The cardiometabolic and physiological health of Australian paramedics

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Abstract

Background: Shift work and a career in paramedicine can be risk factors for poor health, and the reasons for this are likely to be complex and multifactorial. Little is known about how elements of health such as diet, physical activity, and the physical demands of work may collectively influence paramedic health status. Additionally, it is unknown when in a paramedic's career poor health may manifest. The studies in this thesis describe a multidisciplinary approach to research that is designed to further understand cardiometabolic and physiological health in paramedics.

Methods: This thesis includes seven peer-reviewed publications that investigate the physiological and cardiometabolic health of paramedics. The first study was a longitudinal study that sought to identify changes in cardiometabolic health, diet, aerobic capacity, physical activity, and health-related quality of life (HRQoL) in graduate ambulance paramedics (GAPs) during the first 12-months of their career. The subsequent cross-sectional study measured the same elements in a sample of experienced intensive care flight paramedics (ICFPs) working for a Helicopter Emergency Medical Service (HEMS). Finally, to examine the relationship between their physically demanding job and cardiometabolic and physiological health status, the final three studies utilised qualitative consensus and quasi-experimental study designs to quantify the physiological demands of rescue tasks that are a critical component of ICFP practice.

Results: In the first 12 months of GAP practice, there were minimal changes in diet, cardiometabolic health, and physical activity. However, baseline body mass index, some aspects of diet and levels of physical activity could be improved upon. For the ICFPs, cardiometabolic health profile was very good, despite extended careers in paramedicine. Additionally, aerobic capacity was high and physical activity levels significantly exceeded international recommendations. For the analysis of the physical demands of the ICFP role, land and water winch rescue were identified as the most physically demanding work tasks. The tasks invoked high physiological workload (≥ 80-85% of maximum capacity) and were required to be undertaken for extended periods of time.

Conclusions: This thesis investigated the cardiometabolic and physiological health of Australian paramedics. In graduate paramedics with no prior exposure to shift work, dietary patterns, HRQoL, cardiometabolic health, aerobic capacity and physical activity levels did not change substantially in the first year of practice. However, baseline BMI, physical activity levels and some dietary behaviours were suboptimal. Conversely, despite extended exposure to shift work and contrary to data reported from the wider paramedic workforce, ICFPs demonstrated good dietary health, good cardiometabolic health, excellent HRQoL and aerobic capacity, and high levels of physical activity. ICFPs have a very physically demanding job which may contribute to their positive health profile.

The findings of this research highlight potential concerns for paramedics as early as the first year of clinical practice, and long-term follow up is required to detect significant health changes. The research also identifies that demanding work tasks may influence health status. Subsequent research is required to further understand why ICFPs have better health status despite extended careers in paramedicine.

Thesis including published works declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes seven original manuscripts published in peer reviewed journals. The core theme of the thesis is the cardiometabolic and physiological health of paramedics. The ideas, development and writing up of all the manuscripts in the thesis were the principal responsibility of me, the candidate, working within the Department of Paramedicine under the supervision of Associate Professor Kelly-Ann Bowles.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research. In the case of Chapters 2, 3, 4, 5, 6, 7 and 8, my contribution to the work involved the following:

Thesis Chapter	Publication title	Publication Status	Nature and extent of Candidate's contribution	Co-author names & % contribution	Co-author(s), Monash Student
2	The health and wellbeing of paramedics – a professional priority	Published	65%. Principal author responsible for the concept, design, literature review and writing of the manuscript	Joanne Caldwell, 5% Luke Perraton, 5% Maxine Bonham, 5% Alex Wolkow, 5% Karen Smith, 5% Brett Williams, 5% Kelly-Ann Bowles, 5%	No
3	Cardiometabolic, dietary and physical health in graduate paramedics during the first 12-months of practice – a longitudinal study	Published	70%. Principal author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing of the manuscript	Luke Perraton, 5% Maxine Bonham, 10% Alex Wolkow, 5% Karen Smith, 5% Kelly-Ann Bowles, 5%	No
4	Assessment of cardiometabolic health, diet and physical activity in helicopter rescue paramedics	Published	75%. Principal author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing of the manuscript	Luke Perraton, 5% Maxine Bonham, 10% Karen Smith, 5% Kelly-Ann Bowles, 5%	No

