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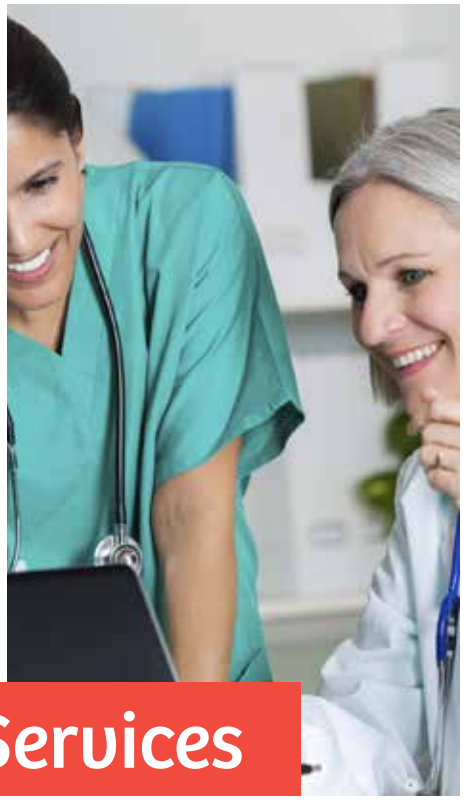
- Futuristic Utilization of Tactical Night Vision Goggles in Darkness by Combat Medics
- Reach, Accessibility and Effectiveness of an Online Self-guided Wellbeing Website
- Serum Level of Nutritional Antioxidants are Decreased in Veteran Smokers with COPD

The Journal of the Australasian Military Medicine Association



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History

Correction: In JMVH Vol 25:1 the following authors were inadvertently omitted from the article titled *'Application of Clinical Governance in a Role 2E Hospital: The 2nd General Health Battalion Experience'*: A. Williams and B McCall. The online edition has since been updated and we would like to offer our sincere apologies for any inconvenience this may have caused the authors.

Front cover: Ambulance arrives at 2GHB, Exercise Hamel 16, Cultana
Photo Courtesy of Murray Hayes

Journal of Military and Veterans' Health

Australasian Military Medicine Association

STATEMENT OF OBJECTIVES

The Australasian Military Medicine Association is an independent, professional scientific organisation of health professionals with the objectives of:

- Promoting the study of military medicine
- Bringing together those with an interest in military medicine
- Disseminating knowledge of military medicine
- Publishing and distributing a journal in military medicine
- Promoting research in military medicine

Membership of the Association is open to doctors, dentists, nurses, pharmacists, paramedics and anyone with a professional interest in any of the disciplines of military medicine. The Association is totally independent of the Australian Defence Force.

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Editorial

Kokoda Trail seventy-five years on

The Kokoda Trail is a single-file path that runs 96 kilometres overland between Port Moresby and Kokoda through the Owen Stanley Range in Papua New Guinea. Following a landing near Gona on the north coast of New Guinea, on the night of 21 July 1942, Japanese forces attempted to advance south overland to seize Port Moresby. Between July and November 1942, a series of battles were fought in Papua between Japanese and primarily Australian forces initially, with assistance from American forces later in the campaign. After a series of advances and withdrawals, with both sides facing significant resupply problems, Kokoda was recaptured on 2 November 1942. The fighting was some of the most desperate encountered by Australian troops in the Second World War, and, although the capture of Port Moresby was not a precursor to an Australian invasion, the victory did ensure that Allied bases in northern Australia would no longer be seriously threatened by air attack. Approximately 625 Australians were killed along the Kokoda Trail and 1,647 were wounded. Casualties due to sickness, including malaria, dysentery and scrub typhus, exceeded 4,000.

Captain Alan Oliver Watson was a dental officer working with the 2/4th Field Ambulance along the Kokoda trail. In addition to treating many dental patients and doing 80 extractions with a very limited dental kit, he also acted as the anaesthetist for the surgical team, giving 90 general anaesthetics between 16 October and 5 November 1942 during the advance towards Kokoda. In January 1943, Captain Watson returned to Australia suffering from malaria and dysentery. He was mentioned in despatches in December 1943 for his services. Captain Watson is just one example of the contribution made by military health staff during this arduous campaign.

Our second issue of 2017 addresses a range of diverse areas. There is a focus on health issues within the serving military, with articles on use of night vision goggles by medics, online mental health support, injury rates in full-time and reserve soldiers, and the military effectiveness of dietary supplements. There is also an article on the effects of smoking in veterans. Finally, there are two interesting historical articles on the malaria during the Second World War and the 1960s.

In 2015, the Canadian Journal of Surgery published a supplement devoted to military health, specifically "caring for the wounded in future" (http://canjsurg.ca/supplement-the-canadian-armed-forces-supplement-on-military-medicine-caring-for-the-wounded-in-the-future/).[1] I am keen to explore whether we could do a similar supplement in 2018, looking at advances in military health across the full spectrum. If you have an idea for an article in your area of expertise, I would be very interested in hearing about it.

We continue to get a good range of articles, but other military and veterans' health articles are always very welcome and we would encourage all our readers to consider writing on their areas of military or veterans' health interest. Our themes are now available for both 2017 and 2018 to allow for authors to research and develop their articles – we certainly welcome articles in these areas but welcome any articles across the broader spectrum of military health.

We would also encourage authors who are preparing to present at the AMMA Conference in October to consider writing up their presentations early for publication in the Journal.

Dr Andy Robertson, CSC, PSM

Editor-in-Chief

Reference:

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Futuristic Utilization of Tactical Night Vision Goggles in Darkness by Combat Medics

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Nowadays, the laws of war and rules of engagement are often disregarded by enemy combatants, and it is common to encounter practices in direct violation of these principles. To perform life-saving interventions and treatment on the battlefield, combat medics need special equipment, including light-emitting devices such as laryngoscopes and finger lights. However, the use of such devices in prehospital critical settings can potentially turn combat medics into targets for the enemy. Using this equipment in the field without taking tactical precautions can significantly increase the risk of enemy fire for combat medics. Night-time operations have also shown that insufficient light can significantly affect the success rate of these skills and procedures. When facing limitations at night or in limited light conditions, soldiers generally resort to the tactical solution of using night vision goggles (NVG). [1] Using light-emitting devices at night-time is associated with the risk of being spotted and killed by the enemy. An Israeli physician was shot by a sniper while performing endotracheal intubation (ETI) at night. [2] There have been a few studies on NVG use in medical interventions, including on an ETI application with NVGs undertaken by anaesthetists[1]; on emergency cricothyroidotomy with NVGs [3]; and on ETI and intravenous line insertion (IVI) with NVGs undertaken by emergency physicians and paramedics. [4] However, considering the nature of military operations, it is well-known that the most frequently encountered types of injuries on the field are injuries to chest, head, abdomen and extremities. We have noted that there are currently no NVG studies on these types of battlefield injuries. [5]

There is consequently a need for NVG studies on life-saving medical procedures. At the clinics of the Gulhane Military Medical Academy Department of Emergency Medicine- Turkey, we are continuing to conduct medical studies on this subject. Our ongoing studies have revealed that combatant medical staff are able to apply chest tube and needle thoracostomy successfully by using the NVG. (Figure-1-2) Military paramedics/medics not only perform patient intervention on the field of combat, but they also have to observe their environment without taking their NVGs off during battle.

The study of Butler et al. [2] is a tragic illustration of the harm and damage that can be caused when an extra light source other than the NVG we recommend is used by paramedics/medics in the field of combat. Medical interventions performed with NVG in the dark should be a part of basic training provided in tactical emergency medicine.

In the future, NVG it can be expanded to other lifesaving interventions like vascular access, in the

darkness and in unsafe circumstances, and can provide safety both for the providers of first aid and for the wounded individuals. More studies can be conducted with NVG to enhance the safety of interventions undertaken in unsafe areas.

The authors state that they have no conflict of interest

Acknowledgement

Dedicated in memory of Lt. Col. Ihsan EJDAR

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Reach, accessibility and effectiveness of an online self-guided wellbeing website for the military community

D Lloyd, T Varker, T Pham, J O'Connor, A Phelps

Abstract

Online mental healthcare resources have proliferated at a greater pace than evidence for their effectiveness. They may nevertheless be an attractive alternative for contemporary veterans and serving personnel who are reluctant to engage in traditional face to face treatment. This has created an urgent need to evaluate the effectiveness of online mental health care for the military community. This paper reports on the two-stage evaluation of the Wellbeing Toolbox, a self-guided website for ex-serving members and their families. Stage 1 evaluated the reach and acceptability of the website. Results from user experience interviews and a survey of 291 open access users indicated that the site reached a relevant audience and was accessible and acceptable for the ex-service community. Stage 2 investigated the effectiveness of the Wellbeing Toolbox in achieving wellbeing goals (the primary outcome) and other mental health outcomes (secondary outcomes). All 30 participants in the effectiveness trial achieved at least some of their individual wellbeing goals, with most success in "getting active", "building support" and "keeping calm" goals. There was no corresponding improvement in overall mental health status. The value and role of self-guided online help is discussed.

Conflict of Interest: None for any author. The Australian Centre for Posttraumatic Mental Health is partially funded by the Department of Veterans Affairs.

Introduction

After a decade of escalated military activity, particularly in the Middle East, we can expect to see an increase in the rate of service-related mental health and wellbeing issues. These include significant health and wellbeing problems, depression, anxiety, PTSD, and associated social, relationship and occupational challenges. However, many returnees are reluctant to seek professional help[1]. In 2010, only 55% of Australian Department of Veterans Affairs (DVA) veteran clients reporting a mental health or wellbeing problem had sought professional support[2]. The unmet need for mental health care is a burden on the community with family, social and economic costs. Engaging in early intervention could assist the adjustment of returning military personnel to post-deployment life and help prevent the development of chronic problems.

In recent years, health services internationally have faced the challenge of adapting to serve the needs of a new generation of military returnees with different preferences to earlier veterans, and reluctance to engage in traditional face-to-face health services[3]. Among military personnel, stigma has been identified as one of the main barriers to accessing mental health care[1,4]. There is a prevailing attitude amongst many military personnel that getting help for a psychological or behavioural problem would be perceived as a sign of personal weakness or that their careers could be adversely affected [5,6].

On-line self-help tools tailored to the military experience may be particularly powerful in their reach because of the privacy benefits, as well as convenience and flexibility to fit around other commitments. Social trends internationally suggest an increasing appetite for personal health control, and preference for the internet as a source of health information[7]. In Australia, younger veterans (up to 55 years of age) are known to be the age group most inclined to use the web to find health information [2].

On-line self-help tools, particularly those with a cognitive or problem-solving approach can be very effective interventions[8]. There is mounting evidence that online tools can be as effective as face-to-face psychotherapy for some disorders, especially depression and anxiety[9,10]. There is preliminary evidence for the effectiveness of online support in reducing posttraumatic stress symptoms in returning

veterans [11]. Some online resources are designed to be used in a stand alone self-help context, whereas others, and those most prominent in the effectiveness literature, provide guided or supported self-help. Many resources studied incorporate elements of therapist contact such as email support, telephone calls or face-to-face counselling. A recent review found that stand alone self-help interventions were effective for motivated clients with sub-threshold mood disorders, while therapist assistance was more important to treatment effectiveness when dealing with clinical levels of symptomatology [12]. The current study targeted sub threshold problems which commonly occur following a traumatic experience, using a self-help website designed for stand alone use by members of the military community. Although the importance of early intervention in mental health is well established, few of the existing self-help websites focus on early intervention and this was, therefore, a novel approach.

The Wellbeing Toolbox (www.wellbeingtoolbox.net.au) was developed by the Australian Centre for Posttraumatic Mental Health on behalf of the Australian DVA. The Wellbeing Toolbox consists of six topics (or modules), a self-management plan and an optional self-assessment questionnaire. The six skill building modules are Problem solving, Building support, Helpful thinking, Getting active, Keeping calm and Sleeping better. These were adapted from an established program 'Skills for Psychological Recovery' (SPR)[13]. SPR, originally designed as an early intervention for the post-disaster context, has an established theoretical background, and face validity for mental health providers [14]. The Wellbeing Toolbox is pitched at the level of generic psychosocial skills for early intervention for challenges arising from transitioning and other life issues, and to prevent difficulties escalating into severe mental health problems.

This paper presents the results of a two-stage evaluation of the Wellbeing Toolbox. First, we evaluated data from the naturalistic users who came to the site in the first 12 months after its launch, to examine the extent to which the site was accessible and acceptable to the target audience. We used Program Logic (i.e. a 'road map' that presents the theory behind and expected outcome of a program's actions) to map the intended outcomes of the website, to identify research questions and align this with data which could feasibly be obtained by manipulating aspects of the website (e.g. building in analytics and page tracking, incorporating questionnaires and a data extraction portal). Methodological challenges included how to obtain rigorous evidence whilst retaining user privacy which is part of the appeal for online self-help audiences.

In addition to satisfaction with the website, the extent to which users benefit from their interaction with the site remained an important unanswered question. Whilst the availability of on-line resources is a positive first step toward improving health in the target population, further evidence was required to determine whether website use leads to measurable improvements in wellbeing. This led to a second study testing the hypotheses that site users would achieve improvements in individual wellbeing goals (primary outcome) and mental health status (secondary outcome) after 3 months of use.

Study 1: Accessibility and acceptability of the Wellbeing Toolbox

This study aimed to determine accessibility and acceptability of the Wellbeing Toolbox for the target audience of current and former military personnel in Australia.

Materials and Methods

Participants

Initial satisfaction data was obtained via an on-line survey completed by 291 naturalistic, open access users of the site. From this group, 15 randomly selected and consenting veteran users participated in telephone interviews.

Measures

An online satisfaction survey asked basic demographic information and four structured satisfaction questions relating to ease of use, helpfulness, whether the user would return if they needed further help and whether they would recommend the site to others. Site usage information was extracted via Google Analytics[15]. A structured 30 minute interview enquired about the way the site was used (e.g. frequency and duration of visits, self-reported impact and outcomes of using the website), and the extent to which this self-help sample used other face-to-face health services.

Procedure

The satisfaction survey was posted on the Wellbeing Toolbox website for the first year of operation. During this period the extent of site usage was measured on a monthly basis by data extracted from Google Analytics. Users willing to be contacted for telephone interview registered their contact details online. Fifteen of these users were randomly selected using a computer generated random number list and were contacted to provide more detail about their experience of using the website in a structured

interview. Interviewers used a checklist to record responses. Open ended explanatory comments and examples were transcribed verbatim. Interview record sheets were categorically analysed by one researcher and verified by a second.

Results

During the first year of use the Wellbeing Toolbox received 7477 unique visitors. Visitors who completed the online survey (*n*=291) were predominantly male veterans with a mean age of 60 years (range 28-88). A breakdown of participants by age category revealed that the age profile of the sample was similar to that of DVA clients overall: approximately 60% between 60 and 69 years of age; 20% between 50 and 59; 10% between 40 and 49; 6% between 30 and 39; and just over 1% under 29 years. Among the 291 users who completed the online satisfaction questionnaire, 68% found the site easy to use, 52% found the site helpful, 70% said that they would return to the site if they needed help in the future and 61% intended to recommend it to others. Among the 15 randomly selected veteran users who were interviewed, the majority (80%) reported that they were benefiting in meaningful ways and could give an example of the way site usage had improved an aspect of their wellbeing or their self-management of wellbeing issues. Just over half of the interviewees (53%) were not currently connected to mental health services and one third (33%) had never received help from a psychologist, social worker or counsellor in the past. As such, the site had reached veterans who were not currently using other mental health services and some who had never used DVA mental health services to which they were entitled.

Study 2: Effectiveness of the Wellbeing Toolbox

The aim of Study 2 was to examine the effectiveness of the Wellbeing Toolbox as a means of improving individual wellbeing and mental health issues for current and former military personnel. The funders and host of the Wellbeing Toolbox, DVA, had a particular interest in whether the site was effective for current and former serving military personnel up to the age of 55. As such, the effectiveness trial targeted this age group. We hypothesized that users who set specific wellbeing goals would achieve improvements in these areas after 3 months of use. It was hypothesized that the use of the Wellbeing Toolbox would also lead to a significant improvement in mental health outcomes on standard mental health measures post-intervention.

Methods

Participants

Thirty participants were recruited to participate in this study. Participants were required to be Australian serving or exserving members or their families, have access to a computer, be interested in improving aspects of their wellbeing, and not to be currently engaged in active psychological treatment. Although the site is intended for subclinical problems, participants were not excluded on the basis of mental health symptom severity. Demographics of the trial participants are shown in Table 1.

TABLE 1. Demographics of trial participants

	Mean (*SD*) / % (*n*)
Age	41.80 (9.87)
Marital status	
Married	53 (16)
Divorced/separated	27 (8)
Single/never married	20 (6)
Employment status	
Employed	46 (14)
Unemployed	30 (9)
Retired	10 (3)
Volunteering	7 (2)
Studying	7 (2)
Service status	
Currently serving	13 (4)
Ex-serving	77 (23)
Partners	7 (2)
Son or daughter of veteran	3 (1)
Mental health treatment history	
Previously or currently receiving mental health treatment	50 (15)
No prior mental health treatment	50 (15)

Measures

Prior to using the website, participants took part in a telephone interview to discuss and set individual wellbeing goals. The interviewer used a structured interview guide to check if each wellbeing domain was relevant to the participant, and if so elicited and clarified a goal the participant hoped to achieve within three months. Post-intervention, participants reviewed and rated the extent to which their goals had been achieved and attained over the three month period of the trial, and provided general feedback on their experience of using the website.

Participants also completed a self-report booklet before using the website and post-intervention. Self-report instruments measured psychological distress, alcohol use, quality of life, and depression, anxiety and stress.

Goal achievement

Achievement of each individual goal was rated on a 5-point scale (1 = 'not achieved at all', 5 = 'totally achieved'), developed specifically for this trial.

Psychological distress

The Kessler 10 [16] is a widely used brief screening tool for psychological distress. It is already available on-line within Wellbeing Toolbox site as an optional questionnaire. The cut-offs are 10-15 mild distress; 16-29 moderate; 30 or over severe.

Depression, anxiety and stress

The Depression Anxiety and Stress Scale (DASS 21)[17]is a 21 item screening tool, it has three sub-scales for depression, anxiety and stress, and is widely used in research and clinical practice. It has good psychometric properties and is routinely used by community veteran mental health clinics for clients presenting to counselling in Australia.

Alcohol use

The Alcohol Use Disorders Identification Test (AUDIT)[18] is a 10-item scale developed by the World Health Organisation as a screening instrument for hazardous and harmful alcohol consumption. The scale has demonstrated strong internal reliability (0.86). This is the gold standard alcohol measure used in many veteran programs and research.

Quality of life

The WHOQOL-Brèf (the short form of the World Health Organization's Quality of Life instrument) is an internationally recognized instrument [19,20], which has been validated for Australian use [21]. The WHOQOL-Brèf comprises 26 questions on four scales measuring physical health, psychological wellbeing, social relationships and the environment. Higher scores indicate higher quality of life.

Procedure

The research was approved by the Department of Veterans' Affairs Human Research Ethics Committee. Advertisements for trial participation were circulated via advocacy and ex-service support organisations, and on social media via the Australian Department of Veterans' Affairs Facebook and Twitter accounts. Participants expressed an interest online, then after receiving study information, those eligible for inclusion in the trial provided informed consent and were admitted to the trial by the interviewer. The initial assessment included a structured interview and completion of self-report measures. Participants, together with the interviewer, developed individual wellbeing goals, which could feasibly be achieved in three months. After the assessment, participants were directed to the Wellbeing Toolbox website (www.wellbeingtoolbox.net.au) and encouraged to use it over the coming 3 months to improve those aspects of their wellbeing using the interactive modules and self-management plan within the site. They were given a log sheet and asked to record the amount of time spent on the site for each visit.

Data analysis

This study utilized a mixed methods approach and a pre- post design. Group means for goal attainment were calculated. Paired t-tests were used to examine whether participant's scores on mental health measures were significantly different over time. Qualitative data including verbatim comments and examples were thematically categorised by one researcher and verified by a second.

Results

We hypothesized that those site users who set specific wellbeing goals would achieve improvements in these areas after 3 months of use. In addition, we examined whether use of the website led to significant improvement in mental health outcomes during this period.

Achievement of wellbeing goals

All trial participants identified areas of their wellbeing that they would like to improve. Examples of wellbeing goals associated with each of the

six wellbeing modules are shown in Table 2. At 3 months when the goals were reviewed, participants rated to what extent their goals had been achieved. Over 75% of participants' goals were achieved in all topic areas. Participants were asked to record how long they spent on the website and to rate the extent to which their use of the website had contributed to achieving their goals. Unfortunately, the site usage logs were rarely used by participants, leaving them to rely on memory. Participants tended to give vague or uncertain estimations of the time spent on site, and to rate lowly the extent to which the website had contributed to their goal attainment. These areas were followed up in the final interview. Participants reported that the process of setting the goals together with the interviewer had been a very helpful part of their experience but that their internet usage was variable and hard to remember to what extent they had used which modules.

TABLE 2. Goal attainment rating

Category/ module (n participants who set goals)	Examples of goals	Number of participants (%) whose goals moderately to totally achieved
Sleeping better (14)	E.g. Establish a sleep timetable	12 (87.5)
Problem solving (17)	E.g. Create two job applications each fortnight	12 (76.5)
Building support (17)	E.g. Search for new social groups	15 (88.2)
Helpful thinking (15)	E.g. Identify and record triggers of negative thoughts and situations as they occur	12 (80.0)
Getting active (17)	E.g. Walk for 30 minutes once a week	13 (76.5)
Keeping calm (18)	E.g. Identify and record triggers to stressful thoughts	17 (94.4)

Mental health outcomes

As a secondary outcome measure, we examined whether use of the website led to significant improvement in mental health outcomes after three months of use. Despite the achievement of personal wellbeing goals reported above, widespread improvements were not found in response to standard mental health outcome measures. Results are presented in Table 3.

As shown in Table 3, participants were experiencing significant mental health problems at initial assessment. Mean psychological distress was in the high range M=29.40 (8.07), means from the depression anxiety and stress subscales from the DASS were all in the severe range. Twenty percent of the participants scored positively for alcohol abuse or dependence.

There was a small non-significant reduction in K10 between baseline and follow-up assessment, a small non-significant reduction in DASS subscale scores for depression, anxiety and stress. No domains of quality of life shifted significantly between baseline and the post-intervention assessment. It was interesting to note that the only significant change in mental health outcomes was a reduction in alcohol use, which was not directly targeted in the Wellbeing Toolbox ($t(13)=2.31$, $p<.05$) . This may have been a secondary benefit of achieving well-being goals but this was not explored in the current investigation.

Discussion

The Wellbeing Toolbox evaluation consisted of two studies. The first examined the accessibility, acceptability and reach of the website. During its first year of use, the Wellbeing Toolbox website was accessed by a significant number of Australian veterans who were generally satisfied with their experience on the site. The second examined the effectiveness of using the site to achieve wellbeing goals and improvement in mental health. The effectiveness trial succeeded in recruiting 30 ex-serving members who sought wellbeing improvements and were willing and interested in participating in an

TABLE 3. Outcomes on self-report measures with frequency (n) for scores by severity category where relevant

Measure	Time 1	Time 2	*t* (df)	*p* (Hedges g)
	Mean (SD) / *n*	Mean (SD) / *n*		
K10 (N=20)	29.40 (8.07)	26.70(8.07)	1.49(19)	0.152
Low	3	7		
Moderate	6	4		
High	2	4		
Very High	12	11		
AUDIT total (N=14)	12.07 (8.07)	8.29 (7.22)	2.31(13)	0.040* (.48)
Abuse	4	3		
Dependence	2	4		
WHOQoL-BREF (N=19)				
Physical health	11.25 (3.85), *13*^	11.85 (4.01), *13*	1.74(18)	0.099
Psychological wellbeing	10.84 (2.70), *19*	11.16 (3.74), *19*	0.47(18)	0.642
Social relationships	10.67 (4.05), *69*	9.96 (3.57), *56*	1.02(18)	0.320
Environment	12.07 (3.90), *75*	11.97 (4.08), *75*	0.20(18)	0.847
DASS-21 (N=19)				
Stress	22.74 (11.78)	19.89 (10.53)	1.78(18)	0.092
Anxiety	15.68 (12.95)	14.00 (12.24)	0.77(18)	.0451
Depression	21.26 (10.59)	18.31 (11.86)	1.07(18)	0.298

*$p < 0.05$; ^ italicised number = transformed mean score

online intervention. Individual wellbeing goals were achieved during three months of site use, but these improvements were not accompanied by reductions in scores on mental health instruments.

Since the site did not aim to treat mental health conditions, the lack of significant results on standard outcome measures is perhaps unsurprising. Meta-analysis and review findings suggest that for clinical levels of disorder, the best treatment outcomes from online interventions require some form of therapist contact [12,22]. However the data trended toward improvement across a range of measures and there was a significant reduction in alcohol use. This points to the potential of 'wellbeing' oriented content providing at least a foundation level of benefit which could be augmented by face-to-face or tele-therapy psychological treatment specifically targeting mental health problems. It was somewhat concerning in this study that participants reported severe mental health problems, given that none were currently receiving other mental health care.

On a related point, few participants were able to set specific, measurable, achievable, realistic and time-related goals without interviewer assistance. Participants struggled to identify wellbeing improvements which could reasonably be achieved in 3 months. Once set, goals were generally achieved independently of further input. This points to opportunities either to strengthen goal setting ability of self-guided site users (some means of helping them to refine their own goals) or to engage therapist support in the goal setting process.

This study points to the potential value of resources like the Wellbeing Toolbox as an appealing entry point

or adjunct to more intensive face-to-face treatment. In practice this means digital resources having features such as push button access to local mental health services, capabilities to send assessment results to a provider, or request a call back from a supporting clinician. In addition, there is room to develop clinicians' awareness of and engagement with digital resources [23] to the extent that they can confidently direct appropriate clients toward digital resources (websites or phone or tablet applications), and support their use of these tools whilst actively referring more severely affected people (or those for whom self-guided strategies have failed) toward more involved care. These features should be a higher priority in future digital resource design, and in practitioner training and professional development [24].

The study has several limitations.

1. The trial was designed as a pilot to indicate if a larger RCT was warranted, and as such was conducted with relatively small numbers and did not involve a comparison treatment arm such as face to face Skills for Psychological Recovery. These factors inevitably limit the interpretation of the findings.
2. It would have been useful to have more reliable information regarding site usage, and to relate the amount of time spent on site, pages viewed and activities undertaken with achievement of goals, but this data was not available as participants tended not to complete the site usage logs. Future study designs may consider, with participants' consent, the use of automated usage tracking.
3. Severity of mental health problems, with the exception of current risk to self or others, was not used as an exclusion criterion because we were interested in how effective the Wellbeing Toolbox would be for participants who were attracted to on-line self-help. However we did not anticipate that almost all participants would be experiencing severe mental health problems, limiting our capacity to assess its effectiveness for sub-clinical problems.

Despite these limitations, this study illustrates the value of online resources in reaching populations in need, their acceptability to people who have not sought help in other forms, and their effectiveness in leading to meaningful improvements in wellbeing of the ex-serving community. For those with more severe mental health concerns, online resources should be part of a suite of support options that also includes face to face treatment.

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Incidence rates for work health and safety incidents and injuries in Australian Army Reserve vs full time soldiers, and a comparison of reporting systems

Rodney Pope, Robin Orr

Abstract

Objective: To determine incidence rates of reported work health and safety (WHS) incidents and injuries in Army Reserve (ARES) and Australian Regular Army (ARA) personnel and assess the relative performance of the WHS incident reporting system, compared to 'point-of-care' systems.

Methods: WHS incident data for a 24-month period were extracted from a military database. Reported WHS incident and injury rates for both populations were calculated and compared. The WHS injury rates were compared with previously published injury incidents rates based on 'point-of-care' incident reporting in Army populations to ascertain relative performance of WHS and 'point-of-care' systems.

Results: In both populations combined, 15065 incidences (11263 injuries) were reported. The injury rates for ARES and ARA were, respectively, 31 and 17 injuries, per 100 person-years of active service. Published Army injury reports based on point-of-care injury reporting have cited much higher soldier injury incidence rates.

Conclusion: Rates of ARES reported WHS incidents and injuries were higher than those of ARA personnel. There appears to be substantial under-reporting of WHS injury incidents on the military WHS database when compared to point-of-care incident reporting.

Key Words: Injury, Surveillance, Military, Health and Safety, Defence

Introduction

Reserve soldiers constitute a substantial and integral part of contemporary military forces and, just like their full-time counterparts, their capabilities can be rapidly degraded by work health and safety (WHS) incidents and associated injuries. Despite these facts, rates and sources of WHS incidents and injuries are rarely reported for reservists, and this knowledge deficit limits the information commanders have at their disposal when seeking to manage associated risks. These risks affect not only the individual, and potentially their civilian workplace, but also the military teams in which they operate and operational capability.

