[5 19 20] The eyes and skin are the most frequently targeted organs. Since South Africa is a subtropical nation, evaluating outdoor workers' risks is essential. The population of South Africa is multiethnic, and during the summer, the ultraviolet index (UVI) can reach 13 (a UVI of 11+ is considered extreme). Moreover, because military personnel frequently spend prolonged periods outdoors in high-UVR environments, this exposes them or the population to UVR risk factors. They are probably going to suffer negative consequences from UVR.[3 5]

Lee, Taubman and Williams[23] report that among US military personnel, the incidence of NMSCs (such as squamous cell and basal cell carcinomas) far outweighs all other cancer types, including melanomas. In addition, the incidence rates of non-melanoma and melanoma skin cancers among US military personnel abruptly rise with advancing age. Compared with members of other racial/ethnic groups, Caucasians have a higher NMSC. Furthermore, compared with their respective colleagues, members of the military occupational groups related to healthcare and fixed-wing aviation in the Air Force and Navy have higher rates of melanoma and NMSC.[23 24]

UVR exposure among outdoor workers

The primary cause of skin cancer is solar UV radiation, which is classified as a group 1 carcinogen by the WHO. Most weekdays during the summer, outdoor workers are regularly exposed to solar UV radiation. They are especially susceptible to the adverse health effects of rising global temperatures.[25] The most common cancer in Canada to be diagnosed is skin cancer, and working outside increases one's risk of developing NMSC. An estimated 1.5 million workers in Canada spend at least 2 hours a day outside.[25] They are thus exposed to ultraviolet radiation from the sun (UVR), which has been widely proven to have detrimental health effects in exposed populations.[26] As part of their job duties, about 75% of these workers are anticipated to spend at least 6 hours outside.[3 10 26] The rates of non-melanoma (squamous cell and basal cell) skin cancer have been identified in outdoor-working occupational groups. Due to their prolonged and intense sun exposure, outdoor workers have a higher risk of developing squamous cell carcinoma, which is why rates of NMSC are significantly correlated with cumulative UV exposure.[27]

The prevalence of melanoma among pilots and crews of military fixed-wing aircraft and commercial airlines has raised concerns in the aviation industry. Studies have shown a notable correlation between their profession and an increased risk of skin cancer, particularly melanoma. This phenomenon can be attributed to their prolonged exposure to solar UV radiation during flight hours.[28] Pilots and aircrew members are exposed to higher levels of UV radiation due to several factors. First, the atmosphere is thinner at higher altitudes, reducing protection against UV radiation. As a result, individuals in flight are more susceptible to direct exposure to the sun. Additionally, the cockpit windows of aircraft do not offer complete UV protection, allowing UV rays to penetrate and reach the occupants inside.[29 30] Because of this, military personnel may be exposed to high levels of solar UV radiation while conducting outdoor training and operations. This issue will probably impact combat engineers, infantry and special operations personnel.[24] People who exercise, compete, or otherwise expose themselves to high levels of UV radiation may be more susceptible to adverse health effects. Additionally, people who engage in outdoor physical activity are far more likely to get sunburned than those who do not. Moreover, the chance of getting sunburn increases with every hourly increase in outdoor physical activity. According to these findings, people who engage in outdoor sports or exercise are more susceptible to the harmful effects of UVR exposure on their health.[4]

South African studies on UVR exposure

The effects of UVR on humans are well known today and depend on several variables, including skin phototype, which determines an individual's risk of excess solar UVR, and atmospheric variables, such as cloud cover and altitude, which influence the amount of surface solar UVR.[5 30] However, the researchers did not explore Fitzpatrick phototype extensively because 85% of the study population are people with skin type V–VI. Even if we had explored this topic, we would not have a fair representation. As mentioned, 85% of the study population is made up of people under the skin type V–VI. Excessive UV exposure can cause sunburn, skin cancer, cataracts and ocular melanoma, among other negative consequences. UVR exposure is linked to most skin-related health effects. The melanoma rate in South Africa is