Thesis Chapter	Publication title	Publication Status	Nature and extent of Candidate's contribution	Co-author names & % contribution	Co-author(s), Monash Student
5	Physiological response in a specialist paramedic during helicopter winch rescue in remote wilderness and extreme heat	Published	80%. Principal author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing of the manuscript	Ella Horton, 5% Luke Perraton, 5% Karen Smith, 5% Kelly-Ann Bowles, 5%	Yes. 5% (Ella Horton)
6	Defining the characteristics of physically demanding winch rescue in helicopter search and rescue operations	Published	75%. Principal author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing of the manuscript	Luke Perraton, 5% Karen Smith, 5% Kelly-Ann Bowles, 5% Joanne Caldwell, 10%	No
7	Comparison of swimming versus running maximal aerobic capacity in helicopter rescue paramedics	Published	65%. Principal author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing of the manuscript	Ella Horton, 5% David Pyne, 5% Luke Perraton, 5% Karen Smith, 5% Kelly-Ann Bowles, 5% Joanne Caldwell, 10%	Yes. 5% (Ella Horton)

Thesis Chapter	Publication title	Publication Status	Nature and extent of Candidate's contribution	Co-author names & % contribution	Co-author(s), Monash Student
8	The physiological demands of helicopter winch rescue in water and over land	Published	70%. Principal author responsible for the concept, design, data collection, statistical analysis, interpretation of results and writing of the manuscript	Ella Horton, 5% Luke Perraton, 5% Karen Smith, 5% Kelly-Ann Bowles, 5% Joanne Caldwell, 10%	Yes. 5% (Ella Horton)

To generate a consistent presentation within the thesis, I have not renumbered sections of published papers.

Student signature: [redacted] Date: 29-10-2021

The undersigned hereby certify that the above declaration correctly reflects the nature and extent of the student and co-authors' contributions to this work.

Primary Supervisor signature: [redacted] Date: 29-10-2021

Publications and awards

Publications related to this thesis

Meadley B, Caldwell J, Perraton L, Bonham M, Wolkow AP, Smith K, Williams B, Bowles KA. The Health and Well-Being of Paramedics-A Professional Priority. Occupational Medicine. 2020;70(3):149-51.

Meadley B, Perraton L, Smith K, Bonham MP, Bowles KA. Assessment of cardiometabolic health, diet and physical activity in helicopter rescue paramedics. Prehospital Emergency Care. 2021; Mar 23:1-11.

Meadley B, Horton E, Pyne DB, Perraton L, Smith K, Bowles KA, Caldwell J. Comparison of swimming versus running maximal aerobic capacity in helicopter rescue paramedics. Ergonomics. 2021; Apr 6:1-12.

Meadley B, Bowles KA, Smith K, Perraton L, Caldwell J. Defining the characteristics of physically demanding winch rescue in helicopter search and rescue operations. Applied Ergonomics. 2021; May 1: 93:103375.

Meadley B, Wolkow AP, Smith K, Perraton L, Bowles KA, Bonham MP. Cardiometabolic, dietary and physical health in graduate paramedics during the first 12-months of practice-a longitudinal study. Prehospital Emergency Care. 2021; Jul 7:1-13.

Meadley B, Horton E, Perraton L, Smith K, Bowles KA. Physiological response in a specialist paramedic during helicopter winch rescue in remote wilderness and extreme heat. Journal of Special Operations Medicine. 2021;21(3):41-44.

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Other publications during candidature not related to this thesis:

Heschl S, **Meadley B**, Andrew E, Butt W, Bernard S, Smith K. Efficacy of pre-hospital rapid sequence intubation in paediatric traumatic brain injury: A 9-year observational study. Injury. 2018;49(5):916-20.

Delorenzo A, **Meadley B**. Point-of-care ultrasound use in the pre-hospital setting. Journal of Paramedic Practice. 2018;10(8):326-32.

Beck B, Smith K, Mercier E, Bernard S, Jones C, **Meadley B**, St Clair T, Jennings PA, Nehme Z, Burke M, Bassed R. Potentially preventable trauma deaths: a retrospective review. Injury. 2019;50(5):1009-16.

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Awards during candidature

2019: Appointed as a Fellow of the Australasian College of Paramedicine (ACP)

2020: Three Minute Thesis (3MT) People's Choice Award: School of Primary and Allied Health Care

Presentations during candidature

"Assessing the physiological demands of helicopter search and rescue operations."

Australian Strength and Conditioning Association International Conference

Online, November 2020

"A standardised protocol for monitoring cardiovascular and physical health in paramedics."

ACPIC2020 – Australasian College of Paramedicine International Conference

Online, October 2020

"Determining critical tasks during performance of helicopter winch rescue."

International Congress on Soldier's Physical Performance

Quebec City, Canada, February 2020

"A novel assessment for swimming aerobic capacity in physically active helicopter rescue paramedics."

International Congress on Soldier's Physical Performance

Quebec City, Canada, February 2020

"Paramedic Health and Wellbeing: a professional priority."

ANZCP National Conference

Melbourne, August 2019

"Paramedic-led prehospital ultrasonography."