In order to begin to address this knowledge deficit, in a recent study [1] we examined WHS incident and injury rates and patterns in Australian Army Reserve (ARES) soldiers and compared them to those in full-time soldiers in the Australian Regular Army (ARA). We found that, *per capita*, ARES soldiers reported fewer WHS incidents and injuries than their ARA counterparts in a recent two-year period, and we identified some key sources of injuries in both ARES and ARA populations. However, we also noted that the *per capita* incidence rates calculated in that study did not take into account the fewer annual days of active service typically served by ARES soldiers, for which the numbers were not available at the time of that study. We therefore recommended that future research be conducted to compare the incidence rates of WHS incidents and injuries in ARES and ARA soldiers, in terms of the numbers of incidents and injuries reported per 100 person-years (or full-time equivalent years) of active service, so that the relative level of exposure to military service was taken into account.

To date, only one other identified publication [2] has compared the reported injury incidence rates for military reserve and full-time personnel. That

publication, the Australian Defence Force (ADF) Health Status report published in 2000 [2], noted that ADF reserve personnel reported more than 3 times the rate of injuries reported by their full-time ADF counterparts for each full-time equivalent year of active service. While the full-time personnel reported 9 injury or illness incidents for every 100 full-time years of active service, the reserve personnel reported 29 such incidents for every 100 full-time equivalent years of active service. This was notably quite different to the *per capita* rate of 4 incidents for every 100 reserve personnel first presented in the Defence Health Status report [2], which initially suggested that full-time personnel suffered a higher rate of injuries and illness when the much lower annual days of active service typical of reserve personnel were not taken into account.

One difficulty in ascertaining both *per capita* incidence rates and incidence rates that take into account the level of exposure is the often unknown threshold for reporting of WHS incidents. In other words, what proportion of injuries that occur are actually reported? It may be that only certain injuries are reported (e.g. a fracture as opposed to a blister) or that only some people routinely report their injuries. When presented with comparative rates of reported injuries for different cohorts, the concern is always therefore whether any differences in reported rates represent real differences between the cohorts in actual injury rates or whether the differences are simply an artefact of different reporting thresholds in the cohorts being compared.

In addition, thresholds for reporting of WHS incidents and injuries are important, as if the threshold is too high and injuries are rarely reported, the volume and quality of data available to guide injury risk management efforts are markedly reduced. Furthermore, injuries sustained may appear to be minimal whereas in fact injury rates could be markedly higher. This data deficit impacts negatively on the statistical power of any analysis of the data to identify emerging risks or spikes in injury rates in a timely manner, with flow-on effects to command capacity to manage the associated risks and thereby maintain Army capability. If 'near misses', 'dangerous occurrences' and 'minor injuries' are not routinely reported, then new or emerging hazards and sources of injury risk can also be easily missed, with similar flow-on effects. WHS incident and injury reporting rates therefore constitute a key indicator of WHS incident reporting system utility for commanders. Other indicators of utility include [3]: having efficient, routine and multi-purpose incident reporting mechanisms; ensuring the system has adequate and suitably tailored and timely information outputs; system capability for timely detection and command alerts regarding emerging incident trends of importance; and ensuring there is a robust feedback loop to those reporting and entering data in order to maintain their commitment to ensuring data integrity.

On this basis, the aim of this study, which drew in part on the same data set used in our other recent paper on this topic[1] and comprised an extension to that previous study, was two-fold: (a) to determine the recent incidence rates of reported work health and safety (WHS) incidents and injuries in ARES and ARA personnel; and (b) to assess the performance of the Australian Department of Defence WHSCAR system relative to 'point-of-care' (health care consultation) injury incident reporting systems, with regard to injury incident capture rates.

Methods

Research design

A retrospective cohort study was conducted to ascertain and compare the incidence rates of both WHS incidents and injuries for the complete ARES and ARA populations in the period 1 July 2012 to 30 June 2014, inclusive. The injury incidence rates derived from the WHS data sources used in this study were subsequently compared to injury incidence rates derived from DEFCARE, the predecessor WHS incident reporting system of the ADF, as well as injury incidence rates from previously published Army injury reports which used 'point-of-care' data capture (data capture at the time of presentation for health care), to assess differences in injury incident capture rates.

Ethics approval

Ethics approval for the study was granted by the Australian Defence Human Research Ethics Committee (ADHREC; protocol LERP 14-024) and the Bond University Human Research Ethics Committee (BUHREC; protocol RO1907). Authorisation to conduct the project was also obtained from the Australian Department of Defence and authorisation to release this paper from Joint Health Command.

WHS incident and injury definitions

For the purposes of this study, the definition of *WHS incidents* included all incidents recorded on the WHSCAR database for the population and period of interest, comprising: (a) minor personal injuries; (b) serious personal injuries (or illness); (c) dangerous occurrences; (d) fatalities; (e) incidents involving exposure to a hazardous substance or material; and

(f) 'near misses'. The definition of *injury* included only the following types of incident reported on the WHSCAR database: (a) minor personal injuries; and (b) serious personal injuries (or illness).

Data sources

WHS incident and injury data and population data for both ARES and ARA were obtained for the period 01 July 2012 to 30 June 2014. The WHS incident and injury data were extracted and provided in a non-identifiable form by an administrator of the Workplace Health, Safety, Compensation and Reporting (WHSCAR) database of the Australian Department of Defence.

The WHSCAR database is designed to record all incident reports submitted in the notification and reporting of Workplace Health and Safety incidents that have occurred in the Department of Defence [4]. The data set extracted from the WHSCAR database confirmed, for each incident record, that the affected individual's Service was Army. It also identified their serving status (part-time or full-time) and the type of occurrence, date of incident, incident status, incident severity, nature of incident, body site affected by incident, mechanism of incident, activity at the time of incident (including specific event, e.g. field exercise, if applicable), incident description, and duty status (on or off duty) at the time of the incident. The mean population sizes for ARES and ARA, across the study period, were derived from published reports of the Department of Defence[5,6]. The total number of days of active service undertaken by ARES personnel, as a cohort, in each year of the study period was provided by administrators of the Army's personnel databases and reflected actual days worked. Finally, injury incidence rates previously reported [2,7-9] for Army populations in DEFCARE, the WHS incident reporting system that predated WHSCAR, and based on 'point-of-care' systems of data capture were compiled to provide comparison rates for reference in evaluating the performance of the WHSCAR system, with regard to incident capture rates.

Participants and eligibility criteria

All records of WHS incidents and injuries extracted from the WHSCAR database in accordance with pre-specified criteria were checked to confirm they met the key eligibility criteria for inclusion in the study data set. Records were included in the study data set if they related to: (a) Australian Army Reserve (ARES) or Australian Regular Army (ARA) personnel; (b) an incident or injury that occurred while the person was 'on duty'; and (c) an incident or injury that occurred between 01 July 2012 and 30 June 2014, inclusive. Records were excluded if they: (a) related to personnel from Australian military services other than the Australian Army; or (b) related to personnel from a foreign defence service, on secondment.

All WHS incident and injury records were categorised by cohort, each defined by service type (ARES or ARA) of the respective participant. These ARES and ARA cohorts formed the primary basis for subsequent comparative analyses.

Outcome measures

The *primary outcome measures* for the study were the incidence rates for WHS *incidents* and *injuries* that were reported as occurring in the 2-year period of interest. These incidence rates were separately calculated for each of ARES and ARA, in two forms, these being *incidents* or *injuries per 100 personnel per year* and *incidents* or *injuries per 100 person-years of cumulative active service*.

The *secondary outcome measures* for the study were the *injury* incidence rates that have been reported in several prior studies in Army populations. One of these prior studies [2] involved WHS incident data derived from DEFCARE, the WHS incident-reporting systems that pre-dated the WHSCAR database, and published in the ADF Health Status report (ADFHSR) in 1998. DEFCARE was very similar to the WHSCAR system, using almost identical data collection procedures and coding systems, and so reported incident rates from each system could be expected to be identical, if actual incident rates were equivalent. The remaining studies [7-9] used reporting of injuries at the time the injured soldier reported for health care for their injury ('point-of-care' injury reporting). These injury incidence rates provided a benchmark against which the stability of performance and relative performance of the WHSCAR system and its incident reporting approach could be assessed, with regard to capture rates of work-related injury incidents. The injury definitions used in all of these systems were very similar – any musculo-skeletal and other soft-tissue injuries that were serious enough to require a health care consultation met the threshold for reporting in each system. Although the time periods covered in these previous studies varied, injury incidence rates reported for the US Army [9] reflected injuries reported in the year 2014, overlapping with the period of time from which the WHSCAR data was drawn. Additionally, comparison of injury incidence rates derived from the WHSCAR and predecessor DEFCARE [2] systems (Figure 1; note in this figure the DEFCARE data is represented by the ADFHSR, 1998) revealed relative stability between 1998 and 2014 in injury incident reporting rates derived from these consecutive WHS systems. These facts justify the approach employed in this

study of comparing the WHSCAR injury incidence rates from the period 2012 to 2014 with rates from the 'point-of-care' systems in the same period [9] and preceding years that were later than 1998 [7,8].

Data Analysis

The WHSCAR data were provided in a raw, non-identifiable format, in a Microsoft Excel spread sheet. Prior to analysis, the data were manually cleaned to ensure that only records consistent with the inclusion and exclusion criteria were retained. In addition, each line of data was reviewed and compared to other lines of data to ensure identification and removal of duplicate entries (same record entered twice).

WHS incident and injury data were subsequently entered into the Statistical Package for the Social Sciences (SPSS) Version 21.0 for statistical analysis. Descriptive analyses were first conducted to establish the numbers of WHS incidents and injuries that were reported in each of the ARES and ARA populations in each period, 1 July 2012 to 30 June 2013 and 1 July 2103 to 30 Jun 2014. In addition, the mean annual numbers of WHS incidents and injuries were calculated across the full 2-year period. These mean annual numbers of incidents or injuries were then divided by the mean numbers of personnel employed in the respective service type (ARES or ARA) across the 2-year study period and the resulting figures were multiplied by 100 to derive mean annual incidence rates for both WHS incidents and injuries occurring in the ARES and ARA populations, reported in terms of *incidents* or *injuries per 100 personnel per year*. Additionally, the total numbers of injuries and WHS incidents that were reported across the 2-year study period were each in turn divided by the total number of years of active service provided to the Army by each cohort (ARES and ARA), across the two-year study period, to derive incidence rates reported in terms of *incidents* or *injuries per 100 person-years of active service (ie* full-time equivalent years). When calculating total years of active service (*i.e* total full-time equivalent years of service) for the ARES, 232 days of active service were assumed to equate to one full year of active service (or one full-time equivalent year of service) based on the following calculation:

> Total days of active service typically completed in a full-time year of army service = 365d in a year – 104d weekends (or 'in lieu' non-service days) – 20d annual leave – 9d public holidays

Population estimates of the ARES:ARA incidence rate ratios (IRR) for both WHS incidents and injuries, indicating the ratios of incidence rates in ARES compared to ARA, were calculated using the following formula [10]:

> IRR = (ARES incidence rate) / (ARA incidence rate)

In these IRR calculations, the incidence rates used were those based on total number of full-time equivalent years of active service (rather than total number of personnel). The ninety-five percent confidence interval (95% CI) around the population estimate of each IRR was then calculated as[10]:

> 95% CI = exp (ln[IRR] – 1.96 x SE(ln[IRR])) to exp (ln[IRR] + 1.96 x SE(ln[IRR]))
>
> *where* SE(ln[IRR]) = $\sqrt{(1/[\text{incident rate}_{ARES}] + 1/[\text{incident rate}_{ARA}] - 1/n_{ARES} - 1/n_{ARA})}$

Finally, the injury incidence rates calculated in the current study based on data from the WHSCAR database were charted, as planned, against injury incidence rates reported in previous studies of injuries reported in Army populations via DEFCARE[2] and 'point-of-care' injury reporting systems[7-9]. Where necessary, these previously-reported injury incidence rates were converted to provide the number of injuries per 100 person-years of active service, with reference to the authors of the respective study to clarify details if needed, enabling a ready comparison to the incidence rates reported in the current study. The comparative chart was designed to provide an indication of the stability and relative performance of the Australian Department of Defence WHSCAR system and its predecessor DEFCARE system, with regard to injury incident capture rates.

Results

ARES and ARA populations and full-time equivalent years of service

The ARES and ARA populations[5,6] and estimated total person-years of active service (full-time equivalent years of service) during the study period 01 July 2012 to 30 June 2014 are detailed in Table 1.

Reported work health & safety (WHS) incidents

A total of 15065 WHS incidents were reported across the two-year period of the study (2012-2013, n=7633; 2013-2014, n=7432; Table 2). Table 3 provides the incidence rates for reported WHS incidents calculated for each Service Type and for Army as a whole, based on the figures from Table 2. IRR are also provided in Table 3, indicating the ARES: ARA ratio of incidence rates for WHS incidents.

Table 1. *ARES and ARA Populations and Estimated Person-Years* of Active Service 2012-2014*

	Population			Person-Years* of Active Service			
	ARES	ARA	Whole of Army		**ARES**	**ARA**	**Whole of Army**
2012 - 2013	14867	28955	43822	2012 – 2013	2296	28955	31251
2013 - 2014	15200	29847	45047	2013 – 2014	2405	29847	32252
Mean population 2012-14	15034	29401	44435	Total person-yrs 2012-14	4701	58802	63503

*One person-year of active service was nominally estimated to be equivalent to 232 days of active service by deducting 104 weekend days (or 'in-lieu' non-service days), 20 days of annual leave and 9 days of public holidays from 365 total available days in a normal year

Table 2. *Frequencies of each reported WHS incident type by year and Service type*

			Minor Personal Injury	**Exposure**	**Serious Injury**	**Dangerous Occurrence**	**Near Miss**	**Fatality**	**Total**
2012-2013	ARES	Incidents	664	50	44	42	1	1	802
		% within year	83	6	6	5	0.1	0.1	100
	ARA	Incidents	4348	1774	427	273	4	5	6831
		% within year	64	26	6	4	0.1	0.1	100
2013-2014	ARES	Incidents	704	36	22	16	10	1	789
		% within year	89	5	3	2	1	0.1	100
	ARA	Incidents	4813	1264	241	234	87	4	6643
		% within year	73	19	4	4	1	0.1	100
Total 2012-2014	ARES	Incidents	1368	86	66	58	11	2	1591
		% within years	86	5	4	4	0.7	0.1	100
	ARA	Incidents	9161	3038	668	507	91	9	13474
		% within years	68	23	5	4	0.7	0.1	100

Note. Percentages rounded to the nearest whole percent except when <1%, rounded to the nearest 0.1%

Table 3. *Incidence rates for reported WHS incidents, by Service type (WHS incidents per 100 soldiers per year [per 100 person-years of active service])*

WHS incident type	ARES	ARA	Whole of Army	IRR (ARES:ARA) & 95% CI
Minor personal injury	4.55 [29.10]	15.58 [15.58]	11.85 [16.58]	[1.87; 95% CI 1.78-1.96]
Serious injury	0.22 [1.40]	1.14 [1.14]	0.83 [1.16]	[1.24; 95% CI 0.96-1.59]
Exposure	0.29 [1.83]	5.17 [5.17]	3.52 [4.92]	[0.35; 95% CI 0.29-0.44]
Dangerous occurrence	0.19 [1.23]	0.86 [0.86]	0.64 [0.89]	[1.43; 95% CI 1.09-1.87]
Near miss	0.04 [0.23]	0.15 [0.15]	0.11 [0.16]	[1.51; 95% CI 0.81-2.82]
Fatality	0.01 [0.04]	0.02 [0.02]	0.01 [0.02]	[2.78; 95% CI 0.60-12.9]
Total	5.29 [33.84]	22.91 [22.91]	16.95 [23.72]	[1.48; 95% CI 1.42-1.54]

Table 4. *Reported injuries by year and Service type*

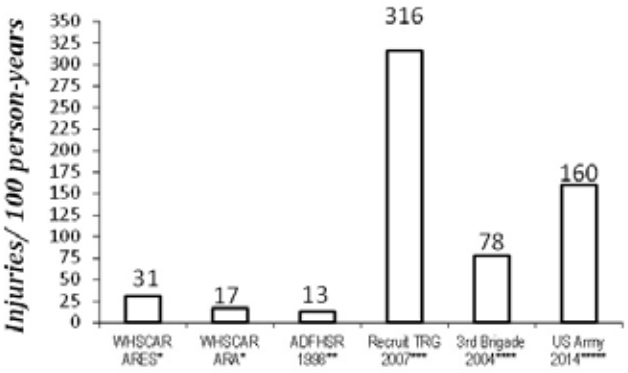
Years		ARES	ARA	Whole of Army
2012-2013	Injuries	708	4775	5483
	% within year	13	87	100
2013-2014	Injuries	726	5054	5780
	% within year	13	87	100
Total 2012-2014	Injuries	1434	9829	11263
	% within years	13	87	100

Note. Percentages rounded to the nearest whole percent

Table 5. *Reported injury incidence rates, by year and Service type (injuries per 100 soldiers per year [per 100 person-years of active service])*

Years	ARES	ARA	Whole of Army	IRR (ARES:ARA) & 95% CI
2012-2013	4.76 [30.84]	16.49 [16.49]	12.51 [17.55]	[1.85; 95% CI 1.72-2.00]
2013-2014	4.78 [30.19]	16.93 [16.93]	12.83 [17.92]	[1.80; 95% CI 1.67-1.93]
Total 2012-2014	4.77 [30.50]	16.72 [16.72]	12.67 [17.74]	[1.82; 95% CI 1.74-1.91]

Figure 1 *Comparative Army injury incidence rates from various studies*



*Current study

**ADF Health Status Report (2000) – DEFCARE dataset

***Goodall R, Pope R, Coyle J & Neumayer, R (2012). Balance and agility training does not always decrease lower limb injury risks: a cluster-randomised controlled trial. *International Journal of Injury Control and Safety Promotion,* 20 (3), 271-281

**** Rudzki SJ & Pope R (2006). Injury reductions seen in an infantry brigade using the Australian Defence Injury Prevention Program. *Medicine & Science in Sports & Exercise,* 38 (5), p. S348

***** US Defence Health Agency: https://www.afhsc.mil/Reports/InjuryReports

Reported Injuries

A total of 11263 injuries (comprised of minor personal injuries and serious injuries) were reported across the two-year period of the study. Table 4 details the numbers of injuries reported in ARES and ARA populations in this period. Table 5 provides the incidence rates for reported injuries calculated for each Service Type and for Army as a whole, based on the figures from Table 4. IRR are also provided in Table 5, indicating the ARES:ARA ratio of injury incidence rates. The figures presented in Table 5 indicate that the reported injury incidence rate was stable in ARES and in ARA populations, year-to-year.

Comparison of WHSCAR to previously published Army injury incidence rates

Figure 1 provides a comparison between injury incidence rates calculated for ARES and ARA populations in the current study, based on 2 years of WHS incident records contained in the WHSCAR database, and benchmark injury incidence rates derived from previously published reports of injuries in various Army contexts[2,7,8].

Three[7-9] of the four previously published reports[2,7-9] indicated much higher injury incidence rates for Army personnel than the rates calculated in the current study based on records from the WHSCAR system. The US Army injury incidence rate[9] of 160 injuries per 100 person-years of active service is indicative of a 'whole-of Army' injury incidence rate, and this injury incidence rate lies midway between incidence rates reported for Army recruits and for an operational brigade in the Australian Army, and thus is probably a sound estimate of overall actual injury incidence rates for Army populations, when considering injuries requiring a health care consultation. The injury incidence rates derived in this study from the WHSCAR database are similar to those derived from its predecessor DEFCARE system[2] and represent only 11-19% of the above estimate of the true incidence rate for injuries that are of sufficient severity to require a consultation with a healthcare provider. Injury incidence rates derived from the WHSCAR database in the current study were slightly higher than those derived from its predecessor, DEFCARE[2], but the relative similarity of these rates when compared to the 'point-of-care' rates (Figure 1) suggests that injury reporting rates in these WHS incident reporting systems have probably been quite stable over the sixteen-year period these studies span.

The three published reports[7-9] which reported much higher injury rates in Army personnel than the rates reported from DEFCARE or WHSCAR records all used a 'point-of-care' approach to injury reporting – for the Australian 3rd Brigade report[8], this fact was confirmed by discussion with one of the study authors. In the other two reports, examining Australian Army recruit injury rates[7] and US Army injury rates[9], this information was provided in the report itself[7] or report source[9]. In this 'point-of-care' approach, injuries were recorded by healthcare personnel at the time when injured personnel reported with their injuries to Army healthcare facilities. In contrast, the WHSCAR system and its predecessor DEFCARE system both used a system of reporting which depended on the injured soldier and their supervisor reporting the injury incident directly to the reporting system, in accordance with Australian Department of Defence policy[4]. In most instances, this latter approach did not involve healthcare providers.

Discussion

The primary aim of our study was to establish the incidence rates for reported WHS incidents and injuries sustained by Australian Army part-time (ARES) personnel during periods of active service

and compare them with rates reported by full-time personnel. In the ARES, 34 WHS incidents were reported for every 100 person-years *(ie* full-time equivalent years) of active service. In the ARA, 23 WHS incidents were reported for every 100 person-years of service, suggesting that ARES soldiers experience almost 50% more WHS incidents than their full-time counterparts in the ARA, when days of active service are considered. The differences in injury incidence rates were even more pronounced. In the ARES, 31 injuries were reported for every 100 person-years of active service. In the ARA, 17 injuries were reported for every 100 person-years of service, suggesting that ARES soldiers experience 80% more injuries than their full-time counterparts in the ARA when days of active service are considered.

Interestingly, however, these substantial incidence rates for both WHS incidents and injuries appear to represent just 'the tip of the iceberg' in both ARES and ARA populations. Comparison of the injury incidence rates alone, derived from the current study of the ARES and ARA populations, to benchmark injury incidence rates from other published studies of Army populations that have used 'point-of-care data capture'[7-9] revealed that the WHSCAR database interrogated in the current study is probably only capturing reports of between 11% and 19% of all injuries actually suffered by soldiers which are serious enough to warrant them seeking health care advice. This means that approximately 80-90% of all injuries suffered by ARES and ARA soldiers that are serious enough to require health care are probably *not* being captured on the WHSCAR system.

This latter finding has several important implications. First, given these very substantial data deficits, it is impossible to say whether the differences in reported incidence rates for WHS incidents and injuries identified in the current study are indicative of real, underlying differences in injury risks between the ARES and ARA or simply an artefact of incomplete reporting and differences between the ARES and ARA in typical reporting thresholds for such incidents and injuries. Table 3 indicates that rates of recorded serious injuries, though 23% higher in ARES than ARA, were nevertheless much more similar between these populations than rates of recorded minor injuries, which were almost twice as high in ARES as in ARA personnel. This finding supports the notion that under-reporting of WHS incidents is one likely cause of the observed differences in recorded incident rates between these populations, since under-reporting of minor injuries is more likely than underreporting of serious injuries. Further research with more robust data capture or sources is required to elucidate this matter. Nevertheless, it should be noted that ARES soldiers are at substantial risk of being injured and a strong focus on management of injury risks not only in the ARA but also in the ARES is warranted.

Second, noting the importance discussed in the Introduction to this paper of comprehensive data capture for adequately informing management by commanders of WHS incident and injury risks and their flow-on effects to personnel availability and operational capability, it would seem important that the evident deficit in incident reporting and data capture is noted and addressed. A key lesson learned in the benchmarking exercise conducted as part of the current study is that those benchmark incident reporting systems which captured 5 to 10 times as many of the actually-occurring injuries in soldiers all employed a 'point-of-care' approach to reporting, in which health care personnel created a record of the incident or injury at the time when an injured soldier presented for healthcare. The WHSCAR system and its predecessor DEFCARE system do not employ this approach, and instead the soldier affected by the incident or injury and their supervisor are responsible to report the incident to the system (and notably not to a person)[4].

On this basis, it would appear prudent that developers and administrators of military WHS incident reporting systems ensure that point-of-care reporting mechanisms are incorporated in these systems to maximise data capture and so support WHS incident and injury risk management by commanders. However, it should also be noted that point-of-care reporting systems will not readily capture data on near misses, dangerous occurrences and exposures to hazards, unless they result in some sort of injury or concern requiring health care. Thus, future WHS incident reporting systems should be developed to use hybrid systems for data capture, incorporating both point-of-care and soldier/supervisor reporting approaches, with the latter approach designed to be as user-friendly as possible.

While this study has considered some aspects of WHS incident reporting systems, it should be noted that ensuring these systems can properly and comprehensively inform command risk management efforts in a timely manner depends on optimisation of many factors other than the data capture approach employed. These other factors are explicated in a previous comprehensive report by McKinnon and colleagues[3], which was based on a study conducted in the Australian military context. That report should also be considered by developers and administrators of WHS incident reporting systems and the military services they seek to serve. Of note, data capture is

also very likely to be enhanced by optimising many of these other factors[3].

Finally, even when WHS incident reporting systems are optimised, their proper use by commanders to inform management of risks that these systems can identify will depend heavily on what support commanders receive to identify and manage such risks. Where commanders and military organisations benefit most from demonstrating low rates of WHS incidents and injuries, rather than from demonstrating sound practice in risk identification and management, interest in enhancing the rates of identification of WHS incidents and injuries will be limited[11]. Lower levels of reporting and thus poorer system functioning in such contexts yield perceived benefits. Determinants of a sound reporting culture are well explicated in the paper by van der Schaaf and Kanse,[11] which constitutes further recommended reading for developers and administrators of WHS incident reporting systems and commanders.

Conclusion

This retrospective cohort study evaluated the incidence rates of reported WHS incidents and injuries that were sustained in both ARES and ARA personnel over a recent two-year period. Previously available information [2] of this nature is limited and aged. The results of the current study suggest that ARES personnel report 50% more WHS incidents and 80% more injuries than their ARA counterparts, when actual days of active service are considered. However, while the current study has used the best currently-available data set and certainly confirms substantial WHS incident and injury risks in both ARES and ARA populations, which we recommend should be a focus of risk management efforts, we have also identified highly-probable, very substantial levels of under-reporting in this data set. These high levels of under-reporting mean that we cannot be certain whether the differences in WHS incident reporting rates observed in this study represent true differences in underlying levels of risk or reflect uncertainties in the data related to substantial under-reporting of incidents.

On this basis, a further important recommendation from the current study is that developers and administrators of military WHS incident reporting systems and the command elements they serve take steps to ensure the systems they use incorporate 'point-of-care' reporting of injury incidents as well as continued reporting by affected personnel and supervisors of near misses, dangerous occurrences and exposures that do not result in significant injury. Additional advice regarding optimisation of WHS incident reporting systems and building a reporting culture has also been provided, based on recent research findings, and is worth considering.

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Conflict of Interest:

Authors Pope and Orr have received research grants from the Defence Health Foundation for research investigating injury rates in Australian Army Reserve personnel, a project from which this paper arose.

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Serum Level of Nutritional Antioxidants are Decreased in Veteran Smokers with COPD

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Introduction

Chronic Obstructive Pulmonary Disease (COPD) is the third leading cause of death in the U.S. and worldwide,[1-4] resulting in an economic and social burden that is both substantial and increasing. Veterans are a group of people who are disproportionately affected by COPD. COPD affects over 40% of the adult veteran population in the urban Midwest, which is five times greater than the general U.S. population.[5] Cigarette smoking is the main etiologic agent for COPD risk and is common among VA healthcare users, hence the prevalence of COPD is expected to continue and increase in upcoming decades.[5,6] Veterans with COPD suffer high morbidity, including poor quality of life, activity limitation and exacerbations leading to emergency department visits and hospitalisations.[7] Therefore, a better understanding of contributing factors to the development, progression and burden of this pervasive disease among veterans is critical in order to design effective interventions.

Epidemiological studies have shown a positive association between intake or serum levels of certain micronutrients, especially those with anti-oxidant or anti-inflammatory functions, and lung function. For example, the National Health and Nutrition Examination Surveys (NHANES) of the U.S. population have repeatedly demonstrated that increased intake or serum levels of some micronutrients, including vitamins E, D, C, A, fibre , and omega-3 fatty acids are positively associated with measures of lung function.[8-19] These results suggest that diet and nutrition may impact lung function and that nutrition interventions could be useful in those with lung disease. However, there is little data available on the intake of these nutrients, or the serum levels of nutrients with anti-oxidant properties in veterans. Thus, the purpose of this analysis was to examine the intake and serum levels of nutrients which have previously been associated with lung health in a population of veterans with COPD.