steady at three cases per 100 000 people for women and five cases per 100 000 for men.[5 26] While there are many occupational risks for outdoor workers, one of the oldest could be solar radiation, as various environmental factors influence exposure risks. Acute health effects from excessive solar UVR exposure can impact the skin and eyes of humans and their immune systems. Additionally, the effectiveness of vaccinations may be negatively affected by solar UVR.[5 31] The effects of sun UVR on the skin extend beyond premature ageing and include a variety of skin cancers, the most serious of which is melanoma, which has the potential to be fatal.[4] Pterygium, cataracts and macular degeneration are among the eye conditions workers are susceptible to over time from prolonged sun exposure.[32] Given that UVR exposures can happen at any time of year, South African outdoor workers are at a high risk of solar radiation.

Health effects of UVR exposure

Exposure to UV radiation at high levels can potentially cause acute health effects. In contrast, long-term exposure can be attributed to diseases like NMSC, ocular melanoma, cataracts, pterygium, climatic droplet keratopathy and pinguecula.[5 19 20] Outdoor workers risk developing UVR-induced ocular and cutaneous damage.[5] Sunburn, photokeratitis and photoconjunctivitis are common conditions, with fair-skinned individuals more prone.[5 33] In summer, outdoor workers are prone to UV exposure and might experience painful, irritated eyes and blurred vision, which are signs of ocular sunburn.[5] The primary environmental risk factor for CMM is sun UV exposure. Individual susceptibility, as indicated by pigmentation and sun sensitivity, is the primary moderating factor for the effect of this exposure. People with light skin, hair and eyes are usually more susceptible to the condition, and their skin's propensity to burn rather than tan also raises the risk.[33 34]

Pterygium is an invasive growth on the conjunctiva that resembles wings and typically begins near the nose. It causes burning and itching sensations in the eye.[4 33] Pterygium is more common in regions with high levels of sunshine, and there is evidence linking it to UV exposure from the sun. A cataract is a clouding of the eye's transparent membrane or lens that prevents light from entering the eye and reduces vision. One of the most prevalent causes of vision impairment worldwide is cataracts, and people in developing nations are disproportionately affected by the disease's morbidity.[17 34 35] Many years ago, epidemiological research connected sunlight exposure to the development of cataracts.[5] Consequently, the WHO has identified sun UVR exposure as the primary environmental risk factor for cortical cataracts.[5 11]

ETHICS AND DISSEMINATION

Ethical statement

The study has been granted ethical approval/clearance from the University of Free State Health Research Ethics Committee (UFS-HSD2023/1227/2811) and the Central University of Technology Free State, Free State Faculty Research and Innovation Committee. Participation will be voluntary and anonymous. Participants can withdraw their consent from participating in the study at any time. The participant's responses will be private and protected by the Bill of Rights, Chapter 2: 16 (Right to freedom of expression) and the Protection of Personal Information Act (POPIA).

Informed consent will be obtained from each participant and will include an explanation of the study. The principal investigator is ultimately responsible for data management in this research project. He will oversee the data collection, processing, storage, analysis, sharing and archiving activities and ensure compliance with POPIA and other relevant laws and policies. The data manager will be assigned the right to change this plan. He will monitor the data management process and inform the ethics committee of any updates or changes before implementing the plan to reflect changes in the research objectives, methods, data sources, formats, standards, quality, security, etc. Data privacy will be ensured through data coding to remove any personal identifying elements within the data, and participants will be asked to complete the questionnaires in the absence of other study participants and put the completed questionnaire in a sealed, unopenable box designed by the researcher. Confidentiality and anonymity will be ensured by not publishing the participants' names or identifying information in the transcripts, and the participants' rights to privacy, confidentiality and anonymity will be safeguarded. Participants' identities will be de-identified for analysis. The results will undergo dissemination through a peer-reviewed scientific journal. In addition, further presentations will be made to the South African Military Services Directorate.

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Contributors SDG led the writing of this paper. Moreover, SDG, KL and PCR developed and drafted the original study protocol. In addition, PCR and KL drafted the methodology. All authors have read and agreed to the published version of the manuscript. The study's guarantor is PCR, who accepts full responsibility for the finished work and controls the decision to publish.

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