EMUGS National Conference, Noosa, June 2019

"Physical Employment Standards in Helicopter Search and Rescue."

Aeromed 2018, Hobart, September 2018

"Paramedic Health and Wellbeing."

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Melbourne, September 2018

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SonoAus 2018

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COVID-19 Preamble

The COVID-19 pandemic has had a significant impact on individuals' lives. Academia and research have not been exempt from this virus, and for some, this period of time has affected the progress and outputs of their research program. Candidates within the School of Primary and Allied Health Care may have experienced impacts on their research progress and outputs from:

- Closure of research laboratories limiting the collection of complete data sets;
- Requirements to work (or prepare to work) in a surge health workforce limiting time to commit to studies;
- Health services ceasing or limiting research not related to COVID-19;
- Additional parental responsibilities as school closures resulted in remote learning for dependent children;
- Closure of child care centres and restrictions on child care arrangements;
- Travel restrictions (both overseas and locally) affecting research progress;
- Additional responsibilities as academic teaching was restructured to an online model;
- Financial restraints to funding research costs;
- Closure of on-campus offices for staff and students
- Effect of repeated lockdowns and social isolation on mental health; and,
- Any of the above issues affecting access to timely feedback from or engagement with supervisors.

Monash University and the School of Primary and Allied Health Care has implemented a range of measures to support candidates through this period, however there are issues beyond the candidate's or University's control. We do ask that when reviewing this thesis, you remain mindful of the challenges our candidatures have faced and assess their work relative to the time in which they are studying. On the following page there is a paragraph (limited to 300 words) prepared by the student to explain the direct effect of COVID-19 on their studies and the preparation of their thesis.

Yours thankfully.

A/Prof Kelly-Ann Bowles

Professor Terry Haines

[redacted]

Director of Research

Primary and Allied Health Care

Head of School

Primary and Allied Health Care

v1 August 2021

The COVID-19 pandemic and the impact on this research

For the vast majority of 2020 and 2021, the residents of Victoria, Australia underwent a series of lockdowns to prevent the spread of coronavirus. These lockdowns had a significant impact on the research projects undertaken to fulfil the requirements of this thesis, including but not limited to:

- The closure of the primary laboratory where physiological testing was performed, thus limiting the collection of follow-up data for the study described in Chapter Three.
- This closure of the laboratory considerably changed the design of the study described in Chapter Four. Twelve-month follow-up of all participants was originally planned, but this was unable to occur, requiring significant re-analysis and study design amendments.
- Several invited presentations of research outcomes at international conferences were cancelled, including the European Rescue Swimmers Association Scientific Conference (Cascais, Portugal, May 2020), College of Paramedics United Kingdom Conference (Bristol, United Kingdom, September 2020), and the Aeromedical Society of Australasia Scientific Meeting (Auckland, New Zealand, August 2020).
- Significant strain was incurred due to the requirement to work predominantly full-time as an operational paramedic when Victoria was seeing hundreds of cases per day of coronavirus, as well as assisting two children with ongoing education whilst schools were closed. Assisting with home learning was required for the vast majority of the last 18 months of the PhD candidature.

Abbreviations

AES	Australian Eating Survey
ALS	Advanced Life Support
ARFS	Australian Recommended Food Score
AV	Ambulance Victoria
BMI	Body Mass Index
EMS	Emergency Medical Services
FFQ	Food Frequency Questionnaire
GAP	Graduate Ambulance Paramedic
HRQoL	Health-related Quality of Life
HOMA IR	Homeostatic Model Assessment for Insulin Resistance
HEMS	Helicopter Emergency Medical Service
ICFP	Intensive Care Flight Paramedic
MAWD	Maximal Acceptable Work Duration
MICA	Mobile Intensive Care Ambulance
MVPA	Moderate to Vigorous Physical Activity
PES	Physical Employment Standards
RPE	Rating of Perceived Exertion
VO_2	Oxygen consumption

“Who is happy?
Those who have a healthy body, a resourceful mind and a docile nature.”

Adapted from the philosophy of:

Thales of Miletus

Chapter One: Introduction

1.1 Background and rationale

1.1.1 Author's perspective

After completing a Bachelor's degree in Human Movement, with a focus on exercise physiology, I considered a research career in elite sport. However, paramedicine came onto my radar during my final year of undergraduate studies, and I instead pursued a career as a paramedic. This resulted in working as a volunteer ambulance officer in rural Victoria for about a year, followed by a move to Sydney from my home in Melbourne, where I completed four years as a paramedic with New South Wales Ambulance. During my final year in Sydney, I completed a Graduate Diploma in Intensive Care Paramedicine, before taking up employment with Ambulance Victoria (AV). After returning to my home state, I briefly worked as a general duties paramedic and shortly thereafter commenced training as a Mobile Intensive Care Ambulance (MICA) Paramedic. After four years of clinical work, clinical mentoring, and management roles as a MICA Paramedic, I applied to become a MICA Flight Paramedic, ultimately being successful and joining a team comprising just one percent of the paramedic population at AV. I continue to work in that role some 13 years later, accumulating more than 23 years in the profession.