Materials and Methods

This was a secondary analysis of data obtained from a cross-sectional study of agricultural exposures and COPD in veterans seeking health care at the General Medicine clinics of the Omaha Veterans Affairs (VA) Medical Center.[20] Briefly, all subjects had greater than 2 years' experience working on a farm. Subject demographics and smoking habits were obtained by in-person and telephone interviews. A participant was considered to be a smoker if they had smoked more than 100 cigarettes in their lifetime. All veterans underwent spirometry and if they had a $FEV_1/FVC < 0.70$, then post-bronchodilator spirometry with 0.083% albuterol was performed. COPD status was ascertained for each participant using the Global Initiative for Chronic Obstructive Lung Disease (GOLD) definition of $FEV_1/FVC < 0.70$[21] or by clinical assessment. FEV_1 and FVC were adjusted for height, weight, age, gender and ethnicity based on NHANESIII reference equations.[22] All participants signed a written informed consent document at study enrolment. This study was approved by the VA Nebraska Western Iowa Healthcare Systems Institutional Review Board.

Nutrient Intake. A Food Frequency Questionnaire (FFQ) was mailed to the home address of the participant, with a follow up phone call in 2 weeks if the FFQ had not been returned. FFQs were analysed by trained personnel in the Harvard University Department of Nutrition. The FFQ administered was the Willet FFQ, which has been validated in adults of all ages and sexes and among a variety of socio-economic groups.[23-28] The FFQ allows for analysis of absolute nutrient intake values from foods and supplements. In addition, studies show that after adjustment for absolute energy intake, the Willett FFQ is robust in validity and reliability in comparison to other validated FFQs.[29-31]

Nutrient intake values calculated from the completed FFQs were compared to the appropriate Dietary Recommended Intake (DRI) values for the appropriate

gender and life stage. The Recommended Dietary Allowance (RDA) was used when a nutrient level had been established; if no RDA had been established, the Adequate Intake level (AI) was used. The RDA and the AI may both be used as goals for individual intake.[32-35] Recommended Dietary Allowances are set to meet the needs of almost all (97 to 98 percent) individuals in a group, while the AI for life stage and gender groups is believed to cover the needs of all individuals in the group, but lack of data prevents the ability y to specify with confidence the percentage of individuals covered by this intake. Specific nutrients of interest were chosen based on prior associations with COPD as reported in the literature and included vitamin A, vitamin D, fibre , vitamin E, vitamin C, carotenes and other vitamin A-related compounds, omega-3 and omega-6 fatty acids. For intake of omega 3 and omega-6 fatty acid, the Adequate Macronutrient Distribution Range (AMDR) was used. While no defined intake level at which potential adverse effects of n-6 polyunsaturated fatty acids was identified, the upper end of the AMDR is based on the lack of evidence that demonstrates long-term safety and human *in vitro* studies which show increased free radical formation and lipid peroxidation with higher amounts of omega-6 fatty acids.[32] The upper end of AMDR for omega-3 fatty acids is based on maintaining the appropriate balance with omega-6 fatty acids, as this has been implicated in the risk for chronic disease.[36]

Serum Nutrient Level. Serum nutrient level was measured at the Biomarker Research Laboratory at the Harvard School of Public Health. Concentrations of lutein+zeaxanthin, β-cryptoxanthin, lycopene, α-carotene, β-carotene, retinol, γ-tocopherol, and α-tocopherol in serum samples were measured using the method described by Hess et al. with some modifications.[37] Serum samples were mixed with ethanol containing rac-Tocopherol (Tocol) as an internal standard, extracted with hexane, evaporated to dryness under nitrogen, and reconstituted in ethanol, dioxane and acetonitrile. Samples were quantitated by high-performance liquid chromatography (HPLC) on a Restek Ultra C18 150mm X 4.6mm column, 3µm particle size encased in a Hitachi L-2350 column oven to prevent temperature fluctuations, and equipped with a trident guard cartridge system (Restek, Corp. Bellefonte, PA). A mixture of acetonitrile, tetrahydrofuran, methanol, and a 1% ammonium acetate solution (68:22:7:3) was used as mobile phase, flow rate 1.1 ml/min, using a Hitachi Elite LaChrom HPLC system comprised of an L-2130 pump in isocratic mode, an L-2455 Diode Array Detector (monitoring at 300nm and 445nm), and a programmable AS-2200 auto-sampler with chilled sample tray. The system manager software (D-7000, Version 3.0) was used for peak integration and data acquisition (Hitachi, San Jose, CA). Every run included two replicates each of a two-level serum pool sample set. For external quality control, the laboratory participates in the standardisation program for carotenoid analysis from the National Institute of Standards and Technology U.S.A.

Table 1: Demographic characteristics of veterans with COPD (n=41)

	Mean (SD)
Age	66.5 (7.8)
Energy Intake, kcals	1873.7 (589.3)
BMI, kg/m^2	29.2 (7.6)
FEV$_1$ (L)	2.4 (0.9)
FEV$_1$, % predicted	68.6 (24.1)
FVC (L)	4.1 (1.0)
FVC, % predicted	87.9 (20.3)
FEV$_1$/FVC, mean	0.6 (0.1)
	N (%)
Male Gender	41/100
White Race	41/100
Smoking Status	
Current	7 (17)
Former	29 (71)
Never	5 (12)
COPD GOLD Stage*	
1 (Mild)	13 (32)
2 (Moderate)	16 (38)
3-4 (Severe/Very Severe)	12 (30)

COPD was defined as FEV1/FVC ≤ 0.7 or a decision by a pulmonologist

Statistical Analysis. Descriptive statistics (counts, percentages, means, and standard deviations) were calculated for all variables. The Spearman correlation coefficient was used to look at associations between lung function measures (Forced Expiratory Volume in One Second, FEV$_1$; Forced Vital Capacity, FVC; FEV$_1$/FVC ratio) and intake and serum level of nutrients. Multivariable regression models adjusted for the possible confounding of age, smoking, body mass index (BMI), energy intake (for models containing intake of nutrients) and serum cholesterol (for models containing the serum tocopherols). Intake and serum level of nutrients were log-transformed for normality and used in the regression models. The Mann-Whitney test was used to compare continuous data between 2 groups. The Kruskal-Wallis test

Table 2: Nutrition Intake of Veterans with COPD

Nutrient	Mean (SD) N = 41	RDA/AI
Vitamin C (mg)	169.3 (214.2)	**90 mg***
Vitamin D (IU)	468.0 (407.2)	**600 IU 51-70 years** **800 IU 70+ years**
Vitamin A (Retinol Activity Equivalents)	1,411.4 (1,311.6)	**900 retinol activity equivalents**
Vitamin E (mg)	16.4 (28.6)	**15 mg**
Fiber (g)	20.1 (9.3)	30**
Omega-3 fatty acids (gm)	0.29 (0.30)	1.6** (AMDR 0.6-1.2)***
Omega-6 fatty acids (gm)	14.2 (10.7)	14** (AMDR 5-10)***
α- carotene (mcg)	736.0 (810.1)	n/a
β-carotene (mcg)	3,986.4 (3,621.1)	n/a
β-cryptoxanthin (mcg)	135.9 (114.2)	n/a
Lycopene (mcg)	4,729.0 (4,942.1)	n/a
Lutein + Zeaxanthin (mcg)	2,190.6 (2,125.3)	n/a

*Individuals who smoke require 35 mg/day more Vitamin C than nonsmokers

Recommended Dietary Allowances (RDAs) in bold type, Adequate Intakes (AIs) in ordinary type followed by an asterisk (**)

*** Acceptable Macronutrient Distribution Range (AMDR) is the range of intake for a particular energy source that is associated with reduced risk of chronic disease while providing intakes of essential nutrients.

was used to compare continuous data between >2 groups and p-values for post-hoc pairwise comparisons were adjusted using a nonparametric multiple-comparison procedure. All statistical tests were two-sided and a p-value < 0.05 was considered statistically significant. Analyses were done using SAS Version 9.4.

Results

A total of 123 FFQs were mailed out with a response rate of 33%. There were no differences between responders and non-responders with respect to demographics including age, sex, race, and FEV_1/FVC ratio. All participants were white males with a mean age of 66.5 years and a mean BMI of 29.2kg/m^2. Baseline characteristics of the respondent population are summarised in Table 1.

Nutrient Intakes. A summary of the intake of anti-oxidant and anti-inflammatory nutrients assessed by the FFQ are compared to existing recommendations as shown in Table 2. Veterans with COPD had suboptimal intakes of vitamin D, fibre, and omega-3 fatty acids, with an intake of omega-6 fatty acids above the recommended level. No DRIs for carotenes, β-cryptoxanthin, lycopene or lutein+zeaxanthin have been established; however, intake values are reported due to prior associations of these nutrients with lung disease.

Intake of nutrients and lung function. In the univariate analysis, we found intake of omega-3 fatty acids were inversely associated with FEV_1 (r= -0.39, p=0.02) and FEV_1 % predicted (r= -0.42, p=0.01). After adjustment for the covariates energy intake, age, BMI, and smoking status, the correlation between omega-3 fatty acid intake and lung function was attenuated (FEV_1, β= -0.21, p=0.07; FEV_1% predicted, β=-5.5, p=0.07). Intake of omega-3 fatty acids was not associated with FVC or FEV_1/FVC ratio (data not shown). None of the other nutrients were significantly associated with FEV_1, FVC and FEV_1/FVC ratio (data not shown).

Serum Nutrient Levels. Serum antioxidant nutrient levels of the cohort are summarised in Table 3. When we evaluated the correlation between dietary intake and serum levels, β-cryptoxanthin intake was significantly associated with serum levels of β-cryptoxanthin (r=0.35, p=0.03).

Serum nutrient levels and lung function. In the univariate analysis, we found statistically significant correlations between serum levels of trans-β carotene and FVC % predicted (r=0.39, p=0.02) and cis-β carotene and FVC % predicted (r=0.39, p=0.02). After adjustment for age, BMI, and smoking status in the multivariable model, these relationships were no longer statistically significant. The remaining

Table 3: Serum Levels of Antioxidant Nutrients

Serum Nutrient (µg/L)	Mean (SD) N = 39
α-carotene	29.7 (28.8)
Trans β-carotene	133.2 (159.1)
Cis β-carotene	9.6 (11.3)
Total β-carotene	142.1 (17.05)
β-crytoxanthin	56.2 (48.7)
Trans lycopene	148.2 (72.3)
Cis lycopene	138.3 (68.7)
Total lycopene	286.4 (139.3)
Lutein+Zeaxanthin	114.9 (51.9)
Retinol	564.3 (112.6)
γ- tocopherol	1317.2 (720.6)
α- tocopherol	9613.9 (9014.2)

Table 4: Serum Antioxidant Nutrients and Smoking Status (n=39)

Serum Nutrient (µg/L)	Smoking status	Serum Level	p-value
α-carotene	Current	12.39	0.004
	Former	26.06	
	Never	70.63	
Trans β-carotene	Current	61.25	0.005
	Former	105.69	
	Never	373.60	
Cis β-carotene	Current	5.27	0.005
	Former	7.44	
	Never	26.75	
Total β-carotene	Current	65.14	0.005
	Former	112.49	
	Never	400.34	
β-cryptoxanthin	Current	36.85	0.03
	Former	48.13	
	Never	124.76	

nutrients assayed in serum were not associated with lung function (data not shown). There was no association between serum nutrient levels and COPD stage.

Nutrient levels and smoking status. There was no association between intake of nutrients (listed in Table 2) and smoking status (current, former, never) (data not shown). Importantly, serum levels of anti-oxidant nutrients (α-carotene, trans β-carotene, cis β-carotene, total β-carotene, β-cryptoxanthin) differed by smoking status (Table 4). There was a dose response of these serum nutrients with smoking status, where current smokers had fewer of these serum nutrients than never- smokers.

Discussion

Participants in our study did not meet the minimum guidelines for intake of three important nutrients that typically have been associated with improved lung health: vitamin D, fibre, and omega-3 fatty acids. Additionally, intake of omega-6 fatty acids, which may have pro-inflammatory properties, were above the Acceptable Macronutrient Distribution Range.

Intakes of nutrients previously associated with lung function Our results are consistent with other studies that show vitamin D intake in populations of patients with COPD are below current recommendations.[38] Because COPD patients spend less time outdoors,[39] they would be expected to have decreased sun exposure, which places them at high risk for vitamin D deficiency. Intake of vitamin D has been shown to be associated positively with FEV_1 (difference in FEV_1 between top and bottom quintiles of intake, 0.079 L; 95% CI, 0.02–0.14; p for trend= 0.007), ratio of FEV_1 to FVC (p=0.008), and associated negatively with COPD (odds ratio [OR] comparing top and bottom quintiles, 0.57; 95% CI, 0.38–0.87; p=0.02).[40] Intake of dairy products, but not specifically vitamin D intake, has been associated with less severe measures of emphysema (defined by computed tomographic lung density) in 3,271 subjects enrolled in the Multi- Ethnic Study of Atherosclerosis (MESA) study (p=0.02 and p=0.01 for alpha, a measure of emphysema, and apical vs basilar distribution of emphysema, respectively).[41] This association was observed primarily for low-fat dairy intake, not high-fat dairy intake, and may have been confounded by other lifestyle factors, because those who choose low-fat dairy products may make different lifestyle choices compared with those who choose high-fat dairy products. The usefulness of evaluating the effect of vitamin D intake from diet may have limited value, given the overall minor contribution of dietary intake to vitamin D status, because the major source for vitamin D is outdoor sun exposure.

The mean intake of fibre in our population was 33% below current recommendations. In large prospective studies, high fibre diets reduced mortality from infectious disease, respiratory disease, smoking-related cancers and cardiovascular disease.[42,43] With regard to lung function, four large prospective studies have shown diets high in fibre are associated with

better lung function and decreased risk of COPD.[16,44-46] A recent study using mouse models demonstrated high amounts of dietary fibre regulated the immune system in the lungs, which included an increase in the haematopoiesis of dendritic cells that could not reactivate T helper type 2 effector cells, resulting in lower airway inflammation.[47] These results provide evidence that dietary fibre can shape the immunological environment in the lung. One proposed mechanism underlying this beneficial effect comes from studies showing that fibre stimulates the growth of beneficial bacteria in the gut, which synthesse, through fermentation, high quantities of Short Chain Fatty Acids (SCFAs).[47-53] SCFAs have been detected in the portal circulation where they are active in the liver and bone marrow to decrease innate immune activation.[47,50,52-56]

Intake of omega-3 fatty acids was extremely low and omega-6 fatty acids was notably high in our cohort. A balance between omega-6 and omega-3 fatty acids is thought to be important in the prevention and treatment of coronary artery disease, diabetes, osteoporosis and other inflammatory diseases.[36,57] In patients with asthma, an omega 6:3 ratio of 5:1 decreased leukotriene production and improved respiratory symptoms.[58] In the secondary prevention of cardiovascular disease, a leading cause of death in patients with COPD, a ratio of 4:1 has been associated with a 70% decrease in total mortality.[36] Our cohort was from a Midwestern state where fish intake is commonly low, and this may have contributed to the poor intake of omega-3 fatty acids resulting in an extremely high omega 6:3 ratio of over 100:1. Fish and seafood are the main source of omega-3 fatty acids, contributing up to 71% of total intake.[59] Fats and oils, meat and poultry, and cereal-based products and cereals, are the primary sources of omega-6 fatty acids in a Westernised diet,[59] therefore it may be difficult for even populations living in an area with an ample seafood supply to achieve a desired ratio.

In the univariate analysis, we found an inverse association between omega-3 fatty acid intake and lung function. However, other studies conflict with this finding. A recent systemic review identified 11 observational studies evaluating the relationship between COPD and intake or serum levels of omega-3-fatty acids. Of these 11 studies 6 found a significant relationship and 5 of those relationships were inverse (protective against COPD).[60] The remaining 5 studies found no relationship.[60] Fish is one of the primary sources of omega-3 fatty acids in the diet, and dietary intake patterns with an increased consumption of fish have been associated with a decreased development of COPD in smokers and nonsmokers, increased FEV^1 and decreased long-term COPD mortality.[61-63] Analysis of the Seven Countries Study, a population-based cohort of 12,763 men, calculated that fruit and fish intake together explained about 67% of the variation in COPD mortality rates after 25 years.[61] Our study did not find such an association between omega-3 fatty acid intake and lung function, however it has been shown that the omega 6:3 ratio is critical in achieving respiratory benefits,[58] and given the high ratio present in our cohort, any findings may have been obscured.

Serum levels of anti-oxidant nutrients A large body of observational epidemiological evidence suggests that higher serum concentrations of β-carotene and other carotenoids obtained from foods are associated with lower risk of several chronic diseases,[35] and serum level of carotenes have been associated with improved lung function in other studies.[12-14,64,65] Although our study did not find this association, we did find a correlation between dietary beta-cryptoxanthin and the serum level of this compound, which suggest that diet is an effective intervention for increasing serum levels of beta-cryptoxanthin in subjects with COPD. This may be especially important in smokers, who exhibited decreased levels compared to non-smokers. Blood concentrations of carotenoids are the best biological markers for consumption of fruits and vegetables.[35] Although no DRIs are proposed for β-carotene or other carotenoids at the present time, existing recommendations for increased consumption of carotenoid-rich fruits and vegetables in patients with COPD would appear to be supported.

Our study also documents lower serum level of β-cryptoxanthin and carotenes in smokers. A dose-response appeared to be present, with serum levels decreasing as the level of smoking increased. Several studies have reported that smokers have lower plasma carotenoid concentrations compared to non-smokers,[66,67] and higher numbers of cigarettes per day have been shown to lead to a corresponding decrease in serum carotenoids in a dose-dependent manner.[66] Whether this is due completely to a decreased intake of carotenoids is unknown; tobacco smoke is highly oxidative, and has been shown to destroy beta carotene and other carotenoids in human plasma *in vitro*,[68] which may contribute to a reduction in serum levels. The association of serum β- carotene and FEV_1 has been shown to be weaker in smokers when compared to non-smokers, and the strength of the relationship decreased as the amount of smoking increased.[8]

Supplementation of micronutrients Should clinicians consider supplementation of micronutrients in their

veteran patients who smoke? In one study, adults at high risk for cardiovascular events received antioxidant vitamins for 5 years (600 mg vitamin E, 250 mg vitamin C, 20 mg beta-carotene). That study failed to identify any effect on lung function, although it was measured only at the last visit, or hospitalisation for non-neoplastic respiratory causes. Individuals with severe COPD, however, were excluded from that study.[69] Another large trial showed a significantly higher incidence of lung cancer in current smokers supplemented with alpha tocopherol and beta-carotene for 5-8 years.[70] However, a high intake of beta carotene and vitamin E from food was associated with an improvement in respiratory symptoms.[71] The latter study seems to suggest that prevention campaigns should stress the importance on nutrient intake from food, especially in smokers.

Limitations Our study has several limitations. Our sample size was small, and it is always difficult to separate the direct effect of a nutrient on an outcome from the overall effects of associated lifestyle factors. Our population is a Midwestern population with agriculture backgrounds, which may limit generalisability to other populations. Some significant results were attenuated after adjustment for confounders, and some potential covariates, such as corticosteroid use, for which no adjustment was made.. We assessed nutrient intake using FFQ methodology, which is subject to various limitations, including measurement error in the estimated portion sizes of foods, and inaccuracies that result from incomplete listings of all possible foods. However, we do provide both serum levels and nutrient intake levels, which are often not studied together. We do not, however, report serum levels of vitamin D, which would be relevant in this population. In addition, very little data exists on nutrients that may be of concern to a population of veterans who may be more likely than the general population to be current or former smokers.

Conclusion

Our study shows that veterans with COPD have low intakes of nutrients associated with lung function and COPD, and that smokers have lower serum levels of anti-oxidant nutrients than non-smokers. Given the importance of inflammation and oxidant stress in lung function, a direct effect of nutrients that have anti-oxidant and anti-inflammatory properties is readily plausible. As measures of lung function are an independent predictor of mortality in the general population as well as in people with lung disease,[72,73] public health initiatives to improve lung function through dietary interventions in veterans could potentially have a profound impact. In the future, larger and well-designed interventional trials are needed to confirm these associations, and to establish whether dietary interventions are effective in the prevention or treatment of lung impairment. Populations of subjects susceptible to a decline in lung function, such as smokers, may provide a target population that would incur the most benefit from the results of such trials. The low cost and safety of dietary interventions such as counselling to increase fruit and vegetable intake to maintain or improve lung function make this a very attractive intervention for researchers, as well as clinicians working with populations of patients either with, or at risk for, lung impairment.

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Military Effectiveness of Five Dietary Supplements Purported to Aid Cognitive and Physical Performance

Bradley Baker

Abstract

Background: The effectiveness of dietary supplements in sustaining physical and/or cognitive performance is of interest to the military. *Rhodiola rosea*, long-chain omega-3 fatty acids (LC omega-3), beetroot juice, arginine and beta-alanine have recently been claimed to enhance cognitive and/or physical performance when taken as supplements.

Purpose: To narratively review recent research on the military effectiveness and safety of five dietary supplements – *Rhodiola rosea*, long-chain omega-3 fatty acids (LC omega-3), beetroot juice, arginine and beta-alanine.

Materials and Methods: The Academy of Nutrition and Dietetics Quality Criteria Checklists were used to assign quality ratings of positive, neutral and negative to reviewed studies.

Results: Of the five substances reviewed, only LC omega-3 (commonly known as 'fish oils') is considered safe and applicable as a potential supplement for use during both fresh and field feeding. This applies to military members who do not consume the recommended intake of oily fish, whether by choice or because oily fish are not available (e.g. when feeding is with combat rations).

Conclusions: Conclusions are drawn on the quality of evidence for beneficial effects on health and/or military performance in the context of sustained arduous training and operations. Although health benefits may result from supplementation with LC omega-3, the available evidence suggests that such supplementation is unlikely to enhance either cognitive or physical performance. A lack of evidence for efficacy and/or possible adverse health outcomes suggest that supplemental use of the other substances reviewed here is not appropriate for military members.

Introduction

Dietary supplements (abbreviated to 'supplements' in the remainder of this report) can be defined as nutrients and other substances that occur naturally in foods and herbs. Military members, particularly soldiers, show interest in many supplements that have been claimed to be effective in sustaining physical and/or cognitive performance. However, such claims are not always based on sound scientific evidence.

Research in this area is relevant not only in guiding the optimal provision of foods in barracks and combat feeding, but also in the potential provision of foods and/or supplements to sustain health and military performance in the long term. In addition, the use of some supplements by military personnel should be cautioned, due to potential risks to health, military performance and/or lack of efficacy.

Various supplements are described by researchers and the supplement industry as 'adaptogens' for their purported ability to help the body adapt to stress and aid cognitive performance, or 'ergogenic aids' for their purported ability to enhance physical performance. Yet others are claimed to be 'nootropics' (boost cognitive performance). Caffeine is an example of a well-understood nootropic that is useful to military members to help sustain alertness during operations[1]. However, few other supplements are currently recommended for military use.

Due to their highly demanding roles, military personnel—Infantry and Special Forces in particular—are often tempted to use dietary supplements to try to enhance their job performance.[2] The self-reported use of supplements of any kind by military personnel in the United States and United Kingdom is in the range 55–61% for males and 65–71% for females[2]. Anecdotal evidence also indicates that dietary use is

highly prevalent in military personnel in Australia. In 2010, The Guide to Herbs and Supplements section of the (US) Warfighter Nutrition Guide cautioned against the use of many dietary supplements claimed to enhance physical and cognitive performance, due to their adverse side effects and/or lack of efficacy[3].

More recently, substances that have shown potential in the literature to increase physical and/or cognitive performance, including in the military context, include beetroot juice, extract from the herb *Rhodiola rosea*, long-chain omega-3 fatty acids from fish oil, and the amino acids arginine and beta-alanine. Many of these substances have also been claimed to enhance human performance during military-specific activities, thus, their effectiveness is of interest to the military. In many cases, the physiological processes by which these five substances may act as either ergogenic and/or cognitive aids have not been fully elucidated.

However, as with many dietary supplements, recent research relating to the effectiveness is contradictory. This paper reviews recent research (experimental and evaluative) on these five supplements, and discusses the quality of the evidence for their efficacy in the context of sustained military training and operations. The potential harmful effects of each supplement are also discussed.

Quality Assessment

The quality of studies reviewed was assessed using the Academy of Nutrition and Dietetics Quality Criteria Checklists (Primary Research and Review Article)[4, 5]. Each of these checklists contains four *relevance* questions and ten *validity* questions that assess scientific rigor. They were used to assign a quality rating of *negative* (i.e. mostly weak methodological design), *neutral* (i.e. some strengths and weaknesses in the methodological design) or *positive* (i.e. mostly strengths in the methodological design) to the research used to assess the effectiveness of each supplement. The strongest quality evidence identified in this review is summarised for each supplement in Table 1.

Rhodiola rosea

Is *Rhodiola rosea* Extract a Cognitive Aid?

Rhodiola rosea is a plant that grows in cold and high-altitude regions of the Arctic. An extract of *Rhodiola rosea*, which contains a substance known as salidroside, has gained the attention of the military due to its claimed ability to enhance cognitive performance by reducing the effects of fatigue in stressful situations[6-8]. The physiological process by which salidroside may act as a cognitive aid has not been elucidated, however advertisements for *Rhodiola rosea* extract have suggested the supplement is useful for military personnel during operations, especially when fatigued, such as during times of sleep deprivation. Supplementation with *Rhodiola rosea* extract has also been reported to have a beneficial effect on stress related to fatigue[9, 10].

Of particular relevance to the military, supplementation has been shown to reduce levels of fatigue during stressors such as night duty[6], and night duty while performing military-related tasks[8]. In total, there is evidence from four studies that support these claimed benefits against fatigue in healthy individuals without a diagnosed mental illness.[6-8, 11] According to the Academy of Nutrition and Dietetics Quality Criteria, these findings arise from studies of positive[6, 8], and neutral quality[7, 11].

Two recent review articles (both of positive quality) assessed the bias/quality of the available research on the effects of *Rhodiola rosea* extract on cognitive performance in healthy individuals, and concluded that there is no convincing evidence of benefits[12, 13]. An earlier review study (of neutral quality) concluded that 'a single dose of *Rhodiola rosea* extract prior to acute stress produces favourable results'[14]. However, two of the three authors of this review were employees of a company which sells *Rhodiola rosea* extract, indicating a conflict of interest and hence the potential for bias. Until the reported benefits of *Rhodiola rosea* extract supplementation are replicated by independent researchers, the body of evidence remains unconvincing[12, 13].

In summary, it is concluded that supplementation with *Rhodiola rosea* extract is unlikely to be of value as a cognitive aid in the military context, and its use should be cautioned due to lack of efficacy. There is no evidence that substantiates a mode of action of the purportedly active substance, salidroside.

Rhodiola rosea Extract and Exercise Performance

Evidence on the effects of *Rhodiola rosea* extract on exercise performance is limited, and findings vary among studies. One recent study (neutral quality) found no benefits to delayed onset of muscle soreness (DOMS) or vertical jump performance[15]. Another recent study (also neutral quality) demonstrated a benefit to performance in a time trial (TT, a measure of endurance performance)[7]. Benefits to time-to-exhaustion (TTE, a measure of endurance capacity) were reported in 2004[16], but to our knowledge, have not been replicated.

Overall, there is some convincing evidence from a small number of neutral quality studies that *Rhodiola rosea* is effective in sustaining exercise performance. Further research, conducted in a manner that reduces potential for bias, is required.

Long Chain Omega-3 Fatty Acids

What are LC Omega-3 Fatty Acids?

All dietary fats contain a mixture of three types of 'fatty acids'—polyunsaturated (abbreviated to PUFA), monounsaturated and saturated. Omega-3 fatty acids are one form of PUFA, and they are essential in the diet (together with the other major form of PUFA, omega-6 fatty acids). Of special importance to health are the long-chain (LC) omega-3 fatty acids docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). These are derived mainly from marine food sources, particularly dark-fleshed fish, so are commonly known as 'fish oils'.

How much LC omega-3 do humans need?

In Australia, the Suggested Dietary Target (SDT)—i.e. the daily intake recommended for the prevention of chronic disease based on the available evidence—for LC omega-3 fatty acids is 610 mg for men and 430 mg for women[17]. The mean intake of LC omega-3 in the general Australian population has been estimated at only 189 mg per day[18]. Although military fresh feeding combat rations contain some fish meals, LC omega-3 intakes in military populations have not been estimated. Military members who do not consume the recommended serves of oily fish or an LC omega-3 supplement may therefore have intakes even less than the general population. Low LC omega-3 levels may have deleterious effects, particularly on mood, as discussed in the next sub-section.

LC Omega-3 and Enhancement of Cognitive Performance

Omega-3 PUFAs are abundant in the brain, and their concentration in brain cells wholly depends on how much is consumed in the diet[19]. LC omega-3 in the brain is an important factor in facilitating many brain processes, including neurotransmission[19].

LC omega-3 supplementation, with the aim to increase the level of LC omega-3 in the brain, has been investigated for its effects on cognitive performance. However, based on the findings of two recent articles, including one of positive[20], and one of neutral quality[21], daily supplementation for between 12 weeks and 3 years does not enhance cognitive performance/functioning or prevent a decline in cognitive functioning in cognitively healthy older adults[20, 21]. However, some researchers have acknowledged that longer term studies are required in this area[19, 22].

A small number of studies have investigated the effects of LC omega-3 on cognitive function and mood in younger populations. These studies are of greater relevance to the military population than those discussed above involving older adult populations. A recent review article (neutral quality) found that the available data from randomised controlled trials (RCTs) revealed 'neither robust benefits nor a clear lack of efficacy' and described the evidence as weak and preliminary[23]. Further investigation is warranted and indeed is continuing[23].

Effects of LC Omega-3 on Cognitive Function and Brain Health

Recent research has placed an emphasis on dietary or supplementary intake of LC omega-3 throughout life for general health and to sustain normal cognitive function and brain health in ageing. Researchers Luchtman & Song reviewed studies involving both animals and humans and found that supplementation with LC omega-3 is consistently shown to have protective effects throughout life on neurodegeneration, cognitive impairment and long-term potentiation (the strength of signals in the brain). Thus, further research is required in this area to explain the way in which LC omega-3 exerts these protective effects[22]. Reviews of human studies have emphasised the importance of an adequate dietary intake of LC omega-3[20, 24, 25].

The effects of LC omega-3 intake—from both supplementation and diet—on various other aspects of cognition have been widely investigated[26-29]. There is strong evidence of a benefit of LC omega-3 supplementation on symptoms of depression in people without a diagnosis of major depressive disorder[27]. Mental health-related benefits of LC omega-3 are of interest in the context of sustained cognitive performance, because negative thoughts may be linked to increased cognitive load and errors in judgement[30]. There is also convincing evidence that a higher intake of LC omega-3 in the diet (and possibly supplementary LC omega-3) are effective in the prevention and treatment of depression[28, 29].

LC Omega-3 and Military Mental Health

The military's interest in the optimal intake of LC omega-3 by military personnel has increased in recent years. Researchers in the U.S. found that male US military personnel on active duty with the

lowest levels of DHA (docosahexaenoic acid) were at a 62% greater risk of suicide than counterparts with higher levels[31]. This and other similar findings led to a recommendation to the U.S. Department of Defense for 'a comprehensive, coordinated research program to evaluate the multiple uses of omega-3 fatty acids'[32]. However, subsequent research involving military service members found no effect of relatively short term (60 days) supplementation on psychological health or cognitive function[33], and another study found no association between blood LC omega-3 level and levels of depression[34].

LC Omega-3, Inflammation and Physical Performance

The effect of LC omega-3 supplementation on inflammation has been widely investigated. However, a recent review article (positive quality) found there is a 'lack of evidence' to support the 'use of omega-3 supplementation to reduce inflammatory biomarkers' in healthy individuals[35]. This finding is consistent with a previous a previous review of the evidence[36].

The effect of LC omega-3 supplementation on physical performance and recovery in the military context was recently reviewed (neutral quality)[37]. It was found that studies reporting positive results for reduced muscle damage and inflammation after physical activity outnumbered those finding no effect. However, it was concluded that there is currently insufficient human data to support the use of LC omega-3 to mitigate the inflammatory and immunologic response to exercise and thus possibly enhance subsequent performance. This is attributed partly to the limited ability to compare findings due to the differing methodologies and dosage protocols used. The use of a single exercise bout to investigate the effect of LC omega-3 on physical performance and recovery has been described as a major limitation in the relevance of the current evidence to the military. Troops are likely to engage in multiple bouts of exercise per day, so the effect may not be strong enough to confer benefits in the military context[37]. Future research involving military personnel should be designed to produce findings which are more applicable to the military. Such experimental designs might include, for example, military personnel engaged in sustained operations in the field, with repeated TTE performance tests throughout.

LC Omega-3 Summary

The effects of LC omega-3 intake on sustained brain and cognitive health are continually being investigated. Currently, the body of research presents various potential cognition-related benefits of an optimal intake of LC omega-3 by military members, particularly during times of deployment (e.g. cognition related to mental health). While it may be premature to recommend supplementation for cognitive enhancement, it is clear that optimal dietary intake of LC omega-3 is important for brain structure and function throughout life.

Current review evidence indicates that there is insufficient consistent and high-quality evidence to recommend supplementation to reduce physical activity-induced inflammation and soreness in the military context.

It is concluded that all military members who do not eat oily fish may obtain health benefits, but probably not performance benefits, from supplementing with LC omega-3 in the range of the NHMRC SDTs (610 mg for men and 430 mg for women) to 3000 mg per day. This applies to military personnel when they are relying on either fresh foods or combat rations.

Beetroot Juice (Inorganic Nitrate)

Inorganic nitrate, the substance of interest in beetroot juice, is abundant in a healthy diet. Various leafy green and root vegetables are good sources. Beetroot juice has been widely investigated for its ability to increase plasma levels of nitrate (NO_3^-), nitrite (NO_2^-), and nitric oxide (NO)[38, 39]. These compounds are involved in activating vasodilation[40]. Thus, increased plasma levels as a result of drinking beetroot juice may beneficially augment blood flow, oxygen uptake and muscle oxygenation during exercise, leading to performance enhancement[39, 40].

The use of beetroot juice as an ergogenic supplement has recently been reviewed numerous times (in studies of neutral quality)[39, 41-43]. However, further research was considered necessary in all of these reviews, and one researcher concluded that there are promising findings for '… enhancing aspects of the physiological response to exercise, such as muscle efficiency and oxygenation, which might augment performance'[39].

Beetroot Juice Supplementation, Endurance Performance and the Military

Military personnel often undertake prolonged physical activity during both training and operations, so substances which are claimed to enhance endurance performance are of military interest. Time-trial (TT) performance—a measure of endurance performance in well-trained individuals—has been used to study the effectiveness of beetroot juice. In a recent review

(neutral quality) of beetroot juice supplementation and TT performance, a meta-analysis of nine studies found an overall 0.9% improvement in TT performance among predominantly well-trained subjects[43]. However, this did not constitute a statistically significant improvement[43]. Even if this is a 'real' effect, it is likely to be valuable only to elite athletes[39], for whom very small enhancements can mean substantial differences in race results. Such a low level of potential benefit is unlikely to have substantial effect on military performance. Furthermore, TT performance is a more accurate measurement of athletic performance than of military performance, as TT performance is measured in controlled environments over set distances—experimental conditions which aren't characteristic of 'real world' military operations.

Beetroot Juice Supplementation and Sustained High-Intensity Exercise Capacity (Endurance Capacity)

Time to exhaustion (TTE) is a measure of the duration over which an individual can sustain high-intensity exercise, and is a more relevant measure of performance in the military context than TT. Hoon et al. (neutral quality)[43] combined the findings of three studies and showed a significant improvement in TTE at a fixed high-intensity work rate in normoxia (i.e. normal levels of oxygen available at sea level)[43]. These studies all involved supplementation with beetroot juice for six days, providing nitrate in the range 316–384 mg daily. Based on the average weight of participants, this corresponds to approximately 3.9–5.5 mg nitrate / kg of body mass per day[44-46]. However, these researchers instructed participants to exclude foods high in nitrate from their diets. This may have resulted in an overestimation of the physiological effects of nitrate supplementation if participants habitually consumed average or high levels of nitrate from eating vegetables[47]. Furthermore, these studies did not estimate dietary nitrate intakes[44-46]. Dietary intakes are likely to have been variable and therefore the reliability of findings is reduced. In the military context, a lower intake of foods high in dietary nitrate may occur during times of combat feeding.

Importantly, one of the TTE studies that was analysed in the Hoon et al. study involved recreationally active participants[43, 44]—a population subgroup that may not be comparable to Infantry and Special Forces soldiers, who are required to have fitness levels above that of the typical recreationally active civilian. For this reason the findings of the Hoon et al. study have limited applicability to the military. A longer supplementation period and/or higher dose—as suggested for elite athletes—may be required to demonstrate any benefits to soldiers. However, concerns remain over taking large doses due to the poorly-understood risks to health[39].

Sustaining Endurance Performance with Beetroot Juice in Hypoxic Conditions

Two studies have found promising effects on endurance performance in hypoxic (low oxygen) conditions through measuring high-intensity exercise capacity[48, 49]. In the first, in which a benefit to TTE was found, the participants were 'young and healthy' and had a mean VO_2 peak of 61.7 ± 2.1 ml/kg/min, and therefore had fitness levels at or above the fitness level of highly trained military personnel such as Infantry and Special Forces soldiers[48]. In the second, a benefit to high intensity, resistance exercise tolerance was found in participants who were 'moderately trained in recreational sport'[49]. In both of these studies participants were instructed to avoid nitrate-rich foods[48, 49].

However, there are differing findings in regards to an improvement in endurance performance through TT tests in hypoxic conditions in two papers so far published on this subject. Both of these studies recruited participants who were competitive athletes and had fitness levels similar to or above those of elite military personnel[50, 51]. The first found no benefit to TT performance during hypoxia from six weeks of supplementation at a rate of 4.3 mg / kg Body Mass (BM) / day[50]. In contrast, the second reported a benefit of a single dose of 310 mg of nitrate taken three hours before commencement of the TT[51]. Aside from differences in their dosage protocols, another methodological difference in these studies is that the first instructed participants to avoid nitrate-rich foods for the duration of the study, whereas the second did not. Neither study estimated total dietary nitrate intakes, indicating the possibility of variable intakes between studies[50, 51]. Further investigation of the effect of dietary nitrate intake on endurance exercise performance in hypoxic conditions is warranted.

The Safe Intake of Inorganic Nitrate

The Acceptable Daily Intake (ADI) of nitrate in Europe is up to 3.7 mg / kg BM / day[52, 53]. Doses used in some TTE studies described previously have been above this level, raising questions about the long-term safety of repeated high dosing. Three studies which found beneficial effects of supplementation on TTE in normoxia instructed participants to exclude foods high in nitrate from their diets[44-46]. Consuming the recommended daily intake of 1–2 serves of leafy green vegetables (such as broccoli or spinach) and one 75 g serve of root vegetables such as carrots would constitute a safe level of nitrate intake[54, 55].

A recent review (neutral quality) concluded that the level of nitrate that has produced beneficial effects can be 'readily consumed within a normal diet', and that there is no evidence that providing supplementation above this level provides greater benefits[39]. Studies typically provide a single dose containing the amount of nitrate that is usually consumed throughout an entire day, and the safety of this manner of nitrate intake has not been demonstrated. A proportion of dietary nitrate is converted into carcinogenic compounds in the stomach[56]. There are opposing findings in the literature regarding the risk of stomach cancer. In addition, although increased risk of other gastrointestinal cancers has not been consistently associated with dietary nitrate intake[38, 56], concerns do remain.

Beetroot Juice and Inorganic Nitrate Summary

The current evidence in support of a significant improvement to TTE and non-significant improvement to TT performance is characterised by neutral quality evidence, indicating somewhat limited reliability in findings. If nitrate supplementation is studied in the military context—such as during times of field feeding when intake of nitrate-rich vegetables is low—it should be conducted in a manner that mimics the usual Australian dietary intake of nitrate-rich vegetables, and total nitrate intake should not exceed 3.7 mg / kg BM / day. Alongside this, it would be worthwhile to investigate the average nitrate intake of personnel engaged in field training. The potential of beetroot juice (inorganic nitrate) supplementation to enhance military physical performance has not been directly investigated, but current evidence suggests this to be unlikely.

Arginine

Amino acids are the building blocks of protein, and there are 20 amino acids which are used by the human body. In recent years, supplementation with various forms of the amino acid arginine has been trialled for ergogenic effects. To researchers and the supplement industry alike, these are known as: L-arginine; L-arginine hydrochloride; products containing L-arginine combined with other ingredients such as glycine-arginine-β-ketoisocaproic acid (GAKIC); and arginine alpha-ketoglutarate (AAKG). The Warfighter Nutrition Guide cautions against the use of products containing a combination of these ingredients, as they are potentially dangerous and their safety is often unknown[3].

In 2011, a review (neutral quality) concluded that it is premature to recommend the use of L-arginine as an ergogenic aid for healthy and physically active individuals[57]. To our knowledge, convincing evidence does not exist for an ergogenic effect of L-arginine in highly trained individuals such as Infantry soldiers and Special Forces troops. In 2012, the Human Performance Resource Center—a U.S. Department of Defense initiative responsible for providing evidence-based information on dietary supplements to the U.S. military—estimated that L-arginine has a low-to-moderate potential for ergogenic benefit and that there is a moderate safety concern associated with its use[58].

Arginine's Claimed Mode of Action

Intake of L-arginine increases the level of nitric oxide in the bloodstream[59]. In theory, supplementation with L-arginine may enhance performance through increasing the availability of nitric oxide, which is involved in activating vasodilation. This occurs during physical activity to increase the delivery of blood and oxygen to the working muscles[40]. One recent article reported that supplementation reduces the amount of oxygen required to undertake moderate intensity exercise[60], a beneficial result that is inconsistent with the findings of four other studies[61-64]. A common methodological weakness in these studies is that dietary intake of L-arginine by participants was not controlled or estimated, indicating that intakes may have varied between the trials, thereby reducing the reliability of findings.

Recent Evidence on Arginine Supplementation and Sustained Physical Performance

Several studies published between 2010 and 2014 found no significant benefits to physical performance from supplementation with differing forms and dosages of arginine, including arginine[65], L-arginine[62, 67], L-arginine hydrochloride[66], GAKIC[68, 69], and AAKG[70, 71]. The fitness levels of participants and physical testing protocols varied greatly among these studies. Three involved participants who were either resistance-trained or had previous resistance training experience[66, 69, 71]; one used trained and untrained participants in separate groups[70]; one used 'trained cyclists' as participants[68]; and the remaining three studies involved either 'recreationally' or 'physically' active participants[62, 65, 67]. Thus, the results from these studies have limited applicability to troops with high levels of fitness, such as the Infantry and Special Forces.

Arginine Supplementation and Strength Performance

Two recent studies reported significant benefits to sustained resistance exercise performance in response to an acute dose of GAKIC relative to placebo in resistance trained individuals. These

included an increase in the total work performed during lower body resistance training[72], and a higher total resistance load[73]. In contrast, four studies that also involved participants with previous resistance training found no significant benefits to resistance exercise performance following differing forms of acute arginine supplementation versus placebo[66, 69-71]. The quality of these studies could not be assessed, due to high variation in methodological design, including differing dosage forms and protocols, and disparate use of dietary controls.

To our knowledge, only three studies have investigated the effects of acute GAKIC supplementation on resistance exercise[69, 72, 73]. These investigations are yet to be replicated by any other research group.

Arginine Summary

In summary, the use of an acute dose of GAKIC warrants further investigation in resistance exercise in dietary-controlled and monitored conditions to confirm the reported beneficial effects. Six grams of L-arginine (the dose administered in various studies showing benefits) could be readily consumed in a diet including foods high in L-arginine. Such foods include red and white meats, fish, eggs, soy foods including tofu, lentils, legumes, and nuts[74].

The current scientific evidence is not convincing that enhanced exercise performance results from taking supplements containing arginine. Further investigation is warranted into the effect of acute GAKIC supplementation on strength performance.

Beta-Alanine

Beta-Alanine and Exercise performance

Soldiers undertake resistance training programs to develop the strength required in their Army roles, and may be tempted to use supplements marketed at improving resistance training ability, such as the amino acid beta-alanine. The military's interest in the effectiveness of beta-alanine supplementation in enhancing exercise performance has increased in recent years, particularly in the U.S. This is consistent with the widespread and continuing investigation of beta-alanine's effect on exercise performance, especially in bouts of exercise lasting up to four minutes, and for resistance exercise[75, 76]. Supplementation has been reported to increase the carnosine content in muscle cells, thereby improving the buffering capacity of the muscle during exercise and possibly leading to performance enhancement[76].

The U.S. Department of Defense recently sponsored an 'evidence-based evaluation of potential benefits and safety of beta-alanine supplementation for military personnel'. This study (positive quality) concluded that the limited available evidence 'did not support the use of beta-alanine supplementation alone or in combination [with other] products for enhancement of athletic performance or improved recovery from exhaustion in active adults'[77]. The quality of the evidence reviewed varied greatly and many studies were poorly documented, indicating the possibility of bias in the findings. Another recent review (positive quality), found that benefits to exercise performance are characterised by moderate-to-high quality evidence[76]. However, both these reviews found no studies investigating the effect of long-term supplementation on exercise performance[76, 77]. The first review indicated that the lack of long-term studies conducted over several months as a limiting factor in the assessment of benefits[77], while the second recommended that until long-term studies are conducted to confirm its safety and long-term efficacy, those considering using beta-alanine to enhance physical performance should err on the side of caution[76].

Reported benefits relevant in the military context include improvements in the number of shots on target, target engagement speed, and jump power[78]. However, these benefits have not been replicated.

Military members should also be aware of the issue of safety—harmful effects of acute use of beta-alanine may include paraesthesia (a tingling sensation) in hands and fingers[76, 77]. This would likely have a detrimental effect on military performance (e.g. shooting accuracy), therefore the use of beta-alanine as a dietary supplement is not recommended.

The use of supplementary beta-alanine, either alone or in combination with other supplements, is not appropriate due to lack of efficacy and the potential for detrimental side effects.

Limitations

It is beyond the scope of this study to capture the entire breadth of research that has been conducted on each of the supplements reviewed. However the findings provide an update on recent research relating to the military effectiveness of each dietary supplement in enhancing physical and cognitive performance.

Conclusions

In summary, of the five substances reviewed here, only LC omega-3 is considered safe and applicable for supplementation—to SDT levels—in fresh and

combat feeding of military members who do not consume the recommended intake of oily fish. Recent neutral–positive quality evidence suggests that cognitive and physical enhancement from this is unlikely; however, there is mounting evidence for benefits to sustaining brain function and mental health throughout life.

No other substances reviewed here currently show potential for cognitive and/or physical sustainment or enhancement. L-arginine, beetroot juice (inorganic nitrate), and beta-alanine appear to be already present in the diet of military members in adequate quantities for optimal physical and cognitive performance. Military members should not expect benefits to cognitive or physical performance from supplements containing these substances. There are chronic safety concerns associated with the use of beetroot juice and acute safety concerns associated with the use of beta-alanine supplements. Accordingly, health professionals should caution the use of L-arginine, beetroot juice (inorganic nitrate) and beta-alanine by military personnel for lack of efficacy and/or deleterious side effects.

Table 1. Summary of Findings

Supplement Name	Effectiveness	Potential Harmful Effects	Strength of Evidence	Dose / time course & administration method	Potential applicability to the Military
***Rhodiola rosea* Extract**	*Rhodiola rosea* has not been demonstrated to be an effective cognitive or ergogenic aid.	Infrequent potential side effects include minor and severe headaches, hypersalivation, and insomnia. The vast majority of people appear to experience no side effects[12].	Two recent positive quality review studies do not support effectiveness as a cognitive aid[12, 13].	Oral dose, such as 170 mg daily, containing approximately 4.5 mg of the (purportedly active) ingredient salidroside.	Not applicable.
LC (Long Chain) Omega-3	As a cognitive aid: ineffective in enhancing cognitive performance in older adults when taken for between three months and three years and in younger adults when taken between four and twenty-six weeks[20, 21, 23]. There is good evidence for LC omega-3 reducing depressive symptomatology[28, 29]. As an ergogenic aid: There is no convincing evidence to support a reduction in the inflammatory or immunologic response to exercise and thus increasing the speed of recovery and enhancing subsequent performance[37].	No known harmful effects in dosages up to 3 g per day. No risk of increased bleeding from injury at this level.	As a cognitive aid: one positive quality review study and two neutral quality review studies do not support the use of LC omega-3 to enhance cognitive performance[20, 21, 23]. As an ergogenic aid: not conclusively shown to reduce inflammation (delayed onset of muscle soreness) and enhance subsequent exercise performance in one positive quality and one neutral quality review study[35, 37].	Oral doses in the range 550–2400 mg of combined EPA and docosahexaenoic acid (DHA) daily[23]. Good dietary sources include dark-fleshed fish.	Increased inclusion in fresh and combat feeding would be appropriate. This should be aimed at achieving the Suggested Dietary Target (610 mg for men and 430 mg for women)[17]. Omega-3 is an essential nutrient that is currently likely to be consumed at sub-optimal levels in the military for general health (e.g. for cardiovascular, mental, and possibly brain and cognitive health).

Beetroot Juice / Dietary (inorganic) Nitrate Supplements	Effectiveness in sustaining physical performance in the military context has not been directly investigated. One report of increased time-to-exhaustion (TTE, i.e. endurance capacity) has little relevance to troops due to the low fitness level of individuals in whom benefits have been observed[44], whilst two other reports of increased TTE have involved individuals with fitness levels of greater relevance to troops[45, 46].	Caution is necessary due to potential for long-term harmful effects. The Acceptable Daily Intake (ADI) in Europe is 0.0–3.7 mg per kg of body weight per day[47, 52].	Not strong. The meta-analysis reporting significant benefit to TTE from pooled analysis of three studies is characterised by neutral quality[43].	Chronic supplementation: single oral dose in the 24 h before exercise, or daily for six weeks[50]. Acute supplementation: single oral dose 1–3 h before exercise. For both acute and chronic protocols, 300–380 mg or 3.9–5.5 mg of nitrate per kg of body mass per day is commonly used.	Potential to enhance military physical performance has not been directly investigated, but current evidence suggests this to be unlikely. Supplementation is not applicable and military members should adhere to the ADI.
L-arginine, L-Arginine Hydrochloride and glycine-arginine-α-ketoisocaproic acid (GAKIC)	Not effective in enhancing aerobic exercise performance. Inconclusive evidence.	L-arginine: acute doses are well tolerated, with side effects rarely reported[57]. GAKIC: no side effects have been reported from acute GAKIC supplementation[69]; however, confirmatory studies need to be conducted regarding safety.	There are differing methodologies and inconsistent demonstration of significant benefits in the literature on strength performance. Overall, the evidence in support of benefits is weak.	Acute doses: taken orally 40–80 minutes before exercise. Oral L-arginine doses studied are in the range 500–750 mg per kg of body weight or 2–6 g total. Oral glycine-arginine-β-ketoisocaproic acid (GAKIC) doses studied are in the range 10.2–11.2 g.	Supplementation is not applicable.
Beta-Alanine	As an ergogenic aid: ineffective in enhancing exercise performance in trained individuals[77]. As a cognitive aid: there is some evidence to support the claimed decrease in subjective feelings of fatigue and perceived exhaustion[76], however this is unconvincing.	Harmful effects of acute use may include paraesthesia (a tingling sensation) in hands and fingers[76, 77]. This would likely have a detrimental effect on troops in their military roles, therefore use is cautioned against.	Recent positive quality review evidence does not support the use of beta-alanine to enhance exercise performance or recovery[77].	Oral dosages vary between 800 and 1600 mg 2–4 times / day (a total of 1.6 to 6.4 g / day)[77].	Supplementation is not applicable; however research appears to be continuing.

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Australian malariology during World War II (Part 3 of 'Pioneers of Australian military malariology')

Ian Howie-Willis

Abstract

This is the third part in a five-part series on the development of Australian military malariology during the twentieth and early twenty-first centuries. Part 1, which appeared in *JMVH* 24(1) in January 2016, traced the course taken by Australian malariology between the South African ('Boer') War of 1898–1902 and the early 1920s in the immediate aftermath of World War I. Part 2 appeared in *JMVH* 24(2) in April 2016. It argued that Australian malariological research between the two World Wars depended largely on the efforts of specialists in tropical diseases who had acquired their knowledge of malaria through practical wartime experience as medical officers serving with the Australian Army Medical Corps (AAMC) in New Guinea and the Middle East during World War I.

This article shows how dire need — the near isolation of Australia after Japan entered World War II in December 1941, plus a series of major malaria epidemics among the troops in Papua — pushed the AAMC into a pioneering program of malariological research.

As with Parts 1 & 2 in the series, Part 3 tells the story biographically, through the lives and work of the Australian Army's medically trained scientists and administrators who led the Army's wartime anti-malaria effort. Because of their endeavour, during World War II the Army sponsored ground-breaking malariological research for the first time.

The nine AAMC medical officers profiled in the sections that now follow were instrumental in initiating and implementing the Army's anti-malarial policies and practices during the period of the 'Island Campaigns' 1942–1945. Without their collective effort, a rising malarial tide in Papua and New Guinea could well have engulfed the Allied forces as they sought to halt the Japanese thrust into Australia's external territories.

Introduction

The rapid Japanese advance across South East Asia and through the archipelagos of the South West Pacific in late 1941 and early 1942 effectively isolated Australia and New Zealand. The lines of communication with their principal Allies, the UK and the USA, lengthened and became more hazardous. Further, the cinchona plantations of the Netherlands East Indies (now Indonesia) came under Japanese control. Until then the plantations had been the source of most of the world's supplies of quinine, the principal anti-malarial drug,

For the first time in the war, Australian forces suffered a series of major epidemics of malaria in Papua New Guinea[1] as the troops there struggled to stem the Japanese tide. Even before the epic battles of the Kokoda Trail, Milne Bay and the north Papuan coast between mid-1942 and early 1943, malarial infection rates among the personnel deployed to the Port Moresby area for the campaigns ahead had soared to levels not seen since the great *falciparum* malaria epidemic suffered by the Australian-led Desert Mounted Corps in Damascus in September-October 1918, during the last weeks of World War I.

The malaria epidemics in Papua New Guinea in 1942–43

The war against malaria in Papua New Guinea soon proved as crucial as that against the Japanese. It was led and conducted by a group of remarkable senior officers of the Australian Army Medical Corps (AAMC) who had trained in tropical medicine during the inter-war decades of 1920s and 30s.

The AAMC's specialists in tropical diseases had already performed a prelude to the sobering drama of the 1942–1946 war against malaria in Papua New

Guinea. In Syria in June–July 1941 the troops of the 2nd Australian Imperial Force (AIF) suffered the Army's first malaria epidemic of the war when 1400 troops succumbed to the disease during the six-week campaign against the Vichy French forces there. By a ratio of four to one, most of these were victims of *falciparum*, the more lethal form, rather than *vivax* malaria. The victims were promptly evacuated to the military hospitals in malaria-controlled Palestine.[2]

The medical officers feared the worst in Syria. AAMC veterans who had served in the Middle East during World War I remembered the catastrophic *falciparum* epidemic that had almost brought the Desert Mounted Corps to a standstill in Damascus in 1918. As in 1918, one of the main approaches into Syria from Palestine in 1941 was along the upper Jordan, still a highly malarious region.[3]

A 2nd AIF anti-malarial team disinfecting a malarial mosquito breeding ground using knapsack sprays, Syria, 1941. Left–right are Lance-Corporal A.W. Branch, Corporal R. Griffiths and Private G. Idle (Australian War Memorial photograph no. 021218).

Fortunately for the troops, the 1941 epidemic in Syria was contained without becoming a catastrophe of 1918 proportions. The reasons for this welcome outcome included the short duration of the campaign, which allowed most troops to be withdrawn from malarious Syria and Lebanon to the malaria-controlled areas of Palestine. In addition, the summer of 1941 in Syria was unusually dry, thus restricting the breeding of the anopheline malaria vectors. The likelihood of transmission was further reduced through strict observation of 'malaria discipline', including the taking of suppressive doses of five grains (0.324 grams) of quinine daily and then ten grains (0.628 grams) after the number of infections began rising. After the first rush of cases during June, in July the anti-malarial effort was intensified. Measures to reduce the troops' chances of being bitten by mosquitoes included placing camps in safer areas away from mosquito breeding sites, limiting night-time troop movements when possible and spraying with insecticides the areas frequented by the troops. As well as these factors, the troops developed a better understanding of malaria through the dissemination of information about the disease and instruction by members of the 2/1st Field Hygiene Section, which had responsibility for malaria control.[4]

When the 2nd AIF returned to Australia in early 1942 to help face the Japanese invasion in Papua New Guinea, many of the AAMC's medical officers therefore had recent first-hand field experience of malaria in the Middle East theatre, and of the measures required to combat the disease effectively. Their knowledge, skills and experience were immediately relevant to the medical situation in Papua New Guinea, which, then as now, was among the most malarious regions on earth.