Whilst undertaking these roles, I have been fortunate enough to be involved a range of projects to advance the profession, including as a member of the AV Clinical Practice Guidelines Committee for four years as the MICA Flight Paramedic representative, becoming a Fellow of the Australasian College of Paramedicine, and travelling across Australia, New Zealand, the United States, Canada, and the United Kingdom to observe ambulance service delivery. Additionally, throughout my clinical career, I have taught into the undergraduate and postgraduate paramedicine programs at Monash University.

Aligned with my academic and clinical roles has been exposure to several research projects. However, my involvement was mostly superficial. I conducted projects investigating the use of alternative medications for the management of clinically significant bradycardia, the use of invasive blood pressure monitoring in critical care paramedicine, and the use of point of care ultrasound to name a few.

In time, I had a growing desire to explore research more, but I couldn't really find a project that I was passionate about. Then after meeting my primary supervisor Associate Professor Kelly-Ann Bowles, it clicked. As Kelly also has a sports science background, we discussed how we might combine my love for paramedicine with my long-standing interest in health and human performance. Thus, this project was born, and it has led to an incredibly satisfying collaboration with researchers from physiotherapy, sports science, physiology, nutrition, and sleep science.

Of note, it is important to disclose that all the participants in the helicopter paramedic cohort of the studies described in this thesis are colleagues and some are close friends. Additionally, the single participant study described in Chapter 5 involves me as the subject, where objective data was captured. Further, the data was not captured with the intention for publication, and this was only decided in retrospect as a result of interest from the journal. When the entire population of the group you are researching is ~45 staff, working in extreme conditions and undertaking shift work across disparate geographical locations, data capture can be challenging to say the least. Whilst my relationship with participants may be considered a conflict and a source of bias, it is imperative to note that I consider ethical research and data integrity to be of the utmost importance. Hence, all data generated from the work detailed in this thesis has undergone independent analysis to ensure research integrity is maintained and ethical conduct is beyond reproach. The collaborations with experts in the field has ensured that all studies underwent extreme scrutiny, further evidenced by peer review and publication in high standard journals.

1.1.2 Why is it important to study the physiological and cardiometabolic health of paramedics?

Paramedics are registered health professionals in numerous jurisdictions including Australasia (1, 2). The profession has an established clinical research profile and has demonstrated that evidence-based practice can contribute to improved patient outcomes in the out of hospital environment. Several significant research projects led by paramedics and ambulance service research teams have changed clinical practice across the health care landscape, and these include the use of anaesthesia to manage brain injured patients and withholding of oxygen in some patients suffering myocardial infarction (3-6). A strong research presence is vital for academic paramedicine, ambulance services and other organisations employing paramedics.

Research in paramedicine should extend beyond patient care and include research into the paramedics themselves. There are concerns regarding several key health outcomes in paramedics (7, 8). Whilst research in paramedicine has historically and appropriately focused on the delivery of improved clinical care, comparably little work has been undertaken to date to assess and enhance the health and wellbeing of paramedics. To ensure paramedics can establish and maintain good health from the beginning to the end of their career whilst continuing to provide excellent patient care, a new research paradigm is required to focus on optimising the health and wellbeing of paramedics. Dedicated and targeted research such as longitudinal studies into paramedic health outcomes and deeper analysis of the nature of paramedics' unique work environment may assist in identifying key areas that require attention. The findings may translate to evidence-based, effective workplace and lifestyle intervention programs, enabling employers of paramedics to meet their duty of care to provide a safe and healthy workplace, as well as informing paramedics of their own responsibilities.

Health concerns for paramedics

Negative effects on health and wellbeing can manifest if work is performed in opposition to circadian rhythms over extended periods of time. These negative effects have been highlighted in various professions where shift work is undertaken. In a review by Kuhn, the author describes the concept of *desynchronosis* in emergency physicians (i.e., circadian rhythm misalignment) and its negative impact on physiologic systems (9, 10). Another review by James et al. discusses the consequences of shift work and circadian misalignment that can result in a range of medical conditions including metabolic syndrome, Type II diabetes and cardiovascular disease (10). Further studies investigating the psychosocial and physiological consequences of shift work demonstrate that shift work may lead to impaired health-related quality of life (HRQoL), increased incidence of cardiovascular disease, weight gain, Type II diabetes, and poor mental health (11-13).