The Japanese invasion of Papua New Guinea had begun with capture of Rabaul, capital of the Territory of New Guinea, on 23 January 1942. Japanese forces then quickly overran the other towns in New Guinea and along the north coast of the Territory of Papua. By early May 1942 the Japanese had occupied the long chain of archipelagos to Australia's north, between Sumatra in the west and the Solomon Islands in the east.[5]

As the Japanese invasion of Papua New Guinea progressed, Australian forces were rushed there to meet the threat, Troop numbers built up rapidly, particularly around Port Moresby, the capital of Papua. Almost immediately, a series of malaria epidemics erupted. The first began in March 1942, as troop numbers around Port Moresby were rapidly increasing. With some fluctuations in infection rates, it continued for five months, until August.[6] Between early and late March 1942, the hospital admission rate of troops suffering malaria increased five-fold, from seven admissions per thousand troops a month to 36. The personnel of any unit being hospitalised at the latter rate would accordingly be entirely replaced within the space of 28 weeks.[7] This was *before* any major campaigns had been fought!

Further, worse epidemics of malaria followed during the campaigns at Milne Bay during the second half of 1942 and along the north Papuan coast at Gona, Buna and Sanananda at the end of 1942 and early in 1943.

The malaria hospitalisation rate during the battles for Gona, Buna and Sanananda quickly rose to a peak of 48 admissions per thousand troops weekly by late January 1943. That was the equivalent of 2496 cases per thousand troops annually, which in turn implied a yearly average of about 2.5 hospitalisations for malaria for each soldier participating in the campaign on the Papuan north coast.[8]

At Milne Bay the malaria epidemic was among the worst ever suffered by the Australian Army. There the malaria hospitalisation rate soared to 82 cases per thousand troops per week in mid-December 1942; i.e. equivalent to 4264 cases per thousand annually or an average of almost 4.3 hospitalisations for each soldier. If sustained, infection rates of that magnitude would have obliterated Milne Force. As the official medical historian, Allan S. Walker observed, 'had this alarming increase in rate continued, bounding upwards in geometrical progression,…the whole [of Milne] Force would have been lost in less than two months'.[9]

By early 1943, malaria hospitalisation rates were so high that drastic action became necessary. The form this took, strongly supported by the Army's Commander-in-Chief, General Sir Thomas Blamey, was the creation of an extraordinary Army malariological research institute — the Land Headquarters Medical Research Unit (LHQMRU) at Cairns. The program of malariological research undertaken by the LHMRQ over the three years from June 1943, was among the best completed anywhere in the world up till that time.[10] Applied in the field in Papua New Guinea, the findings flowing from the LHQMRU radically reduced malarial infection rates among the Allies. That in turn enabled the Allies to turn the tide of war and eventually to defeat the Japanese.[11]

Australian troops making their way along a muddy track at Milne Bay, 1942 (Australian War Memorial photograph no. 013339). The campaign was fought during an unusually wet 'wet season'; drainage ditches flooded; roads soon became rutted expanses of mud and water; mosquito breeding sites proliferated; malaria was endemic among the local indigenous village population; and at first 'malaria discipline' among the troops was slack. Under these circumstances, a serious malaria epidemic was inevitable.

The following sections of this paper now profile nine AAMC medical officers, all but one of them malariologists, whose efforts to combat malaria made the Allied victory possible. Even brief profiles like the following demonstrate how Australian military malariology rose to the level of 'world best practice' because of the necessity of combatting malaria in Papua New Guinea.

Sir Neil Hamilton Fairley KBE FRS (1891–1966)

Neil Hamilton Fairley, the son of a bank manager, was born in Inglewood, Victoria, on 15 July 1891. He was the third of six sons, four of whom survived to adulthood and became medical practitioners. He was educated at Scotch College, Melbourne, where he was dux of his year. He was also a talented athlete. He represented Victoria in tennis and became the Australian inter-varsity high jump champion while studying medicine at the University of Melbourne.[12]

After graduating MB BS in 1915, Fairley served a period as a resident at the Melbourne Hospital. He was awarded the MD degree from the university in 1917, but by that time he was serving overseas with the 1st AIF. He had enlisted as a captain in the AAMC in August 1915. His first published paper was a major report on the cases of meningitis he had studied during an epidemic of the disease in Victorian army camps.

In September 1916 Fairley joined the 1st Australian Imperial Force (AIF) and was posted to the 14th Australian General Hospital (AGH) in Cairo. He remained on the staff of the 14th AGH until demobilised in 1919. While at the hospital he came under the influence of Lieutenant-Colonel (later Sir) Charles Martin, the director of the Lister Institute of Preventive Medicine, a physiologist and pathologist who had earlier lectured at the Universities of Sydney and Melbourne. Martin had enlisted in the 1st AIF, served with the 3rd AGH in Cairo and established the Australian Mobile Bacteriological Laboratory there.

Captain N.H. Fairley, probably 1915 after enlisting in the AAMC (Scotch College, Melbourne, photograph).

While at the 14th AGH Fairley became interested in tropical diseases. He undertook research on schistosomiasis, dysentery, typhus and malaria, for which he was promoted to senior physician with the rank of lieutenant-colonel. He was also mentioned in despatches and awarded the OBE.

After the war Fairley went to London to work under Charles Martin at the Lister Institute, where he spent the rest of 1919. During this period he earned a Diploma in Tropical Health and Hygiene from Cambridge University and was admitted as a Member of the Royal College of Physicians. He returned to Melbourne in early 1920 to a position at the Walter and Eliza Hall Institute of Medical Research, where he was engaged in developing a test for echinococcosis (hydatids). He resigned after less than a year, however, to take up a position in Bombay (Mumbai), India.

In India Fairley became a medical officer at the Bombay Bacteriological Laboratory and consultant physician at two local hospitals. He undertook further research into schistosomiasis as well as dracunculiasis (Guinea worm disease) and tropical sprue (a nutrient malabsorption condition in which the symptoms are diarrhoea, anaemia and stomatitis). After suffering an attack of tropical sprue himself, he was invalided out of India. He recuperated in London, where he married Mary Evelyn Greaves in October 1925. (It was his second marriage. He had married Violet May Phillips (1893–1965), a 25-year old Army nurse from Mount Morgan, Queensland, in Cairo in 1919; but they had divorced in 1924.)

Fairley returned to the Walter and Eliza Hall Institute in Melbourne in 1927. He continued his work on echinococcosis and investigated tiger snake, death adder and copperhead snake venoms with the aim of developing anti-venoms. He left Australia again at the end of 1928 to take up appointments as a physician at the Hospital for Tropical Diseases and as a lecturer at the London School of Hygiene and Tropical Medicine. In London he worked on leptospiral jaundice and filariasis (elephantiasis), for which he devised a diagnostic test. He also undertook sustained research into Macedonian blackwater fever, a complication of malaria. In connection with this work, he made annual visits to the League of Nations Malaria Research Laboratory at the Refugee Hospital in Salonika, Greece. His work in London during the 1930s earned him election as a Fellow of the Royal Society (FRS), thus becoming one of the few Australian scientists ever so honoured.

Early in World War II, the AAMC head, Major-General Rupert M. Downes, the Australian Army Director General of Medical Services (DGMS), appointed Fairley as Consultant Physician to the 2nd AIF. He formally took up the position on 15 July 1940 with the rank of colonel. In that capacity he joined the 2nd AIF headquarters staff in Gaza in September 1940. He also acted as Consultant Physician to the British Army in the Middle East.

Fairley remained with the Australian Army in the Middle East until January 1942, when the 2nd AIF units began returning to Australia. During his 17 months in the region he worked closely with Colonel J.S.K. Boyd, the senior British pathologist, and Colonel J.A. Sinton VC, the senior British malariologist. Together they produced a handbook on malaria for medical personnel, which 2nd AIF headquarters published.

Concerned by the threat of a malarial epidemic among the troops of Lustre Force sent to Greece, Fairley and Boyd first had to tackle the British commander in the Middle East, General Wavell, to try to convince him of the priority that anti-malarial measures deserved. Initially Wavell did not welcome their advice because he regarded their attitude as defeatist, but eventually agreed to give their recommended anti-malarial program high priority. Two months later, during the campaign in Syria and Lebanon, their advice became the basis for the anti-malarial measures implemented by the British-led invasion force. As well as malaria, Fairley was obliged to tackle the other diseases of the Middle East which commonly infected Australian troops. These included shigellosis (bacillary dysentery) and sexually transmitted diseases, the incidence of which was high among 2nd AIF troops. For his work in the Middle East Fairley was mentioned in despatches and awarded the CBE.

On his way back to Australia from the Middle East in January 1942, Fairley stopped over in Java to secure supplies of quinine, which he knew would be required in the forthcoming campaigns against the Japanese in Papua and New Guinea. He procured all the available stocks, about 120 tonnes, which was to be transported in two shiploads. Mysteriously, these supplies never reached Australia, probably because of sabotage.

Back in Australia, Fairley was promoted to Brigadier and appointed Director of Medicine of Allied Land Forces Headquarters during the Army reorganisation of April 1942. He immediately faced a series of medical crises in Papua and New Guinea, which the Japanese had overrun. These included epidemics of bacillary dysentery during the Kokoda campaign and of malaria during the Milne Bay campaign. In

September 1942, the Australian Commander-in-Chief, General Sir Thomas Blamey, sent Fairley to the USA and the UK as head of a medical mission charged with procuring anti-malarial supplies. The mission succeeded in guaranteeing the Australian armed forces adequate supplies of atebrin, the anti-malarial drug which became the basis of the subsequent Allied campaign against malaria in the South-West Pacific theatre. It was used with great success both prophylactically and as a curative.

Strongly supported by the DGMS, by now his close friend Major-General S. Roy Burston, Fairley was instrumental in persuading Blamey to establish the Land Headquarters Medical Research Unit (LHQMRU) at Cairns in June 1943. The task of the LHQMRU was to assess the prophylactic and curative properties of quinine, atebrin and other anti-malarials and the dosages required for each purpose. This was done in a series of experiments using 1189 volunteer human subjects recruited from the armed services. Mosquito larvae were collected and flown in from Papua New Guinea, grown to maturity, infected with malarial parasites and then used to transmit the parasites to their human hosts, who were carefully monitored. Fairley designed the program of experimental work, which was carried out by a highly skilled team of medically-trained specialist malariologists, microbiologists and entomologists.[13]

Brigadier N.H. Fairley at his desk in Victoria Barracks, Melbourne, March 1946 (Australian War Memorial photograph no. 126353.)

The LHQMRU malaria research program devised by Fairley was by far the most sophisticated and elegant ever undertaken in Australia. It placed the LHQMRU at the forefront of world malariological research during the three years the unit remained operative. The LHQMRU research essentially demonstrated that a daily dose of 0.2 grams of atebrin (also spelt atabrine as well as being called mepacrine and quinacrine) would suppress both *vivax* and *falciparum* malaria. That dosage would also cure *falciparum* malaria but would not prevent relapses of *vivax* malaria, to guard against which atebrin levels in blood plasma must be maintained above 3.4 micrograms per litre.[14]

The practical outcomes of these findings had far-reaching effects because when the AAMC officers in the field applied the LHQMRU's recommended regimen of atebrin treatment, the result was a dramatic fall in the rate of malarial infection. The rate soon dropped from 'plague' proportions of more than 100 cases of infection per 1000 troops a week in some places to less than one case per thousand weekly. That in turn helped keep the Allied forces relatively malaria-free. This became a significant factor in their eventual victory against the Japanese, whose mortality from malaria in Papua and New Guinea was a disastrous 10 per cent of their total strength.[15]

Important aspects of the LHQMRU's success were Fairley's leadership and his authority as a research scientist. His associates were inspired by his belief that the best way of achieving a result was to believe it could be achieved and then to select the right team to achieve it. One of his LHQMRU team members, Lieutenant-Colonel Charles R.B. Blackburn, later wrote that working with Fairley 'was a continuing pleasure' and that 'everyone always gave of their best to Neil'.[16]

Fairley returned to his life in London in 1946. He was appointed inaugural Wellcome Professor of Tropical Medicine at the London School of Hygiene and Tropical Medicine, where he continued his wartime malariological research. He was forced to resign this position after suffering a cerebral thrombosis in December 1947. After his recovery, which took a year and a half, he resumed private practice but his output of research papers diminished. He continued contributing articles to the leading journals of the day, including the *British Medical Journal*, the *Medical Journal of Australia* and the *Transactions of the Royal Society of Tropical Medicine and Hygiene*, in which he most often published his research findings. His last journal article appeared in 1960.

Fairley remained a revered 'father figure' in his field even though he might no longer have been 'the acknowledged world leader in tropical medicine' that he had been at the end of the war.[17] In his later years he received many distinctions and awards. Those in medicine included the Strong Medal of the American

Foundation of Tropical Medicine, the Moxon Medal of the Royal College of Physicians, the Manson Medal of the Royal Society of Tropical Medicine and Hygiene and the Buchanan Medal of the Royal Society. He was knighted (KBE) in 1950.

After resettling in England in 1946, Fairley returned to Australia every two or three years to give lectures and visit family and friends. On his last visit in 1963 they noticed that he was slowing down. Unbeknown to them, he was suffering arteriosclerosis and had begun slipping into dementia.[18] After that trip he retired to Sonning, a village on the Thames in rural Berkshire 53 kilometres west of London, where his family thought life would be less stressful for him than in London.

N.H. Fairley, age 65 in 1956, ten years before his death (photograph from the Fairley Collection, Australian Academy of Science, Canberra).

Fairly died at home in 'The Grove', Sonning, on 19 April 1966 and was buried nearby in the graveyard of the ancient Church of St Andrew. His survivors included his second wife and three sons, the oldest of whom was an army officer in Australia and the other two medical practitioners in England. The family later donated his papers, including his extensive records of the LHQMRU experimental program, to the Basser Library of the Australian Academy of Science in Canberra.

In 1975 the youngest Fairley son, Gordon Hamilton Fairley (1930–1975), a renowned oncologist, was killed outside his London home when a bomb planted by the 'Balcombe Street Gang', a terrorist group within the Provisional Irish Republican Army, detonated prematurely. The bomb was intended for his next-door neighbour, the Conservative parliamentarian Sir Hugh Fraser.

Although Neil Hamilton Fairley spent most of his life overseas, he was a great Australian medical scientist. He published 149 papers in scientific journals in addition to various booklets and manuals. He was also a great Australian Army doctor-soldier. He promptly suspended his professional career to respond to the call of duty in two world wars. He spent nine of his 75 years in full time active Army wartime service. The impact of his research on the health of his fellow soldiers was such that many were spared death from the killer diseases that afflict armies. In the case of malaria, his efforts became a war-winning achievement.

Dr George Aloysius Makinson Heydon MC (1881–1963)

George Aloysius Makinson Heydon was an Australian-born medical parasitologist. He was the son of Charles Gilbert Heydon and his wife, Miriam Josepha (née Makinson). Heydon Snr. was a barrister, politician and later a judge.[19]

George's earlier education was at the Holy Cross College in Ryde, Sydney. He finished his schooling in Somerset, England, at Downside College, a Catholic boarding school run by Benedictine monks. After Downside he entered Christ's College at Cambridge University, from which he graduated with a BA degree. He then returned home to study medicine at the University of Sydney.

Dr George A.M. Heydon MC (1881–1963) (photograph of the Sydney Medical School, University of Sydney).

After graduating MB ChM in 1908 Heydon hoped to become an ophthalmologist, but service with the AAMC on Gallipoli and in France during World War I changed his career direction. He enlisted as an

AAMC captain in the 19th Battalion in May 1915. He served with the unit on Gallipoli and again in France in 1916–17. He was wounded in action in August 1916 in an engagement for which he was awarded the Military Cross. He was transferred to the 8th Battalion as Regimental Medical Officer in February 1917 and was promoted to major in June 1917. In September that year he suffered a gunshot wound in his left wrist and then spent two months in hospital in England before returning to active service in France.

Granted leave from the AIF in April 1919 until his demobilisation in August 1920, Heydon spent his leave living in London while studying for the Diploma in Public Health and the Diploma in Tropical Medicine and Hygiene at Cambridge University.

Heydon joined the laboratory service of the Commonwealth Department of Health after returning to Australia. During the early 1920s the department posted him to Rabaul to establish a government health laboratory for the mandated Territory of New Guinea. While there he became interested in parasitology and vector-borne diseases. His significant achievement was to demonstrate, through breeding and dissection experiments, that *Anopheles punctulatus* was the principal transmitter of malaria in Rabaul. That in turn enabled the local health authorities to institute a more effective mosquito control program in New Guinea.

In 1925 Heydon moved to Townsville to teach parasitology at the Australian Institute of Tropical Medicine (AITM). He also had responsibility for conducting field surveys for malaria and filariasis while at the AITM. In addition he studied human hookworm and the microscopic nematode worm *Onchocerca gibsoni* in cattle (a parasite transmitted by the Black Fly).

Heydon moved back to Sydney in 1930 when the AITM was merged with the School of Public Health and Tropical Medicine (SPHTM). He remained on the SPHTM staff until his retirement in 1946, teaching parasitology, conducting research and running a diagnostic service for general practitioners. He also served as the parasitologist to the Taronga Park Zoo, a job requiring him to examine for parasites post-mortem material from zoo animals.

Heydon's interest in malariology continued during his years at the SPHTM. He conducted a series of experiments to determine the extent to which the local Sydney anopheline species, *An. annulipes*, could become a malaria vector in the Sydney region.

During 1934 Heydon and a SPHTM colleague, Arthur J. Bearup, spent some time at Mount Hagen and Kainantu in the recently opened and heavily populated highlands of New Guinea. The aim of their research there was to examine the extent of protozoan and helminth infections among the indigenous communities and to determine the degree of their exposure to bacterial infections such as tuberculosis, diphtheria and scarlet fever.

A Junkers aircraft on the Mount Hagen, New Guinea, airstrip, Christmas 1934. Left–right are: Daniel J. ('Danny') Leahy (plantation owner), the pilot, Lord William F. Forbes-Sempill (pioneering aviator), Father William A. Ross (Catholic missionary), the two Fox brothers (Jack and Tom, prospectors), Dr George A.M. Heydon and an unnamed New Guinean (National Library of Australia photograph no. pic-vn3598868-v).

In 1938 Heydon and Bearup conducted an experiment with *Aceylanicum* hookworms obtained from a patient from the Solomon Islands. They infected themselves and two other volunteers with larvae bred from the hookworms, developed the symptoms of infestation, treated themselves and recovered adult hookworms. Such experiments provided data and material for their practical classes at the SPHTM.

Heydon did not re-enlist in the AAMC during World War II but did much to assist the war effort. Among other contributions, he examined Army recruits for parasitic infections. He ascertained that three per cent of the recruits were infected with *Entamoeba histolytica*, a protozoan parasite which, among others, can cause dysentery and liver abscesses. In 1942 he was a member of a team of eminent malariologists that investigated an epidemic of *vivax* malaria in Cairns. He was the first to recognise that the vector, previously unknown, was *Anopheles punctulatus moluccensis* (later called *An. farauti*), the main transmitter of the disease in Australia.

Another of Heydon's wartime contributions was unrelated to parasitology. He learned to fly in 1935, subsequently becoming a highly proficient pilot who retained his licence for the next 21 years, until he

was 75. During the war he frequently flew his own aeroplane over Sydney to give searchlight and anti-aircraft batteries practice in tracking aircraft.

Heydon retired in 1946 after 21 years of training successive cohorts of Australia's emerging parasitologists. Colleagues regarded him as 'the father of medical parasitology in Australia'.

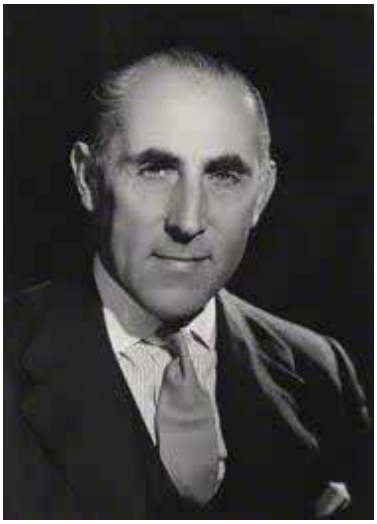
Sir Edward ('Ted') William Spencer Ford OBE (1902–1986)

Edward ('Ted') Ford was born in Bethanga, Victoria, the son of Edward Ford Snr. and his wife Mary (née Armstrong). He received his schooling in Clunes in central Victoria then started work as a telegraph messenger with the Postmaster-General's Department after turning 15. He matriculated at 24 while working as an accounts clerk with the department then trained in medicine at the University of Melbourne. He graduated MB BS in 1932 and MD in 1946.[20]

After graduating, Ford became a resident at the Melbourne Hospital. In 1933 he was appointed as a lecturer in anatomy at the university and then senior lecturer in 1934. During this period he developed an interest in tropical medicine. In 1937 he moved to Sydney as a lecturer in the School of Public Health and Tropical Medicine (SPHTM), where he earned a Diploma in Tropical Medicine in 1938. During 1938–39 he undertook field studies in malaria and other tropical diseases in Papua for the Papuan administration. He then spent a period during 1939–40 as the medical officer in charge of the Commonwealth Health Laboratory in Darwin. His service there was cut short by his joining the Australian Army Medical Corps (AAMC) as a major and enlisting in the 2nd AIF.

Ford, who commanded the 1st Mobile Bacteriological Laboratory, arrived in Palestine in March 1941. During the campaign in Syria he was attached to the 2/3rd Casualty Clearing Station from July 1941. He returned to Australia in March 1943, was promoted to lieutenant-colonel and was appointed Assistant Director of Pathology for both I Australian Corps and New Guinea Force.

In early December 1942, during the near-catastrophic epidemics of malaria among the Allied troops at Milne Bay and on the north Papuan coast, Ford was selected by the Deputy Director of Medical Services (DDMS) of I Australian Corps, Brigadier W.W.S. Johnston, to give the Commander-in-Chief, Blamey, a personal briefing on the malaria situation. Ford is said to have told Blamey bluntly that unless he gave the highest priority to the AAMC's campaign against malaria, very soon there would be no army left for him to command.[21]



Professor Sir Edward William Spencer ('Ted') Ford, 1959. By the time of this portrait Ford was regarded as the 'Father' of Australian malariology because of the pivotal role he had played in the Australian Army's struggle against malaria during World War II. (This photograph, taken by Walter Bird in February 1959, is produced with the kind permission of the National Portrait Gallery, London, the copyright holder. Its reference number is NPG x167171.)

Ford's advice to Blamey proved critical. Among other outcomes, it led to the establishment in June 1943 of the Land Headquarters Medical Research Unit in Cairns. This unit carried out pioneering malariological research. When the unit's findings were applied in the field, the results were war-winning. The malaria hospitalisation rate fell dramatically, enabling combat units to fight at full strength.

In March 1943 Ford was appointed as Malariologist at Land Headquarters in Melbourne. In this position he played a key role in the major effort the Australian Army made 1943–1946 to control malaria in Papua and New Guinea and the archipelagos to the north-west. Among others, his contributions included the publication of the booklet *Malaria in the South West Pacific* in 1943. His doctorate in medicine (MD) in 1946 was awarded for a thesis with the title 'Malaria Control in Australia and the Pacific Dependencies: With Special Reference to Anti-Mosquito Methods'.

Ford was appointed as the Army's Director of Hygiene, Pathology and Entomology in March 1945 and soon promoted to colonel. For his contributions to malariology in the Army he was mentioned in despatches in 1943 and appointed OBE in 1945.

In 1946 Ford travelled to the UK on a Rockefeller

Fellowship to study for the Diploma in Public Health at the London School of Public Health and Tropical Medicine. This was awarded in 1947, the year he was appointed as both Professor of Public Health and Director of the School of Public Health and Tropical Medicine at the University of Sydney. He held both positions for the next 21 years, until his retirement in 1968.

Professor Sir Edward Ford, a hero of the war against malaria in New Guinea during World War II, unveiling a commemorative plaque at the official opening of the premises of 1st Malaria Research Unit at Ingleburn Military Camp on 19 April 1974 (Australian Army Malaria Institute photograph).

Ford enjoyed a distinguished academic career. As well as his professorial appointment, at the University of Sydney he variously served as Dean of the Faculty of Medicine, a member of the Senate, acting Vice-Chancellor and a board member of Sydney University Press. He retained his interest in the Army and military medicine by serving in the Citizen Military Forces as Director of Army Health for eleven years 1953–64.

As well has his military awards, Ford received many civilian and medical honours. He was knighted in 1960. His academic and medical honours included Fellowships in the Royal Australasian College of Physicians, the Royal College of Physicians of London, the Royal Australian College of Medical Administrators and the Royal College of Pathologists of Australia. He was also awarded an honorary D.Litt. by the University of Sydney.

Beyond the Army and medicine, Ford had diverse interests and tastes. He was a passionate bibliophile who not only collected books but made many generous donations of books to universities and professional institutions. He never married but had a large circle of friends, including many from professional and artistic backgrounds.

Colonel Esmond Venner ('Bill') Keogh MM DCM (1895–1970)

Esmond Venner Keogh was born in Malvern, Victoria. He was one of four children of an estate agent, Esmond Keogh, and his wife Helen (née Moore). The parents separated in 1900 after the estate agency failed. The father then became a bush labourer in Western Australia, leaving the mother to raise the children. Wishing her children to be well educated, she sent Esmond ('Es' within the family) to Catholic boarding schools at Mornington in Victoria and Bathurst in New South Wales. The poet and industrial activist Lesbia Venner Harford (1891–1927) was one of his sisters.[22]

Although a Catholic, Es won a scholarship to Melbourne's elite Anglican academy, Melbourne Grammar School, which he began attending at the age of 14 in 1910. After finishing school there, he enrolled in agricultural science at the University of Melbourne but after a year he enlisted in the 1st AIF and joined the 3rd Light Horse Field Ambulance at the age of 19. This unit was commanded by Lieutenant-Colonel Rupert M. Downes, who later led the Desert Mounted Corps campaign against malaria in Palestine and Syria in 1918. (As seen in the first article in this series, Downes later commanded the Australian Amy Medical Corps [AAMC] and as the Director General of Army Medical Services [DGMS] led the Corps into World War II.)

Keogh served with the 3rd LHFA in Egypt and on Gallipoli and Lemnos before being withdrawn to Egypt at the end of 1915. Claiming to be a medical student, in March 1916 he returned to Melbourne, where he joined the 3rd Australian Machine Gun Battalion. He sailed for England with this unit in August 1916. Previously known as 'Es' among family and friends, from now on he called himself by the name his soldier mates used — 'Bill'.

Sent to the Western front in November 1916, Bill Keogh took part in the battle of Messines in June 1917. That October he was wounded in the hand during the advances near Ypres. His actions at the time earned him the Military Medal. After a period in hospital in England, he returned to his unit in April 1918. Promoted to sergeant, he took part in the capture of Mont St Quentin and in September he led a section without an officer at Quennemont

Farm, for which he was awarded the Distinguished Conduct Medal. After the end of the war he returned to Melbourne and was discharged in July 1919. Exhausted by his wartime experiences, Keogh drifted aimlessly for a year then spent 1921 working on the dairy farm near Maffra granted to his father as a soldier settler. (Keogh Snr. had served in the Camel Corps during the campaign in Palestine.)

Major E.V. ('Bill') Keogh MM in 1940 in his laboratory in Gaza, when he was an AAMC pathologist attached to the 2nd AIF in the Middle East (AWM photograph no. 002235).

In 1922 Keogh returned to university, studying medicine rather than agricultural science. After graduating MB BS in 1927, he joined the Commonwealth Serum Laboratories (CSL) as a pathologist; however, he spent periods at Bendigo and Kalgoorlie, where he worked among miners and became interested in public health. In 1935 he established his own pathology unit at CSL but was also seconded part-time to the Walter and Eliza Hall Institute, where he worked on viruses. He published a series of 18 papers on virology 1936–41.

Keogh was travelling in the USA attending medical conferences when World War II broke out. He hurried home and joined the Australian Army Medical Corps (AAMC) as a major in October 1939. The next month he was appointed pathologist to the 2/2nd Australian General Hospital. In April 1940 he travelled with the 2/2nd AGH to the Middle East. While there, he formed close working relationships with the Director of Medical Services, Major-General S.R. Burston, and Colonel N.H. Fairley, the 2nd AIF's consultant physician. With them, he helped persuade the British commander, General Wavell not to commit any large force to Macedonia because of the endemic malaria there.