For paramedics specifically, shift work is necessary for the delivery of an emergency medical service (EMS). Recent work from AV shows that paramedic workload is constant, with rates of ambulance service utilisation high at all hours of the day and night (14). In an escalation of an already unprecedented strain on health systems, Lees et al. recently described how the rise of COVID-19 in the United Kingdom affected and exacerbated paramedic workload with resultant worsening health (15). Likewise, Andrew et al. showed a similar demand pressure in Australia during the ongoing pandemic (16). If we accept that high-demand shift work is and will be part of health care delivery for the foreseeable future, these persistent pressures on paramedics and the wider health care system highlight the need to promote and protect workforce health in this vulnerable population.

In addition to the strains and associated health consequences described above, several other mechanisms are proposed for long-term poor health in paramedics. These include paramedics working in unpredictable environments and undertaking complex clinical and manual handling tasks (17, 18), the physical demands of roles within paramedicine, (18, 19), chronic exposure to critically unwell and injured adults and children, inability to adapt to changing work schedules causing circadian rhythm misalignment, sleep disturbance, poor nutrition, limited physical activity and musculoskeletal injury (11, 12, 20, 21).

The incidence of metabolic, cardiovascular, and inflammatory diseases reported in those performing shift work for extended periods is concerning. Many of the aforementioned work-related factors are probable co-contributors to the high incidence of obesity, Type II diabetes, cardiometabolic and inflammatory diseases reported in long term shift workers (including paramedics). One meta-analysis of 28 observational studies of shift work showed a significant increase in risk of diabetes in shift workers when compared to day-only workers (11). Another systematic review and meta-analysis of 26 studies of shift workers demonstrated an association between shift work, and overweight and obesity (22). Further, UK Biobank data studying more than 70,000 night shift workers indicated rotating shift work (which is commonplace in paramedicine) was associated with higher Type II diabetes odds (21).

Similar findings have been reported in paramedics specifically. A study of North American paramedics revealed > 80% of paramedics were overweight or obese, > 80% had elevated blood pressure, and < 50% completed the minimum recommended amount of physical activity (21). In a study of 747 Australian paramedics, mean body mass index (BMI) was above the threshold for overweight and HRQoL was lower than the general population (23). In another study of 140 paramedics working in regional Australia, physical capacity was considered poor, and was worse for older staff in particular (24). Identifying and optimising health and wellbeing in paramedics requires attention to be paid to the central components of health, but it should also be noted that achieving this can be challenging in this population (8, 23). This may be, in part, due to the dynamic nature of their work environment. Nonetheless, it is vividly apparent that strategies to address poor paramedic health are a priority.

Whilst some areas of paramedic health and wellbeing such as post-traumatic stress disorder and mental illness have been well-studied (25-28), research into the other key areas of health such as diet, the incidence of cardiometabolic disease, levels of physical activity and the physically demanding nature of paramedic work is limited. Additionally, an area yet to be studied in depth is whether poor health in paramedics manifests at an accelerated rate when compared to non-shift working populations. It is timely and important to investigate the elements of whole-body health that can be targeted to minimise the health effects of a career in paramedicine, and this work should ideally align with the commencement of a paramedic's career to allow for longitudinal monitoring. This multifactorial concept of paramedic health and wellbeing is discussed below and is represented conceptually in Figure 1.1.

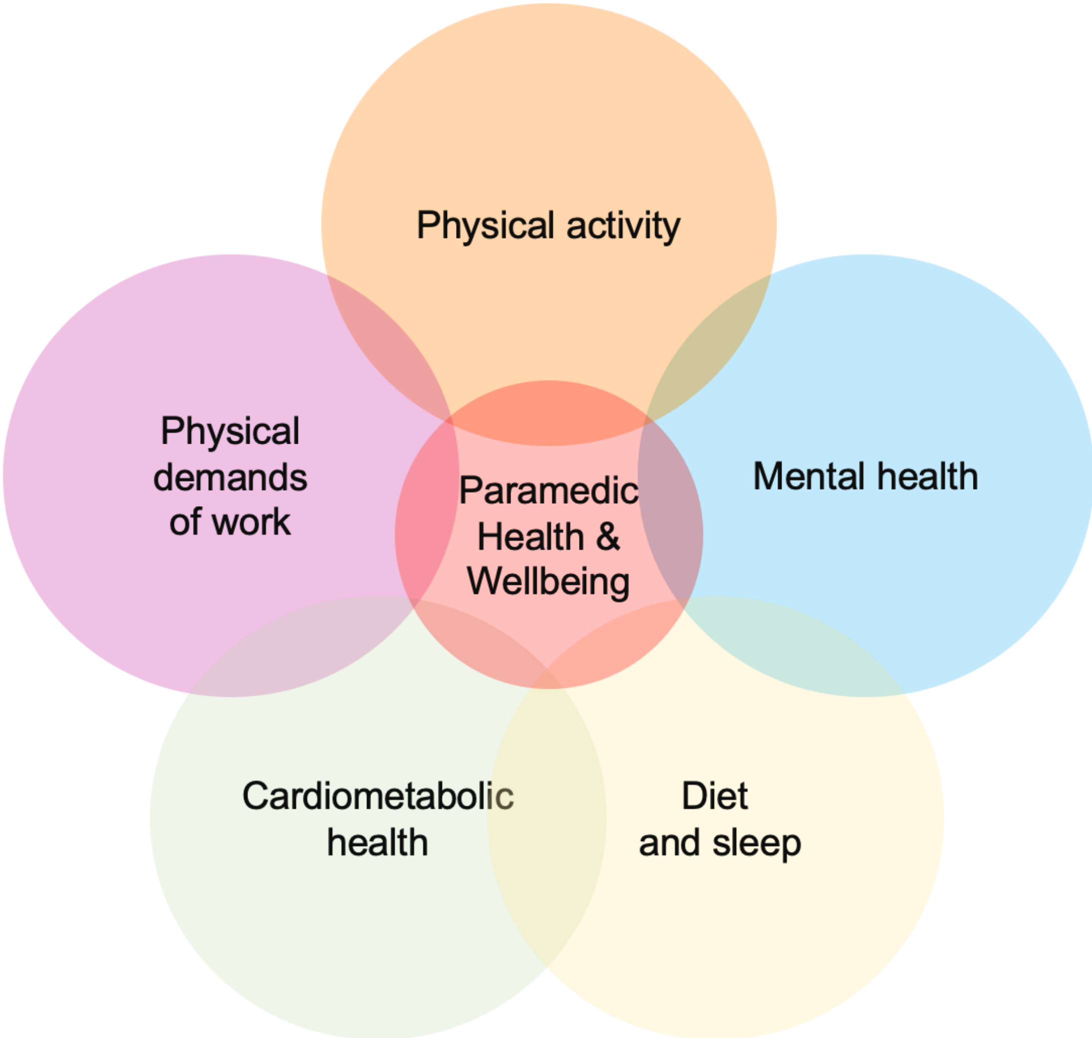


Figure 1.1 A multi-factorial approach to improving paramedic health and wellbeing. (Source: Original creation by author)

Diet

Diet is an important factor for the maintenance of good health. Combined with the previously mentioned physiological mechanisms, shift work may influence dietary behaviours and thus affect cardiometabolic health. In a study of 73 nurses, shift work was associated with variability in energy intake and positive associations with increased BMI and waist circumference (29). Another study demonstrated meal timing variability and higher energy intake was associated with high density lipoprotein (HDL) levels in shift working nurses. Additionally, a qualitative study of inexperienced and experienced shift-working nurses by Gifkins et al. revealed that shift work patterns negatively affected meal choice, meal timing and snacking, with experienced nurses actively employing strategies to mitigate these effects (30). Similar findings were seen in a mixed methods study of shift working firefighters, where shift schedule, sufficient time to access healthy foods, colleagues' food choices and poor knowledge of the link between diet and health were identified as influences on dietary intake (31). In other studies of shift workers, there is some indication that manipulation of meal timing (e.g., limited eating overnight) and altering macronutrient composition may have a role in reducing the excursions in plasma glucose and insulin that is seen in controlled simulated laboratory studies of those who eat late at night (32-34), but further work is required to determine if such strategies affect cardiometabolic health risk.

Specifically for paramedics, the high workload and unpredictable nature of emergencies alongside the mobile workplace means it can be difficult for personnel to plan for, prepare, and source nutritious meals. Paramedics in Australia and in other jurisdictions have reported several barriers to achieving a nutritious diet. In a study by Anstey et al., paramedics specified a reliance on take away foods and insufficient meal breaks as obstacles to healthy eating (35). In a qualitative study of paramedics in the United Kingdom, Kirby highlighted shift work as a barrier to healthy food choices, impacting paramedics' physical health and fatigue (36). Further, a study that reported dietary intake in 295 Canadian paramedics identified associations between unhealthy food choices and worse health status, including higher BMI, when compared to non-shift working participants from the general population (37).

However, these studies provide limited data regarding paramedic dietary intake, and further work is required using validated methods. Dietary intake can be assessed via methods such as dietary records (38), 24-hour dietary recall (39) or instruments such as food frequency questionnaires (FFQ) (40). Due to the mobile nature of the paramedic role and the wide geographical dispersion of the workforce, measuring dietary intake using a tool such as the validated Australian Eating Survey (AES) FFQ may be feasible (40) to allow researchers deeper insights into the dietary behaviours of paramedics. Currently, no studies using FFQ in Australian paramedics are reported, and their use could be explored further.