After returning home from the Middle East with the 2nd AIF in March 1942, Keogh was promoted to lieutenant-colonel and was appointed as Director of Pathology at Army headquarters at Victoria Barracks. His main task was to establish pathology laboratories at the military hospitals and appoint the staff to run them. Of necessity, he again worked closely with Burston and Fairley, who had respectively become the Director General of Medical Services (DGMS) and the Director of Medicine. He also worked collaboratively with Lieutenant-Colonel Ted Ford, formally his Assistant Director of Pathology but in effect (with Fairley) one of the AAMC's two chief malariologists.

Following the catastrophic epidemics of malaria in Papua New Guinea in 1942–43, Keogh became a key figure in the campaign against malaria. According to Ford, it was under pressure from Keogh that Burston persuaded General Blamey, to authorise the establishment of the Land Headquarters Medical Research Unit (LHQMRU) in Cairns in June 1943. Thereafter, as Keogh's biographer wrote, 'Fairley planned the strategy, Keogh the tactics, daily atebrin was forced on the troops [and] the result was a triumph'.

Another of Keogh's wartime successes was the use of penicillin by the AAMC. Without its effects being fully proven, Keogh followed his instincts with the new 'wonder drug'. He arranged for its production in Australia. The AAMC used it for the first time during the Finschhafen campaign in New Guinea in 1944. After its success there, Australia became one of the first nations to use penicillin extensively.

Keogh spent the nine months April 1945–January 1946 as the medical adviser of the Australian Military Mission in Washington. Among other duties, he arranged Carnegie and Rockefeller grants for Australian medical scientists to study in the US and also Nuffield grants for them to study in the UK. After the war Keogh returned to the CSL and resumed productive research there. In 1949 he resigned to join the Department of Health, where his responsibility was organising the Victorian phase of the national anti-tuberculosis campaign, which involved mass chest X-ray screening of the public. He retained the position until 1955, in the meantime working with Macfarlane Burnet of the Walter and Eliza Hall Institute to have the Salk vaccine against poliomyelitis manufactured at CSL. He then organised the mass immunization program that began in 1956. His next position was medical adviser to the Anti-Cancer Council of Victoria, which he retained until his retirement in 1968. Among his achievements here was an extensive program of smear-testing for the early detection of cancer of the cervix.

Colonel E.V. ('Bill') Keogh, ***by unknown photographer, at his desk in Army Headquarters, Victoria Barracks, Melbourne 1946 (Australian War Memorial photograph no. 126249).***

Away from his involvements in public medicine, Keogh's main pastimes were racing, betting, bridge and poker. His cultural interests included modern art and both classical music and jazz. He also read widely. He never married, but with a talent for friendship, he made and retained a wide circle of friends of both sexes and was a popular 'Uncle Bill' to his nieces and his many friends' children.

After Keogh's death from cancer, his body was bequeathed to the Anatomy Department at the University of Melbourne. He had requested that no memorials or obituaries be arranged but his colleagues and friends conducted a memorial event at which the address was delivered by one of his protégés. This was Sir Benjamin Rank, a plastic surgeon and an AAMC colleague since their time together in the Middle East in 1940.

Lieutenant-Colonel Ian Murray Mackerras (1898–1980) and Major Mabel Josephine ('Jo') Mackerras (1896–1971)

Ian Murray Mackerras and Mabel Josephine ('Jo') Mackerras (née Bancroft) were pioneering Australian medical entomologists who were married to each other. They met as classmates while studying medicine at the University of Sydney then married in 1924, the year they graduated, while they were final year students.[23]

Ian Mackerras, born near Otago, New Zealand, was the son of a local farmer and his Australian wife. They separated when Ian was a boy; she then brought him to Australia, where he was educated at Sydney Grammar School. He enlisted in the 1st AIF in December 1915 at the age of 17, having overstated his age. He served as a laboratory assistant on the hospital ship *Karoola* before joining the 13th Field Artillery Brigade on the Western Front, where he was gassed. After recovering in hospital in England, he returned to Sydney, where he enrolled as a medical student at the University of Sydney in February 1919. He graduated MB ChM, BSc in 1924 and also won the university medal in zoology.

Left: Dr Ian M. Mackerras as a CSIRO scientist after World War II (National Library of Australia photograph no. nla. pic-an12107347-11-v); right: Dr M.J. ('Jo') Mackerras in 1971, the year of her death ('Sprent' photograph, from the 'Increasing Disorder' website, www.increasingdisorder.wordpress.com).

Mabel Josephine Bancroft, usually called by the shortened form of her middle name, was born near Caboolture, Queensland, the daughter of a Brisbane-born mother and her English-born husband, Thomas Lane Bancroft. The latter was a medical practitioner who developed an interest in parasitology and medical entomology. While at school at Brisbane Girls' Grammar, Jo assisted her father in his entomological work. After leaving school she completed a science degree at the University of Queensland then worked for the Walter and Eliza Hall Institute of Medical Research before beginning her medical training at the University of Sydney. She graduated MB in 1924 and was later awarded a MSc degree in 1930.

Ian and Jo's marriage was one of minds as well as of a couple mutually attracted through shared interests. As their joint biographer later observed, 'theirs was to prove one of the most productive and distinguished husband-and-wife partnerships in the history of Australian science'.

After their graduation Ian worked as a research fellow in zoology at the University of Sydney. He then spent two years as a microbiologist with the New South Wales Public Health Department before moving to Canberra in 1928 as a senior entomologist with the Council for Scientific and Industrial Research (CSIR). The position involved research in veterinary entomology and parasitology, mainly in the control

of sheep blowfly, buffalo fly and tick fever in cattle. During this period, Jo completed a year's residency at the Royal Prince Alfred Hospital in Sydney then combined private practice with a part-time appointment at a hospital for women and children. In 1926 she suspended her medical career to care for her infant son. She resumed her career in 1930, joining Ian's section of the CSIR as an assistant entomologist. They collaborated in publishing a series of papers on blowfly infestation and ephemeral cattle fever.

In October 1939 Ian enlisted in the 2nd AIF and was appointed as an AAMC major. Sent to the Middle East, he served as a pathologist at the 2/1st Australian General Hospital at Gaza. While there, he spent time in North Africa advising on the prevention of enteric diseases. After returning to Australia with the 2nd AIF in May 1942, he was appointed as Director of Entomology at Land Headquarters in Melbourne. Meanwhile, Jo had enlisted in the AAMC as a captain in February 1942 and had been serving in Sydney.

In June 1942 Ian was a member of the team of malariologists that investigated an epidemic of malaria in Cairns. That same month he travelled to Papua with the Director of Medicine at Land Headquarters, Brigadier N.H. Fairley, to investigate the preparedness of New Guinea Force for the malaria epidemics that they were certain would follow. It was the first of many tours he undertook in Papua and New Guinea to develop control procedures for malaria, dengue fever and scrub typhus. He also toured the US and the UK during 1944–45.

Left–right: Lieutenant-Colonel Charles R.B. Blackburn (Commander of the Land Headquarters Medical Research Unit [LHQMRU]), Major M. Josephine Mackerras (head of the LHQMRU Entomology Section in Cairns) and Brigadier N.H. Fairley (Director of Medicine, Land Headquarters), who designed the LHQMRU research program. (Photograph from the website of the Joint Health Command of the Australian Defence Force, http://www.defence.gov.au/health/.)

Following the disastrous epidemics of malaria during and following the Papuan campaigns of 1942–43, Ian was one of the group of senior AAMC officers who urged the DGMS, Major-General S.R. Burston, to create a discrete Army scientific organisation to undertake research on malaria. (The others included Fairley, E.V. (Bill) Keogh and Ted Ford.) The Commander-in-Chief, General Blamey, approved this proposal and the unit, formally called the Land Headquarters Medical Research Unit (LHQMRU), was established in Cairns in June 1943.

Dr Ian M. Mackerras as Director of the Queensland Institute of Medical Health, 1950 (photograph of the Australian Academy of Science).

Jo was appointed to the LHQMRU as the entomologist soon afterwards. Promoted to major, she became responsible for the LHQMRU Entomology Section. The section bred and maintained a large stock of infected mosquitoes, which were used to transmit malaria to volunteers from many Army units. The LHQMRU experimental program, which depended on the efforts of Jo's section, enabled malaria to be controlled in Papua New Guinea and elsewhere in the South-West Pacific Area theatre. That in turn was an important factor in the eventual Allied victory.

After the war, the Mackerrases returned to Canberra to resume work with CSIR (soon renamed CSIRO). In April 1946 they moved to Brisbane to positions at the Yeerongpilly laboratories, where Ian worked on cattle tick and Jo on blackflies. In 1947 Ian was appointed foundation director of the Queensland Institute of Medical Research (QIMR); Jo also obtained a position there. He also returned to the Army part-time as the commander of the 1st Mobile Malaria Control Company in the Citizen Military Force.

Both Ian and Jo retired from the QIMR in 1961 and returned to Canberra, where they settled in the inner suburb of Turner. They remained very active in retirement. Jo made a detailed study of cockroaches while Ian edited and wrote substantial sections of a huge volume, *The Insects of Australia*, which was published in 1970. Their shared pastimes included boating, fishing and flying. Each held a pilot's licence and they became foundation members of the Canberra Aero Club. They remained active in a range of scientific organisations. Among many other honours, each was elected a Fellow of the Royal College of Pathologists of Australasia. Each became a Fellow of the Australian Society of Parasitology. Each was awarded the W.B. Clarke Medal of the Royal Society of New South Wales; and each was awarded an honorary doctorate in science, Jo by the University of Queensland and Ian by the University of Sydney.

Strangely, neither Ian nor Jo received military awards for their contributions to the war on malaria in the South-West Pacific Area. Ian received two 'Mentioned in Despatches' for his service in the Middle East, but that was all. Jo was recommended for a military MBE on three occasions by the DGMS, Major-General S.R. Burston. In his recommendations Burston wrote that *'few women can have made a greater contribution to the Allied war effort'*. That, however, was insufficient to sway the Chief of the General Staff, who rejected each recommendation. His reasons essentially reduced to her being a woman and one who had not served in a combat zone.

Jo died at home on 8 October 1971 and was buried in the Canberra Cemetery. Ian died in Canberra on 21 March 1980 in Canberra and was cremated. Their only child, David, a reader in electrical engineering at the University of Queensland, became an authority on lightning.

The Mackerras's biographer later wrote of Jo that she was 'characterised by her wisdom and strength of character'. In addition, she 'possessed a serene charm, a placid smile and a shy, self-effacing manner'. Further, 'quietly and unobtrusively, she fostered young scientists and won the esteem of senior colleagues'. Ian was 'a sympathetic, stimulating and critical researcher who gave time and often financial support to young scientists'. In addition, he 'instilled in his teams the qualities of trust, goodwill, and genuine pleasure in learning and discovery'.

Professor Frank John Fenner AC CMG MBE FRS (1914–2010)

Frank John Fenner was a medically trained virologist. He was born in Ballarat, Victoria, in 1914, the son of a geologist, Charles A. Fenner. In 1916 the family moved to Adelaide, where his father worked in technical education and eventually rose to become the State Director of Education. Frank was educated at Adelaide Boys' High School and the University of Adelaide, where he studied Medicine. After graduating in 1938 he completed a Diploma in Tropical Medicine at the University of Sydney in 1940 because he rightly guessed that the looming world war would be mainly fought in tropical countries.[24]

Fenner enlisted in the 2nd AIF as a medical officer in May 1940. After service in Egypt and Palestine with the AAMC, he served in Papua and New Guinea. In early 1943 he was promoted to major and appointed as one of three malariologists attached to New Guinea Force. He later served as the malariologist to I Australian Corps.

Among other duties as a malariologist, he chaired the Allied Malaria Control Conference, an inter-service forum with both US and Australian membership. In August 1943, while the campaign for Salamaua was being fought, he undertook a major malariological survey of the coast region between Salamaua and Morobe (to the south, near the Papuan border). As a result of his survey, more energetic mosquito eradication work was undertaken and anti-malarial discipline among the troops was more strictly enforced. His survey report also drew attention to high wastage of troop strength because of the disease. Having worked through a series of malaria epidemics during the New Guinea Offensives and the Final Campaigns, by the time of his discharge in 1946 he was one of the Army's most experienced malariologists. He was awarded the MBE for his wartime work.

Captain F.J. Fenner (2nd from left) ***with fellow officers of the 2/1st Casualty Clearing Station at Nazareth, Palestine, May 1941 (Australian War Memorial photograph no. P02212.059).***

Fenner's scientific career took off in the early postwar years. After his discharge he spent two years working with Sir Macfarlane Burnet at the Walter and Eliza Hall Institute for Medical Research in Melbourne, where he worked on mouse pox, which he found to be a useful laboratory model for smallpox. He then spent a year at the Rockefeller Institute in New York, where he met many eminent medical scientists, including Albert Sabin, who developed the oral vaccine for poliomyelitis.

Fenner returned to Australia in 1949 at the urging of Sir Howard Florey, the pioneer of penicillin research, to become the foundation Professor of Microbiology within the John Curtin School of Medical Research at the new Australian National University (ANU) in Canberra. He remained based in Canberra for the rest of his life. In 1967 he became the Director of the John Curtin School, retaining the position until 1973, when he became the Director of the ANU Centre for Resource and Environmental Studies — a reflection of his interest in the environment. He formally retired in 1979 but retained his links with ANU as a Visiting Fellow (non-salaried staff member) at the John Curtin School and as a leading member of the adjacent Australian Academy of Science.

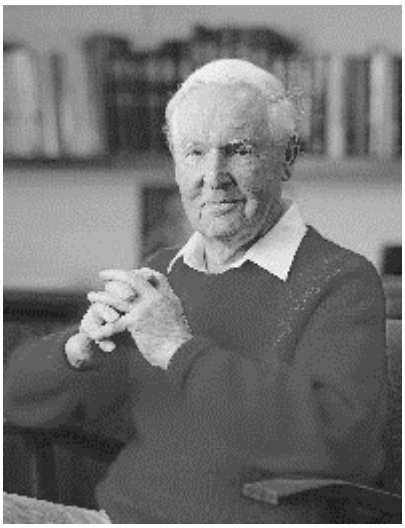
Professor Frank J. Fenner in 1959 when head of the Department of Microbiology at the John Curtin School of Medical Research at the Australian National University in Canberra (photograph from Immunology and Cell Biology Vol. 77, 1999).

Fenner had many research interests in virology and molecular biology. Among his projects were the Bairnsdale bacillus (which causes Buruli ulcer, the world's third most common mycobacterial disease after tuberculosis and leprosy); the development of myxomatosis in rabbits; the genetics of the vaccinia virus group; and smallpox and its eradication.

To prove that the Myxoma virus was harmless to humans, Fenner together with Sir Macfarlane Burnet and Sir Ian Clunies-Ross (Director of the CSIRO) publicly injected themselves with the virus. Arguably, Fenner's two greatest achievements were, first, the control of Australia's rabbit plague through the introduction of the Myxoma virus and, second, his work on the global eradication of smallpox. Significantly, it was Fenner who announced the worldwide eradication of smallpox to the World Health Organisation in May 1980. It was the first — and so far the only — occasion that a disease has been eliminated from the planet.

To these two achievements, malariologists might add a third — Fenner's painstaking, perseverance in helping reduce the risk of malaria among the Allied armies in Papua and New Guinea during the four years of the Pacific War 1942–45, the work that kick-started his long career in microbiology.

Fenner wrote 11 textbooks on medical and veterinary virology and a history of Australian microbiology. He also published some 300 research papers in specialist scientific journals. He published his first in 1934 when aged only 20 and was still publishing them 70 years later as he approached his 90s.



Professor Frank Fenner at age 88 in 2002. By then he was among the most celebrated of all scientists in Australian history (photograph from the 'Prime Minister's Prizes for Science' section of the Commonwealth Department of Industry website.)

Widely recognised as one of Australia's most eminent scientists, Fenner was showered with honours, awards and distinctions. As well as the wartime MBE, he was awarded the CMG (1976) and in 1989 was appointed as a Companion in the Order of Australia (AC). In 1958 he was elected a Fellow of the Royal

Society (FRS), becoming one of the few Australians ever to achieve that honour. In 1995 he was awarded the most prestigious scientific honour of all — the Copley Medal of the Royal Society. (Instituted in 1731, the Medal is awarded annually. Others to receive it have included Captain James Cook, Benjamin Franklin, Charles Darwin, Louis Pasteur, Albert Einstein, and the Australians Howard Florey and Macfarlane Burnet.)

In 1944 Fenner married Ellen ('Bobbie') Roberts, an Army nurse he had met while she was nursing the volunteers infected with malaria during the experiments of the Land Headquarters Medical Research Institute in Cairns. Frank and Bobbie had two adopted daughters. Bobbie predeceased Frank in 1994. In later life he was cared for by his younger daughter, who survived him. He died in Canberra a month short of his 96th birthday in November 2010.

Dr John Iredale Tonge CBE (1916–2013)

John Iredale Tonge was a medically trained forensic pathologist. He was the last of six children of the English-born Rev. Arthur W. Tonge (1869–1947) and his wife Elsie (née Love, 1874–1963). Rev. Tonge was an ordained Anglican clergyman but spent most of his life as a peripatetic teacher of Classics in Church of England boys' schools. His appointments included the King's School (Parramatta,1899–1905), Melbourne Grammar School (1905–1911), Trinity Grammar School (Melbourne, headmaster 1911–16), Guildford Grammar (Western Australia, 1920–1921), Ivanhoe Grammar (Melbourne, 1921–29) and King's School again (from 1932). In between these appointments he spent three years as a chaplain in the 1st AIF 1916–20, during which he saw active service in four of the major battles on the Western Front. He also spent a year in the late 1920s serving as a parish priest in England.[25]

Rev. Tonge's family accompanied him to most of these postings, with the result that his youngest son, John, who was born in Melbourne, was educated at Melbourne Grammar, Hurstpierpoint College (Sussex, England) and the King's School. After leaving King's, John studied Medicine at the University of Sydney. Graduating in 1939, he worked as a resident at the Prince Alfred Hospital, Sydney, where he began specialising in anaesthetics.

Major John I. Tonge (left) and Private K. Watkins examining blood slides in the Malaria Control Section of 104th Casualty Clearing Station, Wewak, New Guinea, August 1945.

After joining the Australian Army Medical Corps (AAMC) in December, Tonge helped establish the Blood Bank in Sydney before being posted to a series of Army hospitals at Cowra, Bathurst and Concord. In 1943 he was sent to Queensland as a pathologist at the 2/2nd Australian General Hospital at Rocky Creek on the Atherton Tableland, which was linked to the Land Headquarters Medical Research Unit (LHQMRU) in Cairns. That brought him into contact with the LHQMRU malariologists and their experimental program using Army volunteer patients.

Tonge's next posting was the command of the 104th Mobile Bacteriological Laboratory, with which he served on the New Guinea mainland and in New Britain. In mid-1945 he was sent to Wewak as a member of a LHQMRU field section investigating an alarming and atypical epidemic of *falciparum* malaria. As the LHQMRU team discovered, an atebrin-resistant strain of the *Plasmodium falciparum* parasite had emerged — the first known instance of drug-resistant malaria recorded. After the Wewak posting, Tonge spent the rest of the war working at the LHQMRU in Cairns as a malariologist, remaining with the unit until its closure in July 1946.

During the post-war decades Tonge did not continue in malariology. Like other LHQMRU 'alumni', however, he had a long and distinguished career in the field of his choice. In his case that was forensic medicine and pathology, in which he became a pioneer in Queensland. After obtaining a postgraduate Diploma in Clinical Pathology, in 1947 he was appointed Director of the Queensland State Laboratory of Microbiology and Pathology. He retained the position

for the next 32 years, until his retirement in 1979. As Director he pushed for the establishment of the Queensland Institute of Forensic Pathology, which he headed and which opened in 1961.

Tonge's achievements as Queensland's leading forensic scientist were many and varied. He expanded the State Laboratory to include a TB laboratory and a virology unit. He made special studies of sudden infant death syndrome, road trauma and aviation pathology. He persuaded the State government to adopt legislation imposing limits on drivers' blood-alcohol levels (1968), enforcing the wearing of crash-helmets by motor-cycle riders (1970) and the compulsory wearing of seat-belts (1972). He also introduced social work support for bereaved relatives brought to identify the bodies of those who had died.

Dr J.I. Tonge in later life (photograph from the estate of E.N. Marks).

In addition to these accomplishments, Tonge was a co-founder of the Royal College of Pathologists of Australasia, was among its inaugural Fellows and served as its third President 1959–1961. He also lectured in forensic medicine at the University of Queensland for over 30 years. Major-General John Pearn, the Surgeon-General to the Australian Defence Force 1998–2001, remembered Tonge as a significant influence on his own medical career.

In retirement, Tonge's interests included the Queensland Sudden Infant Death Syndrome Research Foundation, the Queensland Bush Children's Health Scheme, the Royal Society for the Prevention of Cruelty to Animals and the Council of the Queensland Institute of Technology. His honours and awards for his medical and community service included the CBE.

The John Tonge Centre of the Queensland Health Forensic and Scientific Services was named in his honour. The Centre, which opened in 1992 at Coopers Plains on Brisbane's southern fringe, is one of the State mortuaries responsible for conducting autopsies under the Queensland Coroner's Act of 2003.

In 1947 Tonge married Loddie Marks, a member of a prominent Brisbane medical and military family. They had a daughter and three sons.

Putting personal principle into practice, at the end of his long life Dr Tonge bequeathed his body to the body donor program of the University of Queensland School of Biomedical Sciences.

Major-General Sir Samuel Roy Burston KBE CB DSO (1888–1960)

Samuel Roy ('Ginger') Burston was a physician who spent most of his life as an officer of the Australian Army Medical Corps (AAMC). He was born in Melbourne in 1888, the fourth of seven children of James Burston, the head of a family malting business, and his wife Marianne (née McBean). Burston Snr. was an enthusiastic and ambitious officer of the Victorian Defence Force who served a term as Lord Mayor of Melbourne, later commanded the 7th Infantry Brigade at Gallipoli and retired from the Army as a major-general in 1920.[26]

Burston, who preferred being called by his middle name but was widely known by the nickname 'Ginger' because of his sandy-red hair, was educated at Melbourne Grammar School and Trinity College at the University of Melbourne, where he studied Medicine. His Army career began while he was still at school, when at age 13 he became a bugler boy. He spent five years bugling and only gave it up after beginning his medical course.

After an undistinguished academic career, Burston scraped through his final year medical exams. On graduating in 1910 he moved to Adelaide to become a resident at the Children's Hospital. He left the hospital after only a year to become a Medical Protector of Aborigines at Darwin in the Northern Territory. He returned to Adelaide in 1912. Soon afterwards he enlisted as a captain in the AAMC and married Helen Culross, a young woman he had met in Adelaide. They settled at Mile End, an inner Adelaide suburb where he ran a general practice from his home.

Burston enlisted in the 1st AIF as a major in April 1915. Sent to Egypt, he was assigned to the 7th Field Ambulance, which was posted to Gallipoli in September that year. After only six weeks' active service with his unit, Burston fell ill with a debilitating attack of paratyphoid fever. He was sent back to Alexandria then to a hospital in London for further

treatment. After a long period of recovery he was attached to the 11th Field Ambulance. He travelled to France with the unit in November 1916 and distinguished himself by commanding its advanced dressing station during the Battle of Messines in June 1917. His service with the unit earned him a Mentioned in Despatches and a DSO. After Messines he was promoted lieutenant-colonel and then filled a series of appointments as a unit commander in AAMC medical base depots and hospitals in both France and Britain.

After returning to Adelaide in 1919, Burston trained and qualified as a specialist physician, practised privately, held honorary appointments at the Royal Adelaide Hospital and lectured part-time in clinical medicine at the University of Adelaide. He also continued his active involvement with the AAMC. Promoted colonel, he spent the two inter-war decades as DDMS of 4th Military District, i.e. South Australia. A keen surf swimmer, in 1928 he was awarded the Bronze Medal of the Royal Humane Society for rescuing a woman being swept out to sea in a dangerous rip near Victor Harbour.

Colonel S.R. Burston, a portrait by Damian Parer, May 1940, the month before Burston flew to Palestine to take command of the 2nd AIF's medical services in the Middle East. He was soon promoted Brigadier then Major-General and appointed Director of Medical Services of the AIF in the Middle East (Australian War Memorial photograph no. 001863.)

Burston resumed full-time military service in September 1939 as soon as the 2nd AIF began enlisting recruits for overseas service at the outbreak of World War II. Appointed as ADMS of the 6th Division, he became the AIF's principal medical officer. He also became the trusted confidante of the AIF Commander, General Sir Thomas Blamey, with whom he travelled to Palestine in June 1940. They worked closely together for the rest of the war. Blamey promoted Burston to Brigadier and then Major-General in quick succession and in November 1940 appointed him as DMS of the 2nd AIF in the Middle East. As such, Burston had responsibility for the medical support of all the campaigns the 2nd AIF fought in the Middle East–Mediterranean theatre during 1940 and 1941, viz. Cyrenaica, Greece, Crete, the Siege of Tobruk and Syria-Lebanon.

Soon after Blamey and Burston had returned to Australia with the repatriated AIF units in March 1942, Blamey appointed Burston as DGMS, that is the head of the AAMC with responsibility for all of the Army Medical Services in supporting the Army wherever its units were deployed. At that time the Army had actively engaged units strung out between the Middle East, Ceylon (Sri Lanka), Papua New Guinea, the Northern Territory, the Torres Strait Islands and northern Queensland as well as troops in every other State preparing for the defence of Australia against a feared Japanese invasion.

During the hard-fought campaigns in Papua New Guinea and Borneo between 1942 and 1945, Burston consolidated his reputation as a superb military-medical administrator. Burston was the quintessential charismatic leader. He easily attracted loyal friends and followers. Popular among Army officers and other ranks alike, his affable, gregarious personality readily won him devoted supporters. As DGMS, he managed the military and medical politics of the position adroitly. He was a shrewd judge of character and talent, ensuring that senior specialist medical officers like Neil Fairley, Ian and Josephine Mackerras, Bill Keogh and Ted Ford were placed in positions in which their talent and experience could be used to best advantage. He made the right appointments to the senior AAMC positions in the Army's operational divisions. He delegated effectively to the hierarchy of AAMC officers. He provided prompt, wise advice to his Commander-in-Chief, using his close links with General Blamey to the optimal advantage of the Army Medical Services.

Burston was not a malariologist; and unlike one of his distinguished predecessors as DGMS, Major-General Rupert M. Downes, he never had to manage an epidemic of malaria in the field. As DGMS from April 1942, however, he took command of the war against malaria in the South-West Pacific Area (SWPA).

Burston and Fairley, who were close personal friends as well as military and medical colleagues, worked productively together in a close professional relationship throughout the war. Thus, Burston ensured that Fairley was placed in a position of authority in which he had privileged access to

Generals Blamey and MacArthur in order to keep them fully informed about the Allies' struggle with malaria. He facilitated the establishment of the Land Headquarters Medical Research Unit (LHQMRU), arranged Fairley's appointment as its Director and ensured that it received the resources it needed to carry on its research program efficiently. He issued a continuing series of widely distributed 'Technical Instructions' to advise AAMC medical officers and units on how malaria was to be managed. Although these were drafted by his specialist advisers, and in particular Fairley, they bore his imprimatur and authority as DGMS.

Burston also convened a decisive high-level conference on malaria for the Army's most senior commanders at Atherton in June 1944. Known as the 'Atherton Conference on Tropical Diseases in Warfare', it was critically important in swinging the support of its audience behind the LHQMRU research recommendations. The main speaker on the program was Brigadier Fairley, who outlined the LHQMRU research findings. Burston himself spoke compellingly to the audience on what they must do to avoid catastrophic malarial epidemics during the Final Campaigns of the war. The Conference proved to be a turning point in the Army's struggle against malaria because Burston followed up on the Conference by persuading General Blamey to issue a General Regulation Order enforcing anti-malarial discipline throughout the forces in Papua New Guinea. Burston accordingly deserves his place on the 'honour roll' of those who furthered Australian military malariology during World War II, even if that meant militarily transforming malaria from a medical problem to a matter of discipline.[27]

Major-General S.R. Burston (right) chatting with the Minister for the Army (and later Prime Minister), F.M. Forde, during the official opening of the 115th Base Hospital at Heidelberg, Melbourne, on 4 December 1943. The others in the photograph are (left–right): an unidentified Army officer, Senator J.S. Collings (Minister for the Interior) and Matron C.J. McAllister (Australian War Memorial photograph no. 060879).

After the war, Burston remained DGMS until his retirement in late 1947. He was knighted (KBE) in 1952 for his services to military medicine. His many post-war business and community involvements included being the inaugural Chief Commissioner of the St John Ambulance Brigade in Australia (1945–1956), serving as the Chairman of the Moonee Valley Racing Club (1952–60) and assisting Australian Red Cross as its Honorary Medical Director (1948–60). He died suddenly at home in Melbourne from an aortic aneurysm in August 1960.

Burston was survived by his two sons and a daughter. His younger son, Robin ('Bob'), became a specialist physician in Adelaide. He joined the AAMC in 1945 and remained in the Corps as a medical officer until his retirement in 1978. In that time he reached the rank of colonel and served as a physician at the 1st Australian Field Hospital in Vietnam.

Conclusion

The foregoing sections have profiled nine medically trained AAMC officers who helped shape the direction taken by Australian military malariology during World War4 II under the aegis of the Army's Land Headquarters Medical Research Unit. The historian of the LHQMRU, Tony Sweeney, has written that the unit's experimental program 'formed the solid foundation on which later advances in malaria research have developed'.[28] In coming to that conclusion he quoted *The Lancet*, the prestigious British medical journal, which opined that the LHQMRU experimental program 'brought a greater advance in the knowledge of chemoprophylaxis [of malaria] than had occurred in the previous 50 years or was to occur in the subsequent twenty'.[29]

Those profiled above were only nine of hundreds of Army Medical Service personnel who fought the war against malaria during the campaigns in the Middle East, North Africa, Greece, Papua New Guinea and South-East Asia. Many of that number are equally worthy of profiles in this article; unfortunately, however, space here does not permit the due acknowledgment of their contributions to Australian military malariology. Suffice to say that their collective effort placed Australia at the forefront of world malariology. The final two articles in this series will demonstrate how the Army's malariologists endeavoured to retain that place for Australian malariology during the post-war decades.

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Abbreviations

AAMC	Australian Army Medical Corps (prefixed 'Royal' from 1948)
AC	Companion of the Order of Australia
ADB	*The Australian Dictionary of Biography*
ADMS	Assistant Director of Medical Services
AGH	Australian General Hospital
AIF	Australian Imperial Force
AITM	Australian Institute of Tropical Medicine
ANU	Australian National University
AWM	Australian War Memorial
BA	Bachelor of Arts
BSc	Bachelor of Science
CB	Companion of the Most Honourable Order of the Bath
ChM	*Magister Chirurgiae* (Latin: Master of Surgery)
CMG	Commander of the Most Distinguished Order of St Michael and St George
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSL	Commonwealth Serum Laboratories
DCM	Distinguished Conduct Medal
DDMS	Deputy Director of Medical Services
DGMS	Director General of Medical Services
DMS	Director of Medical Services
DSO	Distinguished Service Order
FRS	Fellow of the Royal Society
HQ	Headquarters
KBE	Knight of the Most Excellent Order of the British Empire
LHQMRU	Land Headquarters Medical Research Unit

MB BS	Bachelor of Medicine and Bachelor of Surgery
MBE	Member of the Most Excellent Order of the British Empire
MC	Military Cross
MD	Doctor of Medicine
MM	Military Medal
OBE	Officer of the Most Excellent Order of the British Empire
QIMR	Queensland Institute of Medical Research
RSTMH	Royal Society of Tropical Medicine and Hygiene
SPHTM	School of Public Health and Tropical Medicine (University of Sydney)

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‘A near-run thing’: The foundation and early years of 1 Malaria Research Laboratory, forerunner of the Australian Army Malaria Institute, 1963–1969 (Part 4 of ‘Pioneers of Australian military malariology’)

Ian Howie-Willis

Abstract

During the 25 years following World War II, malaria re-emerged as a major threat to Australian military personnel deployed to malarious regions in South-East Asia. By 1952, malariologists in Britain knew that drug-resistant strains of the malaria parasites *Plasmodium falciparum* and *Plasmodium vivax* had emerged in Malaya.[1] Successive contingents of Australian soldiers serving in Malaya from the mid-1950s to the early 1970s and then in Vietnam from the early 1970s encountered drug-resistant malaria. They suffered a series of malaria outbreaks and epidemics.

Drug-resistant malaria was an issue causing severe tensions between the Royal Australian Army Medical Corps (RAAMC) medical officers serving in the field in South-East Asia and their superiors in the Army Medical Directorate (AMD) in Melbourne and later Canberra. The Directorate had adopted an orthodoxy which required that the anti-malarial drug Paludrine (also called Proguanil) be taken prophylactically in accordance with strict AMD-ordained guidelines by all troops posted to malarious regions. Disagreements soon developed between the AMD and RAAMC medical officers in the field. The AMD dogmatically maintained that outbreaks of malaria resulted from slack ‘malaria discipline’, including soldiers’ failing to take their Paludrine tablets regularly. The field medical officers, however, realised that because the soldiers were strictly observing the discipline but still contracting malaria, the parasites’ acquired drug resistance was probably the reason.

These tensions and the reality of Paludrine-resistant malaria parasites in Malaya and Vietnam prompted the establishment of a new Army malaria research facility in 1966. This was the 1 Malaria Research Laboratory (1MRL). Modelled on the Army’s Land Headquarters Medical Research Unit (LHQMRU) of World War II, 1MRL eventually developed into the present Australian Army Malaria Institute (AAMI). That the 1MRL would survive was, however, doubtful, because its early years were troubled and it could do little to stem the rising tide of drug-resistant malaria in Vietnam during the late 1960s.

As with Parts 1 to 3 in this series of articles, Part 4 tells its story biographically, through reference to the lives and work of the Army’s medically trained administrators, field officers and scientists who led the struggle against malaria in Malaya and Vietnam. The article profiles three senior Army medical officers who were significant in the early development of 1MRL — Major General W.O. Rodgers, Professor R.H. Black and Major General C.M. Gurner.

Introduction: 'a near-run thing' and 'necessity is the mother of invention'

In his field headquarters after the Battle of Waterloo on 18 June 1815, the victorious field marshal, Arthur Wellesley (1769–1852), the 1st Duke of Wellington, was heard to remark that his victory had been 'a near-run thing'.[2] What the Duke probably meant by this expression was that the outcome of the battle had never been certain until near the end. His decisive victory could easily have become a spectacular defeat.

However interpreted, *'a near-run thing'* is a phrase that comes readily to mind when the student of military-medical history contemplates the early years of 1MRL. In that context the phrase suggests survival by the skin of the institutional teeth. Like the 'Iron Duke's' victory at Waterloo, during the Laboratory's first three years, there was no certainty about its continuation and every chance it might be shut down.

In arguing that case, this article will also use another phrase — the proverb *'necessity is the mother of invention'*. The proverb suggests that the primary driving force for innovation is need; and when a need becomes critical, people find ways of satisfying it. That, too, is an idea applicable to the 1MRL in its early years. The article argues that the Laboratory was brought into being and then allowed to survive because of escalating malaria infection rates among Australian soldiers in Vietnam during the mid to late 1960s.

To appreciate the pertinence of the two phrases just used in relation to 1MRL, the reader must step back two decades from the foundation of the Laboratory to World War II and the years immediately following the end of the war.

The period 1945–1963: new drugs and drug-resistance

A series of major epidemics of malaria had occurred in Papua New Guinea[3] among the Allied military forces in 1942–1943 as they struggled to halt the Japanese advance through the chain of islands to Australia's north. The senior medical officers of the Australian Army Medical Corps (AAMC) [4] responded to the threat of malaria by establishing a remarkable research unit in Cairns, north Queensland, to investigate the disease. This was the Land Headquarters Medical Research Unit, which in the time it was active, 1943–1946, became the world leader in malariological research. The LHQMRU task was to experiment with the available anti-malarial drugs, using soldier volunteers as subjects. The aim was to determine the levels of drug intake required for both prophylactic and treatment regimens in order to quell malaria sufficiently to enable the Army to keep fighting in Papua New Guinea. As seen in Part 3 in this series of articles, the LHQMRU's experimental program was developed and supervised by the Army's Director of Medicine, Brigadier (later Professor Sir) Neil Hamilton Fairley FRS, arguably the greatest Australian malariologist of all time.

Alarmingly for the Army Medical Directorate (AMD) and the medical officers of the RAAMC, drug-resistant strains of malaria parasites emerged during the 1950s in the post-World War II conflicts in South-East Asia, particularly in Malaya and later Vietnam. This phenomenon had first become apparent during the last few months of World War II, when an Atebrin-resistant strain of *falciparum* malaria was discovered in the Sepik District of Papua New Guinea.[5]

For the previous two years, Atebrin had been trumpeted far and wide as the new anti-malarial 'wonder' drug. The orthodox position of the Medical Corps was that, if taken prophylactically in accordance with established guidelines, Atebrin was guaranteed to protect soldiers against malaria and would also cure both the *falciparum* and *vivax* forms of the disease.[6]

The next anti-malarial drug of choice was Paludrine, trialled late in World War II by the LHQMRU at Cairns, a detailed history of which, *Malaria Frontline*, Dr Tony Sweeney, a 1MRL staff member, published in 2003.[7]

As soon as Paludrine became commercially available in sufficient quantities, it replaced Atebrin as the Australian Army's anti-malarial drug of choice. During the Malayan Emergency in the mid-1950s to early 60s, Paludrine remained the frontline defence against malaria. The Paludrine prophylaxis regimen became an article of faith, an orthodoxy of the AMD as strictly adhered to as that of Atebrin in Papua New Guinea in 1944 and 1945.

The new orthodoxy, however, was soon challenged by the experience of the units sent to northern Malaya during the Emergency. The frontline Regimental Medical Officers (RMOs) of the Royal Australian Regiment (RAR) quickly realised that even the strictest supervision of the Paludrine prophylactic regimen could not prevent malaria from erupting among their troops. A Paludrine-resistant strain of the *falciparum* parasite seemed to have evolved rapidly in South-East Asia.

Ironically, the ordinary soldiers, too, realised that

their experience invalidated the Paludrine orthodoxy. In their scepticism they were ahead of the AMD in Melbourne, where faith in Paludrine remained firm. Regarding the RMOs in the field as heretics, the AMD threatened disciplinary action; however, as further evidence of Paludrine-resistant malaria parasites accumulated in Cambodia, Thailand and Vietnam their faith weakened as well.[8]

Major General William Rodgers (1936–)

Major Bill Rodgers was typical of the young frontline RMOs who served in Malaya during the Emergency and earned the displeasure of the AMD hierarchy in Melbourne by questioning its Paludrine orthodoxy. His disagreements with the AMD paralleled those of other RMOs who had served in Malaya before he did.

Lieutenant Colonel (later Major General) W.O (Bill) Rodgers OBE, about 1967 (AWM photograph no. P01002.073).

William ('Bill') Orrill Rodgers was born in Naracoorte, South Australia, on 1 December 1936. His father was a policeman and his mother a dairy farmer's daughter. He received his primary schooling in Wolseley (near the Victorian border) and his secondary education at Birdwood High School in the Adelaide Hills. A bright student, he topped the State in Latin, Physics and Chemistry in his final year of school.[9]

Bill Rodgers wished to be a veterinarian but thought he was too soft-hearted for that; and so after being awarded a Commonwealth Scholarship to study medicine, he chose medical training instead. Coming from a humble background, he earned money to support himself by trapping water rats and selling the pelts. He entered the University of Adelaide at the age of 16 and graduated at age 21 in 1958. In his third year, he was granted an Army scholarship, one of 17 offered the first time such awards were made to prospective Army medical officers. He then remained in the Army until his retirement in 1990.

After his graduation, Rodgers spent a year, 1959, as a resident at the Royal Adelaide Hospital. His first Army posting was as the RMO at 1 Recruit Training Battalion at the Kapooka Recruit Training Centre at Wagga Wagga in southern New South Wales. His next appointment was as the CO of the 7th Camp Hospital at Kapooka in 1961. He spent the period from late 1961 until 1963 as the RMO of the 2nd Battalion of the Royal Australian Regiment (2RAR) in Malaya. Among other duties during his time in Malaya, during 1962 he was sent to South Vietnam to investigate disease patterns. He spent several weeks travelling the length and breadth of the nation in a light plane.

The officers of the 2nd Battalion, Royal Australian Regiment at Malacca, Malaya, November 1961. The Regimental Medical Officer, Captain W.O. Rodgers, is seated at the left end of the front row. The Commanding Officer, Lieutenant-Colonel Alan S. Stretton, is seated at the centre (AWM photograph no. P09707.003).

While serving in Malaya, Rodgers had to manage an outbreak of Paludrine- and Chloroquine-resistant malaria among 2RAR troops stationed near the Thai border. He incurred the wrath of the AMD by issuing Chloroquine tablets in addition to the regulation daily dosage of 100-milligram Paludrine tablets. Eventually he was vindicated when Professor Robert H. Black of the School of Public Medicine and Tropical Health at the University of Sydney investigated the outbreak and found that drug-resistant *falciparum* parasites had indeed been responsible for the outbreak.

Major Rodgers (as he then was) spent 1964 in the UK, studying for a Diploma in Tropical Health and Medicine at the Hospital for Tropical Diseases in London. After returning from his studies in London,

he was appointed as the Deputy Assistant Director General of Medical Services in Melbourne (DADGMS). At that time the DGMS was Major General Andrew J. Clyne, who had severely criticised his management of the *falciparum* malaria outbreak in Malaya in 1961–1962, and had even threatened to have him court-martialled.

Rodgers' next appointment was as a lieutenant colonel and the Commanding Officer (CO) of the 2nd Field Ambulance at Puckapunyal, north of Melbourne, where he spent three months preparing the unit for service in Vietnam. He took the unit to Vietnam, arriving there in April 1966. In 1967 he was awarded an OBE for his service in Vietnam. After his year with the unit in Vietnam, he was posted to the 1st Military Hospital at Yeronga in southern Brisbane as CO. He spent two years in the position, 1968–1969, before the unit was moved to the Enoggera Barracks in Brisbane's northern suburbs.

After Rodgers had undertaken a second tour of duty in Vietnam, this time as the Assistant Director of Medical Services, Major General Colin Gurner, who had succeeded Clyne as DGMS in 1967, suggested that Rodgers should seek specialist qualifications. (Like Clyne, Gurner has criticised Rodgers' management of the outbreak of drug-resistant malaria in Malaya.) Rodgers opted to become a physician and spent the next 18 months at the Royal Adelaide Hospital qualifying for a Fellowship of the Royal Australasian College of Physicians (FRACP). In 1982 he earned a second Fellowship when appointed as a Fellow of Royal Australasian College of Surgeons (FRACS).

Papua New Guinea was the next move for Lieutenant Colonel Rodgers, in 1970. The country was making its transition to Independence in 1975; and during this period the two Pacific Islands Regiment battalions were readying themselves to become the Papua New Guinea Defence Force. On returning to Australia, he was promoted to colonel in 1974 after 11 years as a lieutenant colonel. As such, he held two appointments, Colonel in charge of Professional Services and Colonel in charge of Army Health. In 1980 he was promoted to brigadier. His posting was to the Department of Defence headquarters in Canberra. In 1985 he was promoted to major general and appointed to succeed Major General W.B. ('Digger') James as Director General of Army Health Services (DGAHS). He spent the next five years in the position, until his retirement in 1990. From 1986 he also held the position of Surgeon-General to the Australian Defence Force.

After retiring from the Army, Rodgers was appointed Principal Medical Officer Repatriation in the Department of Veterans Affairs in Canberra. He then moved to Noosa on the Queensland Sunshine Coast in 1991. He spent 15 years 1991–2006 as the Medical Superintendent of the Nambour General Hospital, a Queensland Health Department appointment.

Major General Rodgers remained a strong advocate of Army-sponsored medical research, as conducted by the AAMI at Enoggera. Convinced that the Army's future deployments would be in malarious regions, he believed that if the activities of the AAMI were to be curtailed there would be adverse consequences for soldiers' health. Civilian research organisations and the universities would not necessarily be interested in Army medicine and could not accordingly be relied on to undertake the Army-oriented medical research that was the AAMI forté.

Rodgers was a career Army medical officer in the best RAAMC tradition. He spent his entire Army career before his retirement within the RAAMC, rising from captain to Major General and head of the Corps. Although he was not a specialist malariologist, he learned much about malaria through practical experience as a RMO in the field, backed up by postgraduate training in tropical medicine. As he demonstrated in Malaya, he was enterprising in his determination to protect the health of the soldiers for whom he was responsible. By tackling drug-resistant *falciparum* malaria in the field with the resources available to him, he set in train a series of events which eventually led to the establishment of 1MRL, the AAMI forerunner.

1963–1966: a period of gestation in Army malaria research

Confronted by the mounting evidence of drug-resistant malaria among Australian troops serving in Malaya during the Emergency, in 1963 the AMD turned for answers to the Army's consultant on tropical diseases, Professor Robert H. Black. Black, formerly a captain on the LHQMRU staff in Cairns 1943–1946, was by now the Professor of Tropical Medicine in the School of Public Health and Tropical Medicine at the University of Sydney. He was also Australia's leading malariologist.

Professor Robert Hughes Black (1917–1988), Australia's leading malariologist from the 1950s to the 1970s and the Army's chief malariological adviser. A complex character, Black persevered with his vision for developing an enterprising, world-class Australian Army malaria research facility.

A new war, in Vietnam, added urgency to the quest for new solutions to the age-old problem of how to defeat malaria. Paludrine-resistant malaria was already emerging in Vietnam as the first Australian soldiers were being sent there in July-August 1962.

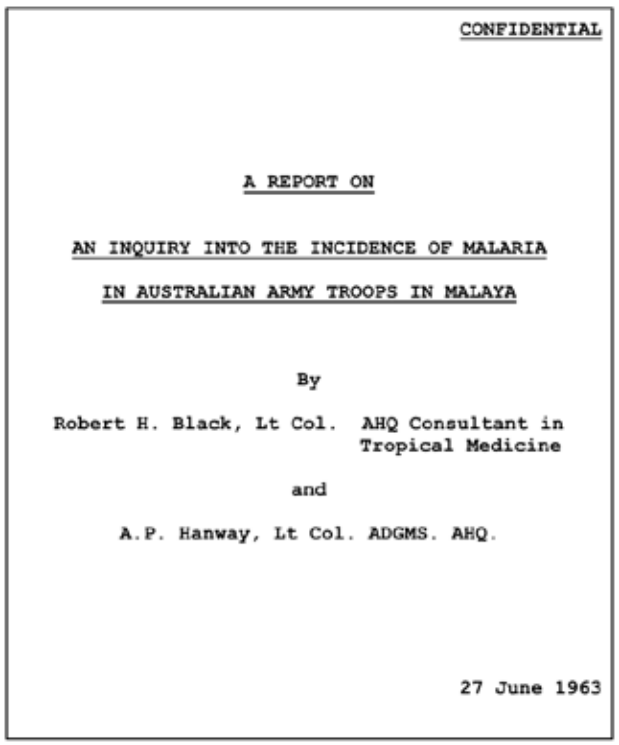
Professor Black began contemplating the possibility of creating a latter-day version of the LHQMRU. The event prompting him was a visit that he and the Assistant Director General of Medical Services (ADGMS), Lieutenant Colonel Aidan P. ('Paddy') Hanway, made to Malaya in June 1963, to inquire into the incidence of malaria among Australian troops there.

Adhering to the AMD's Paludrine orthodoxy, Major General Clyne, the Director General of Medical Services (DGMS) and his deputy (and successor), Brigadier Colin Gurner, were maintaining that the hospitalisations for malaria in Malaya, approaching 500 by 1963, resulted from slipshod 'malaria discipline'. That is, they believed the troops in Malaya were not taking their Paludrine pills, were not sleeping under mosquito nets and were not buttoning up their shirts and rolling their sleeves down at night.[10]

The young RMOs in the field, however, knew that the troops were punctiliously adhering to the malaria discipline but were still contracting malaria. They concluded that Paludrine-resistant parasites were the cause and that Paludrine had become ineffective in controlling them. They accordingly experimented with the drug regimen, increasing the Paludrine dosage and adding Chloroquine. Clyne and Gurner at AMD headquarters in Melbourne saw the RMOs rejection of the Paludrine orthodoxy as insubordination; and that led to threats of severe disciplinary action.

Black and Conway spent a fortnight in Malaya, interviewing the RMOs in the field, consulting the Australian Commander in Malaya, Lieutenant Colonel Alan Stretton, and discussing malaria with the senior members of the British RAMC.

On their return from Malaya, Black and Hanway submitted a detailed report to Clyne. In tone it was generally condescending to the RMOs in the field. It found fault with those who, like Major W.O. Rodgers, were openly sceptical of the Paludrine orthodoxy. Black and Hanway were, however, convinced that Paludrine- and Chloroquine-resistant strains of *falciparum* malaria were indeed present in Malaya. That in turn persuaded Black that the AMD and the RAAMC should conduct research analogous to that of the LHQMRU during World War II.[11]



CONFIDENTIAL

A REPORT ON

AN INQUIRY INTO THE INCIDENCE OF MALARIA

IN AUSTRALIAN ARMY TROOPS IN MALAYA

By

Robert H. Black, Lt Col. AHQ Consultant in Tropical Medicine

and

A.P. Hanway, Lt Col. ADGMS. AHQ.

27 June 1963

An unpretentious but epoch-making document — typescript of the cover of the Black-Hanway report on malaria among Australian troops in Malaya, 27 June 1963. This report set in motion the chain of events leading directly to the foundation of 1 Malaria Research Laboratory three years later.

During the months that followed, Black discussed the research possibilities with Major General Clyne, What they had in mind at that stage was 'a research

project into drug resistance in malaria similar to the investigation conducted by Sir [Neil] Hamilton Fairley [at the LHQMRU] in Cairns during the last war'.[12] By June 1964 their ideas had progressed to the point where Clyne could formally notify the Adjutant General of their wishes and request permission for their project to use soldier volunteers in experiments.[13]

Major General Andrew J. Clyne, Australian DGMS (second from left) visiting 2nd Field Ambulance, Vietnam, March 1967. Two years earlier, Clyne had formally set in motion the train of events leading to the establishment of 1 Malaria Research Laboratory on 14 June 1966. Earlier, during the Malayan Emergency, he had been highly critical of the actions of the junior medical officers in the field who varied the established Paludrine prophylactic regimen in order to cope with outbreaks of drug-resistant falciparum malaria (AWM photograph no. CUN/67/0170/VN).

Meanwhile, Black had been discussing the proposal with colleagues among the malariologists of the World Health Organisation and in the US at the University of Chicago and the National Institute of Health at Atlanta.[14] He also advised the AMD that Sir Edward Ford, a great World War II Australian Army malariologist and head of the School of Public Health and Tropical Medicine, had agreed to have a young Army biochemist attached to his (Black's) Department of Tropical Medicine.[15] This was Lieutenant G.M. Galvin, whom the AMD had referred to Black after he had expressed an interest in research work within Black's department.[16]

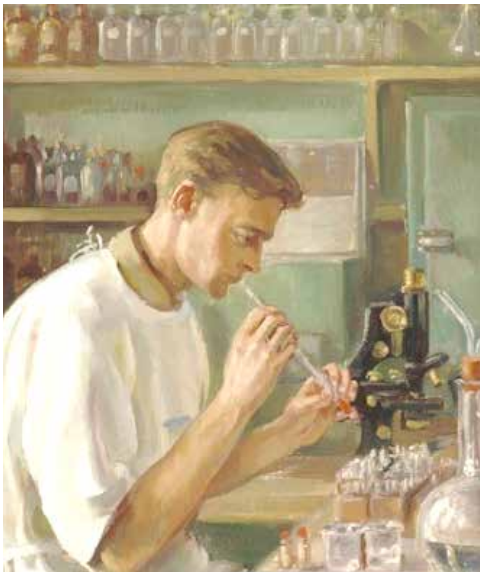
Professor Robert H. Black, the Army's consultant on tropical diseases 1959–1979

The AAMI owes its existence to Robert Hughes Black, the Professor of Tropical Medicine at the School of Public Health and Tropical Medicine of the University of Sydney 1963–1982. Without his vision and perseverance, the AAMI might never have been conceived or could have died in infancy. Because he was both 'parent' and 'midwife' at the birth of 1MRL, at this point the reader should appreciate who Black was and why his achievement was important.

Professor Robert Hughes Black (second from left), 1985, with fellow members of the Army Malaria Advisory Board. (Australian Army Malaria Institute photograph).

Black was born in Willaura, Victoria, on 20 December 1917, the son of a bank manager. He attended many schools but completed his secondary education at Parramatta High School in Sydney. He then went on to study medicine at the University of Sydney. He graduated MB BS in 1939, winning a University Medal. He spent 1940 as a resident at the Royal Prince Alfred Hospital in Sydney and then another year in Innisfail, Queensland, as a senior resident at the local hospital. At the end of that year he married another medical practitioner, Dr Dorothy R.E. Tandy, in Innisfail. They divorced in 1952.[17]

In November 1941 Black enlisted as a captain in the AAMC, serving as a militia officer at first. In July 1942 he transferred to the 2nd AIF. He was posted first to the 19th Field Ambulance and then to the 117th Australian General Hospital (117 AGH) at Toowoomba. In August 1943 he was posted to the 106th Casualty Clearing Station and accompanied the unit to New Guinea. In Lae and later with the 2nd Blood and Serum Unit in Sydney he experimented with cultivating *falciparum* malaria parasites in red blood cells *in vitro*.



Captain Robert H. Black, titrating sera in a laboratory at the 2nd Australian Blood and Serum Preparation Unit in Sydney, 1944: an oil on hardboard portrait by the war artist Nora Heysen, who became Black's second wife (AWM picture no. ART22409).

In December 1943 Black joined the staff of the LHQMRU at Cairns, where he used his *in vitro* technique to demonstrate that anti-malarial drugs metabolised in the body were active against cultured parasites. At the LHQMRU he became a key member of the research team conducting experiments on volunteers to ascertain the correct dosage levels of Atebrin for use in anti-malaria prophylaxis.

After his discharge in June 1946, Black spent a year as a bacteriologist at the Institute of Medical Research at the Royal North Shore Hospital in Sydney. In 1947 he earned a MD degree from the University of Sydney for a study of the chemotherapy of malaria. He then travelled to the UK, working his way as a ship's surgeon. He spent two years 1946–1948 working and studying at the Liverpool School of Tropical Medicine, where he earned a Diploma in Tropical Medicine and Health.

On returning to Australia, Black gained a position in the School of Public Health and Tropical Medicine at the University of Sydney in 1949. He was promoted successively to lecturer, senior lecturer and in 1963 Professor of Tropical Medicine. By this stage he was one of Australia's few world authorities on malaria. He wrote over 200 journal articles and monographs on malaria. He participated in international malaria surveillance programs. He was called on as a consultant in malaria by several international agencies, notably the World Health Organisation and the South Pacific Commission. In Australia he maintained the central national register of malaria cases.

In 1959 Black had been appointed as the consultant in tropical diseases to the Australian Army headquarters and granted the rank of lieutenant colonel in the Citizen Military Force (CMF) branch of the RAAMC. As seen, in 1963 at the request of the AMD he undertook an investigation of outbreaks of drug-resistant *falciparum* malaria in northern Malaya, where malaria had erupted among Australian troops serving during the Malayan Emergency. In 1964 he was promoted to colonel. He subsequently advised the AMD on the use of drug combination therapy in cases of drug-resistant malaria during the Vietnam War. By this stage drug-resistant malaria had appeared in various locations in South-East Asia.

As a result of his experiences in Malaya and Vietnam, Black became the leading advocate for the creation of an Army malaria research unit analogous to the LHQMRU. In 1965 he proposed that an Army malaria research laboratory be established within his department at the University of Sydney. Permission was granted in 1966. A six-member unit known as the 1 Malarial Research Laboratory (1MRL) then formed and began work during 1966–67. 1MRL remained located within Black's department at the university until it moved into its own premises at the Ingleburn Army Camp in 1973.

Professor Robert H. Black (left), Sir Edward Ford (centre) and Dr Ian M. Mackerras (right) view the portrait of their World War II commander and colleague, the great wartime malariologist Brigadier Sir Neil Hamilton Fairley, in the 1st Malaria Research Unit at Ingleburn, 19 April 1974. All three, who were pioneering malariologists, were attending the unit's official opening in its new premises (Australian Army Malaria Institute photograph).

Colonel Black retired from the Army in 1979 and from the University of Sydney in 1982. Until a new

generation of specialists emerged during the 1980s, he remained Australia's foremost malariologist.

As a result of his research into drug-resistant malaria in South-East Asia, New Guinea and the Pacific Islands, Professor Black became interested in the sociological ramifications of malaria control. To understand this aspect of malariology better, he undertook studies in anthropology at the University of Sydney, for which he was awarded a Diploma in Anthropology in 1963. As part of this program he undertook a special study of life on a coconut plantation in the Solomon Islands. Following this experience, he advocated social science training for workers in malaria control programs.

Black's honours and awards included election to a Fellowship of the Royal Australasian College of Physicians in 1965. In 1986 he was awarded the Darling Foundation Medal of the World Health Organisation, a prestigious prize presented for significant contributions to malariology.