Cardiometabolic health

In isolation, dietary intake may provide a useful guide to health status. However, to build a complete profile of dietary health and alignment with overall cardiometabolic health, important biomarkers of health, body composition and anthropometric data can be combined (41, 42). Biomarkers of cardiometabolic health status that are routinely sampled in population health studies include: fasting insulin and glucose to determine the risk for or presence of insulin resistance and Type II diabetes (43); lipid profile for determination of risk for atherosclerotic disease (44); and high-sensitivity C-reactive protein (hsCRP) assay for assessment of chronic inflammation (45). A study in Czech paramedics revealed low high-density lipoprotein (HDL) and elevated low-density lipoprotein (LDL) cholesterol in experienced paramedics, indicating higher risk for cardiometabolic disease. In other work studying 452 North American paramedics with an overall poor cardiometabolic health profile, hyperlipidaemia was self-reported in 16.2% of participants (46), but formal measurement was not undertaken, and true proportions are not known. As a supplement to biomarker assessments of cardiometabolic health, the homeostatic model assessment of insulin resistance (HOMA-IR) is an established metric to estimate insulin resistance and is calculated from the fasting insulin and glucose values. Data from a large study investigating HOMA-IR cut off values suggest an association with metabolic syndrome (47), and insulin resistance using this metric has been reported in other health care workers completing shift work (48). Despite the value in these assessments to determine cardiometabolic health risk, there are limited data in paramedics (specifically regarding markers of inflammation, such as hsCRP), presenting an opportunity for further investigation.

Simple anthropometric assessments to indicate cardiometabolic health risk include body mass index (BMI) and waist to height ratio. Elevated BMI remains a strong predictor for cardiovascular disease (49). BMI is reported in several studies investigating paramedics including paramedics in Australia (23, 24, 50), North America (37, 46, 51) and Europe (52), where a significant proportion of paramedics exceed the threshold for overweight or obesity. For waist to height ratio, a threshold of ≥ 0.50 is a strong indicator for risk of cardiometabolic disease (53), but data specific to paramedics is generally limited to waist circumference only, except a study reporting high waist to height ratio in 20.6% of Polish Helicopter Emergency Medical Service (HEMS) workers (54). Additionally, the readily measured haemodynamic parameters of resting heart rate and blood pressure are well established to indicate risk for cardiovascular disease (55, 56), and these metrics are ubiquitous in most of the previously mentioned studies into paramedic health. The combination of diet, biomarker, anthropometric and haemodynamic metrics may be useful for identifying risk of disease in paramedics and may aid in developing strategies to improve their health.

Physical activity

In addition to diet and cardiometabolic health profile, physical activity has an established role in the prevention of a range of disease states. The positive effect that regular physical activity has on several health and wellbeing elements has been demonstrated in large cohort studies (57, 58). Improvements in cardiovascular or cardiometabolic health are associated with certain physical activity metrics, namely steps per day and minutes per day of moderate to vigorous physical activity (MVPA) (59). Recent updates to international physical activity guidelines consolidate the important role of frequent MVPA in improving and maintaining health (60). Previous work investigating physical activity levels in Australian paramedics indicates that shift work as a paramedic may impede access to regular vigorous, non-occupational physical activity (23), and that there are suboptimal amounts of steps per day completed, as well as significant variability in physical activity depending on the shift worked (61). Nonetheless, little research has been published regarding the consequences of paramedic work on access to regular exercise and resultant health outcomes, specifically over an extended timeframe.

To capture and analyse physical activity data, several methods are available. These include self-reporting physical activity via a retrospective survey such as the International Physical Activity Questionnaire (IPAQ) (62) and the use of actigraphy devices over short periods of time (63, 64). Whilst research-grade actigraphy devices are valid and reliable, data collection periods tend to be short, and do not account for the variation that may occur over an extended period. For example, Khan et al. reported paramedics undertook less than the recommended steps per day when assessed by actigraphy, but the data collection period was only eight days (61). More recent studies have demonstrated modern consumer-level wearable fitness trackers to be cost-effective, valid, and reliable (65-67). Physical activity monitoring using such devices has been conducted in other health professionals (68, 69). As opposed to short term analysis associated with actigraphy and the IPAQ, these devices can be synchronised to real-time monitoring databases to enable reliable tracking of study participants over extended periods (69-71). Thus, objective assessment of physical activity in paramedics and other shift workers over a prolonged timeframe is possible (to account for variance in shift and leave patterns and seasonal changes), and the use of such devices in other studies allows for comparison to other health professionals (68, 69). Coupled with metrics of dietary and cardiometabolic health, physical activity data may be useful to identify risks to health and assist in the development of programs to improve the wellbeing of paramedic personnel.