Black's second marriage, in 1953, was to the war artist, Nora Heysen, whom he had met during his time in the Army in New Guinea in 1943. She subsequently produced several sensitive portraits of him carrying out his research at the LHQMRU. Their marriage ended in 1972. In 1976 he married Gail Lorraine Grimes, a nurse who was 28 years his junior. He died of cancer on 17 March 1988, survived by his third wife and his son from his first marriage.

Some of Robert Black's associates found him difficult to deal with. His biographer, Yvonne Cossart, hinted at this by writing that 'frequent travel abroad, coupled with a reserved manner and introspective temperament, sometimes impeded his professional collaboration and placed a strain on his personal relationships'.[18]

Whatever his personal foibles, Robert Black was a towering figure in Australian malariology for over 30 years. He trained several generations of malariologists at the University of Sydney. His legacy to the Australian Defence Force was his advocacy of the unit that evolved into the Australian Army Malaria Institute. AAMI remains a monument to his vision and persistence.

A prolonged labour: birth of 1 Malaria Research Laboratory, 1965–1966

In early March 1965 Professor Black visited Army Headquarters in Melbourne to discuss his ideas for an Army-sponsored malaria research project with Brigadier Gurner, the DDGMS. Gurner later told the DGMS, Clyne, that Black believed that the unit could become one of the three leading centres for malaria research in the world and would 'greatly increase the status of the RAAMC'.[19]

Shortly after the conversation between Gurner and Black, Clyne submitted a minute to his superiors formally proposing the establishment of a new 'RAAMC Malaria Research Laboratory'. The unit would be located at the University of Sydney and would have a staff of six comprising a major as commanding officer, two captains and three sergeant laboratory technicians, all of whom would be seconded from medical field units.[20]

In the months that followed, Clyne's proposal gained increasing urgency as reports from Vietnam indicated that the US Army medical units were grappling with Chloroquine-resistant strains of *falciparum* malaria.[21] The AMD began receiving reports on this issue in May 1965 as the Australian government was preparing to commit operational troops to the war in Vietnam.[22]

The reports kept coming during the following months.[23] In September Clyne provided the Minister for the Army (Alexander James ['Jim'] de Burgh Forbes MC) with a briefing on 'Malaria — A New Strain'.[24] After several months of negotiation between the AMD, Black and the Army's Director of Personnel Administration (DPA) over staffing levels and service conditions at the proposed Malaria Research Laboratory (MRL), the DPA approved the recommended staffing establishment on 13 May 1966.[25]

Army Headquarters in Canberra then authorised the setting up of the MRL a month later, on 14 June 1966. The notice of authorisation, 'Raising Instruction [no.] 26/66', was circulated to all branches of the Army and to its seven regional Commands. This half-page document advised its many recipients that '1 Malaria Research Laboratory' would be 'a Regular Army unit administratively allotted to Eastern [i.e. New South Wales] Command but located at the School of Tropical Medicine at the University of Sydney.'[26] If institutions may be said to have 'birthdays', 14 June 1966 would be the AAMI's; and 'Raising Instruction 26/66' would be the AAMI 'birth certificate'.

(Chief of the General Staff)

Army Headquarters
Russell Offices
CANBERRA ACT

Quote in Reply
605/R2063/2

8 June 66

E Comd (10)

RAISING/DISBANDING INSTRUCTION 26/66
1 MALARIA RESEARCH LABORATORY RAAMC

1. Approval is given for the raising of 1 Malaria Research Laboratory, RAAMC, on establishment IV/131/1 (HE). The Unit has a total of six all ranks (three officers and three NCOs). A copy of the establishment is attached.

2. 1 Malaria Research Laboratory is to be an ARA AHQ unit and is allotted to E Comd for local administration. It is to be located at the School of Tropical Medicine, Sydney University.

3. The three officers are to be provided from the establishment of 2 General Hospital. In order that provision is made on the establishment for three other rank laboratory technicians, the establishment of 2 General Hospital (IV/370/2 (TE)) is to be restricted by three Pte Med Orderlies (ECN 564). Suitable amendment to the 2 General Hospital establishment will be advised separately.

4. The authority for the issue of stores and equipment is HET 1631. Pending the issue of this HET, the provision of such items of stores and equipment which are considered necessary, is to be the subject of a separate instruction.

5. The costing of officers and OR is to be the subject of separate advice from AHQ (MS and DAR respectively).

6. AHQ is to be advised when this instruction has been implemented.

7. Amendments to the ORBAT are to be advised separately.

(illegible signature with initials 'SRC'] fr at
pa (G.D. Solomon)
Brigadier
DSD

Enclosures 1. Copy of establishment

Copies to:

AG Branch (10), QMG Branch (10), MGO Branch (10), Secretary's Branch (12), DMO and P (2), IMT (4), DAR, CARO (6), MS (2), MA to CGS, PA to DCGS.

Copies for information: N Comd, S Comd, T Comd, C Comd, W Comd, NT Comd, PNG Comd.

Internal:

SD (Coord), SD (P and EC) (2), SD (ORBAT), SD (Estb) (2), SD (Gen Org) (2).

Ref 5900 (copy) on 11901

Typescript of an institutional 'birth certificate' — Raising/Disbanding Instruction 26/66: 1 Malaria Research Laboratory, RAAMC. A legible copy of the original is unavailable. The only known copy is a nearly illegible poor photocopy of a faint carbon-copy of the original, in the archival holdings of the Australian War Memorial. Its Army jargon and frequent acronyms are a challenge for the uninitiated; however, even an uninformed lay person will realise that this is an important 'raising instruction'.

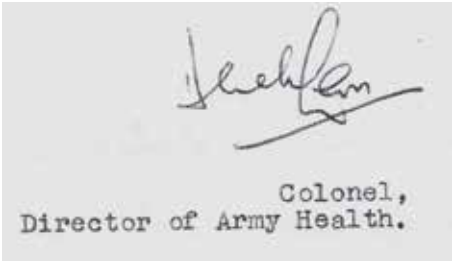
The inception of 1 Malaria Research Laboratory, 1966

A fortnight after Army Headquarters had authorised the establishment of 1MRL, Professor Black wrote to Brigadier Gurner to say how he envisaged the Laboratory developing, outlining the role he thought that 1MRL ought to perform. He believed it should fulfil three basic functions, which he described as being the investigation of: (1) the activity of anti-malaria drugs against malaria parasites using human volunteers and mosquito-transmitted malaria; (2) malaria strains suspected of being resistant to certain anti-malarial drugs; and (3) associated clinical, parasitological, entomological and biochemical research.[27]

Black saw the 1MRL progressively taking on its role through three main stages. Stage I would involve recruiting and training the staff. Stage II, into which he hoped 1MRL would move in early 1967, would entail 'advanced training and development of techniques'. Stages I and II could be undertaken within his department at the university, but Stage III, 'the carrying out of research projects', would require 1MRL to 'move to a hospital unit'.[28] That was more or less how things turned out, though not quite in the manner that Black had foreseen.

The 22-year old Lieutenant (later Captain) Galvin formally took up duty with 1MRL during late June 1966. He was given the task of raising the unit; and he became its first Commanding Officer. Apart from himself, 1MRL had three Army privates with previous laboratory experience, two of whom were National Servicemen.[29] They were accommodated in a room barely large enough for them let alone the laboratory equipment and supplies they would soon accumulate. Among Galvin's first tasks was the ordering of equipment and supplies. In lieu of administrative and accounts staff, he also performed clerical duties. While he undertook these tasks the three privates worked in the laboratories of the Entomology and Parasitology departments of the School under Black's supervision.[30]

The AMD in Melbourne closely monitored 1MRL during the unit's first months. At the end of July 1966 the Director of Army Health, Colonel (later Major General) Derek G. Levis (1911–1993), a RAMC officer on secondment to the RAAMC, travelled to Sydney to inspect 1MRL and discuss its needs with Lieutenant Galvin. Levis subsequently reported to the DGMS that the most urgent priorities for 1MRL included: (a) definitive terms of reference to guide the unit; (b) the appointment of a Commanding Officer; (c) the securing of adequate accommodation for staff, equipment and storage; and (d) the recruitment of permanent technical staff rather than short-term National Servicemen.[31]



No known photograph of Colonel Levis is available; however, his distinctive signature (above) appears on much correspondence about 1 Malaria Research Laboratory during 1966-1967.

Levis also drafted a set of four terms of reference for 1MRL. First among these was 'the evaluation of alternative drugs which may be suitable for the treatment or suppression of malaria in human subjects'. Second was 'the investigation and classification of strains of malaria which are resistant or suspected of being resistant to known anti-malaria drugs'. Third was to conduct such evaluations and investigations using 'human volunteers who had been infected with mosquito-transmitted malaria under controlled laboratory and hospital conditions'. Fourth, 'the mosquitoes to be used should include the known or suspected vectors from those areas of South-East Asia where resistance of the malaria parasite to known anti-malarial drugs has been proven or is suspected'.[32]

After receiving Levis's report, Clyne sent Black a long memorandum setting out the terms of reference for 1MRL that Levis had drafted. The memorandum also adopted the three-stage development of the 1MRL role that Black had proposed earlier. It then went on to ask Black a series of pointed questions about the relationship of 1MRL to the School of Public Health and Tropical Medicine. For example, Clyne wished to be advised what separate laboratory space 1MRL would be granted. He told Black that such issues must be resolved swiftly.[33]

A struggling unit, 1967–1968

A year after its foundation, 1MRL was still struggling. This became obvious in a long memorandum that Galvin sent to Levis detailing the difficulties the unit was experiencing.[34] A particular difficulty was finance. 1MRL had no separate financial allocation or budget of its own. Instead, the unit drew whatever equipment and supplies it needed from Eastern Command medical stores base. Galvin opined that unless such issues were swiftly resolved, the unit would make little progress.[35] Evidently dissatisfied, in 1968 he transferred to another position away from 1MRL.[36]

Further difficulties centred on Professor Black. In the opinion of Colonel Levis, Black was spending too little time with 1MRL staff and giving them insufficient supervision. He often travelled overseas in connection with his WHO work, and while away was unavailable to either the 1MRL staff or the AMD. Levis believed that when Black was present he regarded 1MRL as a source of additional staff for his own research projects provided by the Army at no cost to his School.[37] Levis concluded that the best strategy for the AMD would be to place the unit 'in a state of suspended animation' — shut it down — for the time being, until such time as it could be co-located with one of the Army hospitals.[38] Black responded very defensively to such implied criticism, giving assurances that things would improve soon.[39]

Despite the difficulties, the 1MRL staff had begun a program of experimental work designed more to give them training in malaria research procedures than to yield any findings immediately applicable in the field in Vietnam. They were accordingly functioning at the Stage II level of Professor Black's scheme for development. The first of the four small-scale projects they pursued was the development of strains of the mouse malaria, *Plasmodium berghei*, that were resistant to the anti-malarial drugs Paludrine and Pyrimethamine. The experiments with mouse malaria yielded some useful results, demonstrating the potentiation of anti-malarial activity by the drugs Paludrine and Dapsone.[40]

Associate Professor Libby Kalucy BSc (Hons), MSc, Dip Ed, OAM. As Lieutenant Elizabeth Kalucy, she was 1 Malaria Research Laboratory's first entomologist. She had the distinction of publishing 1MRL's first scientific research paper.

Meanwhile, the work of the unit's entomologist, Lieutenant Elizabeth Kalucy, was progressing well. She had established a colony of a local species of anopheline mosquito, *Anopheles annulipes*.[41] Kalucy had the distinction of publishing 1MRL's very first research paper, which had the title 'Transmission of *Plasmodium berghei* by *Anopheles annulipes Walker*'. Not only that, but the paper appeared in the very prestigious British journal, *Nature*. The mouse malaria transmission model developed by Kalucy was still being used almost half a century later by 1MRL's successor, the AAMI.[42]

During May and June 1968 a team of 1MRL staff undertook mosquito surveys in Papua New Guinea

around the Igam Barracks of the Pacific Islands Regiment near Lae and also around the Moem Barracks near Wewak. The team also undertook blood analysis in two Markham Valley villages inland from Lae.[43].

A female Anopheles annulipes *mosquito taking a blood meal. The species, widely distributed in Australia, was used in establishing 1MRL's first mosquito colony. This particular female has become so engorged with blood she has begun exuding globules of blood from her anus. (Photograph by Richard C. Russell, Department of Medical Entomology, University of Sydney.)*

In the months following the surveys in Papua New Guinea 1MRL lost both its officers. Captain Galvin, perhaps tiring of the Laboratory's slow progress, sought a transfer away from the unit. (He is thought to have undertaken medical training later and to have entered General Practice in Perth.) Lieutenant Kalucy resigned in 1969. (She entered secondary teaching but eventually specialised in community health, a field in which she published widely. At her retirement in 2010, she was an Associate Professor at Flinders University, South Australia.) For a time, it seemed that Kalucy's colony of *An. annulipes* mosquitoes might not survive; however, Captain Tony Sweeney, the entomologist who succeeded her, took it over, which in turn enabled the experimentation with *P. berghei* to continue.[44]

Major General Colin Gurner, the Army's Director General of Medical Services 1967–1975

At this point the reader needs to appreciate something of the background of Major General Gurner, who succeeded Major General Clyne as DGMS in 1967. It was during Gurner's eight years as DGMS that 1MRL came closest to being shut down and then at last secured its own survival by succeeding in demonstrating its usefulness to the Army.

Major General Colin M. Gurner, about 1975 (photograph from Australian Radiology, *2007).*

Colin Marshall Gurner was born in Adelaide, South Australia, on 26 December 1919. His father, also called Colin, was a radiologist. Both Colin Gurners, father and son, enlisted in the AAMC during World War II.[45] Gurner Snr. had joined the AAMC as a temporary captain in June 1918, five months before the end of World War I, while he was a fifth year medical student. He served with the Corps for the next year, spending all that time at the Keswick Barracks in Adelaide. He re-enlisted in August 1939 three days before World War II broke out, again as a captain. During 1940 and 1941 he served with the 2/1st, 2/2nd, 2/3rd and 2/9th Australian General Hospitals (AGH) in the Middle East. After returning to Adelaide in March 1942 he was promoted to major. He then spent the rest of the war as a specialist radiologist in a series of Army hospitals within Australia, including 2/9 AGH, 101 AGH, 105 AGH and 121 AGH.

Colin Gurner Jnr. received his schooling at Prince Alfred College in Adelaide. He then studied medicine at the University of Adelaide. While still a medical student, in 1939 he joined the part-time Army, the CMF. A keen sportsman, he played district cricket in Adelaide and was awarded blues in both cricket and football while at university. He enlisted in the AAMC as soon as he could after his graduation. He joined as a captain in December 1942. He subsequently served in various Army hospitals in both Australia and Papua New Guinea, including the 101 AGH at the same time as his father. At his discharge in September 1946 he was a captain attached to the 2/2nd Field Ambulance.

After his discharge in 1946, Gurner Jnr. trained as a radiologist at the Royal Adelaide Hospital. He gained his Membership in the Royal Australasian College of Physicians in 1950. He then studied radiation

therapy at the Memorial Sloan-Kettering Cancer Centre in New York, where he gained a Diploma in Radiation Therapy. On his return to Adelaide he became a junior partner in his father's radiological practice on North Terrace. He also held honorary appointments at the Royal Adelaide Hospital and the Adelaide Children's Hospital.

Gurner rejoined the CMF in 1948. He continued as a part-time CMF medical officer for the next 12 years. In that time he commanded two CMF medical units and was promoted to colonel. He returned to full-time Army service in 1960, when he accepted an offer to become the Deputy DGMS in the Regular Army. He was promoted to brigadier in 1961 and to Major General in 1967 when appointed DGMS, succeeding Major General Clyne in the position. He remained DGMS for the next eight years, 1967–1975. (In 1974 the position was renamed 'Director General of Army Health Services.)

Among other achievements as DGMS, in 1968 Gurner relocated the Army Medical Directorate from Melbourne (where it had been based for the past 66 years) to Canberra to give the AMD greater access to Defence headquarters and the Minister for the Army. His main contribution to the AMD was to shepherd the Army Medical Services through the Vietnam War — the Army's largest and longest overseas military involvement since World War II. A notable accomplishment here was to solve the perennial problem of providing medical officers for such conflicts by recruiting specialists to undertake three-month tours of duty in Vietnam.

Although Gurner was not a malariologist, as DGMS he was obliged to acquire an extensive knowledge of tropical medicine generally and malaria in particular. His time as both DDGMS and DGMS extended through the last three years of Australia's commitment to the Malayan Emergency and then across the entire period of Indonesia's Confrontation of Malaysia and the Vietnam War. As a result of this experience, malaria control became one of his principal medical interests.

Gurner worked closely with the Army's adviser on malaria, Professor Black, and was the DDGMS at the time when the new 1 Malaria Research Laboratory was established within Black's department at the University of Sydney in 1967. Gurner was in frequent contact with 1MRL in its early years to ensure that it developed into the kind of organisation that would be of maximal value to the Army.

During the successive outbreaks of drug-resistant malaria in Vietnam in the late 1960s, Gurner monitored closely his medical officers' efforts to contain the disease. At times this led to disputes with the RAAMC officers in Vietnam, but it was always he as DGMS who bore ultimate responsibility when Australian soldiers suffered and died from the disease. In a time of widespread public opposition to the war, high malaria casualty rates were a politically sensitive issue for the Australian government; and so it was from Gurner that successive government ministers in the Defence portfolios sought advice.

As DGMS, Gurner was responsible for the establishment in 1969 of the Army Malaria Advisory Board, which oversaw the activities of 1MRL and its institutional successors. In 1970 the Board decided that 1MRL should be renamed, becoming the 1st Malaria Research Unit (1MRU). Gurner also appointed the first of 1MRU's successive Directors, Dr A.P. Ray, an eminent Indian malariologist who held the position 1973–1977. By the time of Gurner's retirement in 1975, 1MRU was well established. It was working purposefully and productively in purpose-built premises at the Ingleburn Army Camp near Campbelltown south of Sydney. The unit had moved from Sydney University to Ingleburn in December 1973.

After his retirement from the Army, Gurner retained his medical-administrative interests. He served terms as President of the Royal Australasian College of Radiologists, as the Joint [Military] Services Medical Adviser, the inaugural Commissioner of the St John Ambulance Brigade in the Australian Capital Territory (ACT), the Chairman of the ACT Medical Board and the Medical Director of the Australian Kidney Foundation. His many honours and awards included Fellowships in the Royal Australasian Colleges of Physicians, Radiologists, Surgeons and Medical Administrators and the [British] Royal College of Radiologists. He was awarded the CBE in 1969 and the AO in 1978.

Late in life Gurner emerged as a military-medical historian. He returned to university in his 70s and gained a Diploma in Journalism. In 2003 he published *The Royal Australian Army Medical Corps 1945–1975*, a short history of the Corps in the post-World War II era.[46] Of necessity, the book dealt at length with the RAAMC medical officers' struggle against malaria in Vietnam.

Colin Gurner married Cynthia Miller, a physiotherapist, in 1943. They lived in Melbourne during the last 20 years of his life. After his death there at the age of 86, he was survived by Cynthia, three of their four children and their grandchildren.

Army dissatisfaction with 1 Malaria Research Laboratory, 1968–1969

In the period two and three years after the establishment of 1MRL, i.e. during 1968–1969, the Army Medical Directorate was growing increasingly frustrated with the unit's failure to make progress beyond its early training phases. Following the Army's worst malaria epidemic since World War II, which had erupted among Australian troops in Vietnam during the second half of 1968, the Adjutant General, Major General Charles E. Long, was pressuring the DGMS, Gurner, for solutions. 'Recent events in South Vietnam have shown us to be extremely vulnerable to the ravages of malaria,' Long wrote. He then observed that 'our research effort at the moment is meagre, ineffective and totally inadequate'.[47] Abashed, Gurner could only agree with the Adjutant General that 'our research effort is negligible'.[48]

The AMD's exasperation with Professor Black and 1MRL is plain in the Directorate's correspondence files during this period. One brief note from the DDGMS, Colonel Hanway, to Gurner at the end of 1968 expresses the prevailing mood nicely. The problem with 1MRL, Hanway wrote, was 'the need for a Director with ability and qualifications if the Lab is going to do anything useful — which it is not doing at the moment'.[49] Hanway then suggested that 'as long as [1MRL] remains a hanger-on in the School [of Public Health and Tropical Medicine] at Sydney it will continue to operate on an *ex tempore* program of projects some of which are of no value to the Army who is footing the bill'.[50] In other words, Black's dominating influence over 1MRL was impeding the unit; the Army was gaining little from its investment in 1MRL; and so the unit should be removed from Black's *de facto* control.

1MRL's chances of survival were about to improve, however. During 1969 the unit succeeded in recruiting its first medically trained staff member. This was Dr Ian Saint-Yves, a Scottish specialist in tropical diseases currently working in Papua New Guinea. Professor Black persuaded him to join the 1MRL staff. He accordingly moved to Sydney, joined the Australian Army and was commissioned as a major. Posted to 1MRL, he filled the vacant position of Commanding Officer, hoping that as the unit developed further and acquired hospital facilities he might be appointed Director.[51]

1 Malaria Research Laboratory staff, January 1970. Left to right are Captain A.W. (Tony) Sweeney, Major Ian F.M. Saint-Yves, Corporal N. Tinney, Corporal R. Green and Corporal C. Gulley (Australian Army Malaria Institute photograph).

Although that did not happen, and Saint-Yves departed in frustration, his appointment had been a critical turning point in the unit's fortunes. He had spent the four years 1969–1973 developing 1MRL to the point where it could be detached from the School of Public Health and Tropical Medicine and relocated on the campus of a major Army barracks. The campus chosen for this move was the Ingleburn Military Camp, where the unit was housed in the grounds of the 2nd Military Hospital.

Changes of name and improving prospects for survival

A sign that the tide of events had turned in favour of 1MRL was a change of name, the first of three. In 1970 1MRL became the 1st Malaria Research Unit (1MRU), a name retained for the next 11 years. Renamed again in 1981, when it became the Army Malaria Research Unit (AMRU), the unit remained at Ingleburn for the next 16 years. In 1997 it became the AAMI and relocated to the Gallipoli Barracks at Enoggera, Brisbane.

The post-1970 history of 1MRU–AMRU–AAMI is beyond the scope of this article. That history has already been related in detail in a series of seven articles in this journal by Professor Karl Rieckmann and his AAMI colleagues between April 2012 and January 2016. The collected articles were published in a single volume later in 2016 to commemorate the AAMI's 50th anniversary.[52]

Conclusion

This article began with two sayings. The author hopes that he has demonstrated that *'necessity was the mother of invention'* in the case of 1MRL's

establishment. He also trusts that in view of the mini-saga of military-medical politics recounted in the article, readers might appreciate the point that the survival of 1MRL to become the 1st Malaria Research Unit and eventually the Australian Army Malaria Institute was indeed *'a near run thing'*.

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Abbreviations

1MRL	1 Malaria Research Laboratory
1MRU	1st Malaria Research Unit
2RAR	2nd Battalion, Royal Australian Regiment
AAMC	Australian Army Medical Corps (prefixed 'Royal' from 1948)
AAMI	Australian Army Malaria Institute
ADGMS	Assistant Director General of [Army] Medical Services
AGH	Australian General Hospital
AIF	Australian Imperial Force
AMD	Army Medical Directorate
AO	Officer of the Order of Australia
AWM	Australian War Memorial
CBE	Commander of the Order of the British Empire
CMF	Citizen Military Force
CO	Commanding Officer
DADGMS	Deputy Assistant Director General of [Army] Medical Services
DDGMS	Deputy Director General of [Army] Medical Services
DDMS	Deputy Director of Medical Services
DGAHS	Director General of Army Health Services
DGMS	Director General of [Army] Medical Services
DPA	Director of Personnel Administration [Australian Army]
DSD	Directorate of Staff Duties [Australian Army]
FRACP	Fellow of the Royal Australasian College of Physicians
FRACS	Fellow of the Royal Australasian College of Surgeons
FRS	Fellow of the Royal Society

HQ	Headquarters
KBE	Knight of the Most Excellent Order of the British Empire
LHQMRU	Land Headquarters Medical Research Unit
MB BS	Bachelor of Medicine and Bachelor of Surgery
MC	Military Cross
MD	Doctor of Medicine
MRL	Malaria Research Laboratory
OBE	Officer of the Order of the British Empire
RAAMC	Royal Australian Army Medical Corps
RAMC	[British] Royal Army Medical Corps
RAR	Royal Australian Regiment
RMO	Regimental Medical Officer
US	United States [of America].

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3 Until after the end of World War II, Australia controlled Papua and New Guinea as separately administered territories. In 1946 they were administratively combined as the 'Territory of Papua and New Guinea'. That name was retained until the granting of self-government in 1973, when the present name Papua New Guinea was adopted. This name has continued since the nation achieved independence in 1975. For convenience, this article uses the present name.

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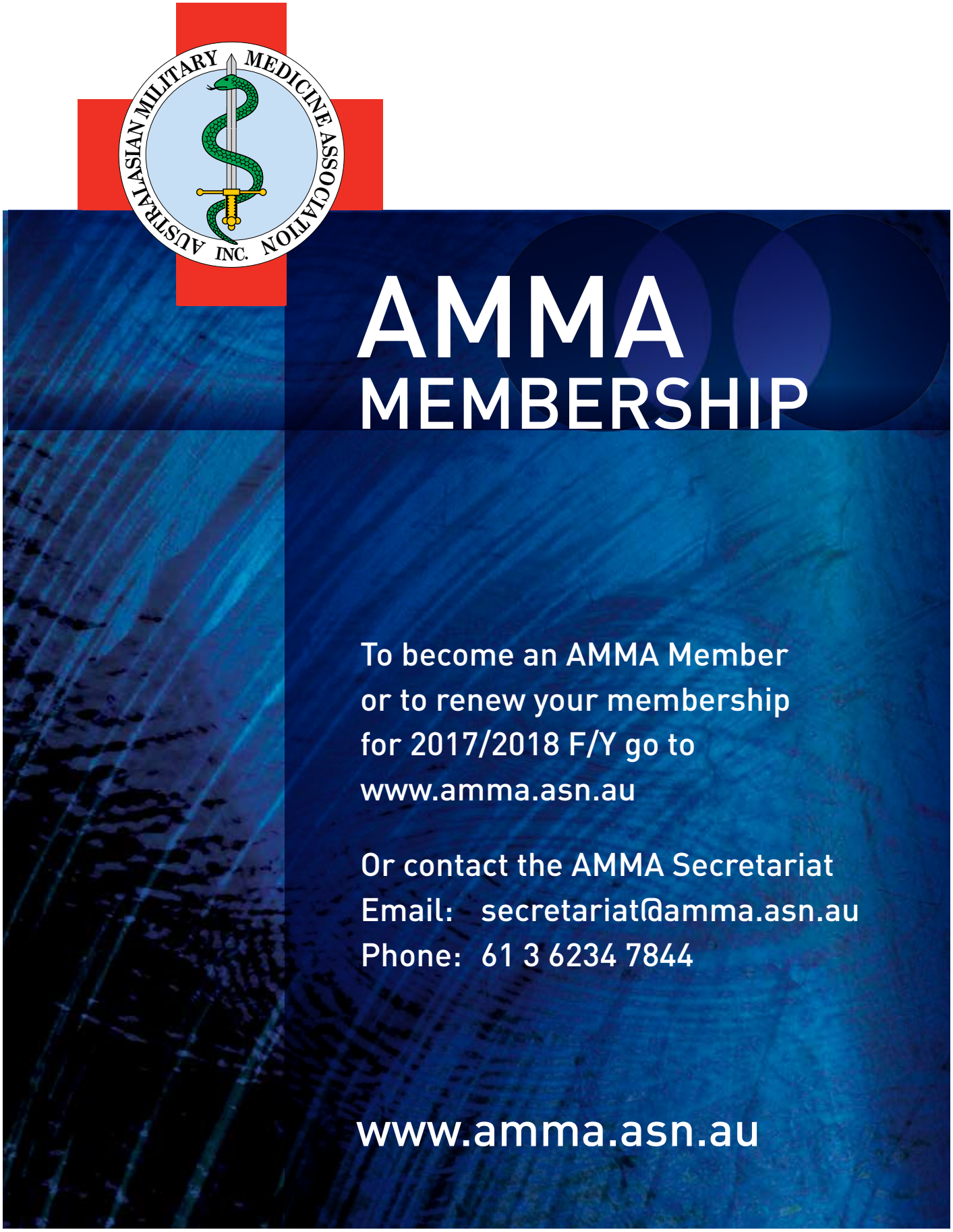
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