Health related quality of life (HRQoL)

HRQoL is a supplementary metric that may be useful in establishing overall health. Assessments of HRQoL rely upon participants self-reporting of health status, and they are used widely by researchers for routine monitoring and assessment of health outcomes. The surveys use a set of generic, coherent, and easily administered questions assessing quality of life measures (72) and are validated in health research (73-75). Several instruments are available, and examples include the 15-dimensional health related quality of life measure (15D), the EuroQol 5 dimensions questionnaire (EQ-5D) and the RAND 36-item Health Survey (SF-36).

HRQoL has been assessed in several paramedic health and wellbeing studies. For example, a study investigating the health and wellbeing of 747 Australian paramedics identified poor HRQoL in paramedics when compared to the general population (23), and these findings were replicated in a second study of 194 Australian paramedics reported significantly lower HRQoL compared to the general population (except for physical functioning) (50). Given its measurement in previous studies of paramedics, HRQoL serves as a valuable comparator, and a useful addition to the aforementioned metrics of cardiometabolic and physiological health status in order to assess overall paramedic health.

The physical demands of paramedicine

An additional factor that may influence paramedic health status, where a modest amount of work has been undertaken, is the physically demanding nature of their work. Emergency services personnel, including paramedics, can be exposed to physically demanding tasks in their roles. Intuitively, physically demanding work may be expected to improve overall health. However, the impact of physically demanding work in paramedicine on overall health status is unknown. Notably, several studies have revealed what is termed the occupational physical activity paradox, whereby job-related physical work does not confer the same health benefits as leisure time physical activity (76-78). Additionally, physically demanding work may contribute to an increased risk of injury (79), and as previously highlighted, long-term exposure to shift work and a career in paramedicine itself is associated with poor health (7, 8, 23), which may negate any benefits that may be derived from occupational physical activity. Whether the occupational physical activity paradox applies to paramedicine is undetermined.

Public safety organisations, including ambulance services and other employers of paramedics have developed minimum physical standards that are required to be met for attaining a position in a paramedic role, at least for initial employment. Foundation work by Fischer et al. has gone some way to establish formal physical employment standards (PES) for the Canadian paramedic workforce (18). However, the formal application of the PES methodology to quantify the physical demands of Australian paramedics' work, assess the relationship of physical work to health status, and develop non-arbitrary physical selection processes, is not reported.

Formal, scientifically developed PES are established to ensure that assessments match job tasks (79), however relatively few organisations have applied them. As an example, AV require graduates paramedics to undertake assessments of strength, power, flexibility and cardiovascular fitness as they commence their careers (80), but the process is not developed via the accepted methodology. Additionally in AV, a separate set of tests are used for other specialist roles such as helicopter rescue and wilderness response paramedics, which examine similar metrics, but in more detail and to higher minimum thresholds (Appendix A). Neither of these processes were developed by a scientific PES process, therefore they may be considered inaccurate or arbitrary, and the true physical nature of paramedic work in this service is not well understood. To accurately quantify the physically demanding work tasks in paramedicine and assess the relationship to overall health status, the established PES process provides the most accurate and reliable method of measurement. The benefits of undertaking a systematic PES process extended beyond determination of physiological workload. PES allow for performance standards to be compared against agreed benchmarks, and assurance that assessments correlate with the actual demands of job tasks, making standards legally defensible should a candidate challenge an outcome (81).

Other physically demanding professions, for example branches of the military, have applied the PES methodology to the point where its use is routine. The science of PES has foundations in work undertaken by Bilzon et al., who demonstrated that primary task or job analysis allows for subsequent accurate and reliable assessment of actual physical job requirements in a study of Royal Navy personnel (82). This method was further developed in subsequent work by Bilzon and colleagues, where the physiological requirements of Royal Navy sailors in the task of ship-board firefighting was specially analysed and quantified (83). Since this foundation work, methods for quantification of the physiological demands of strenuous tasks have been investigated in non-military rescue organisations. Reilly et al. investigated the physiological requirements of beach lifeguards in the United Kingdom (84), establishing a three-step process. Initially, subject matter expert (SME) interviews were conducted to determine the specific tasks of the role. Next, theoretical analysis was performed to determine time-limits for performance of tasks. Finally, the actual metabolic requirements of these tasks were quantified (84).

In a further evolution the science, Tipton et al. proposed an expanded six-stage methodology for the determination of PES (81). This comprehensive, systematic process provides a template for scientists and organisations to accurately determine the physiological demands of a technical role and has become the criterion standard. The six stages are shown in Figure 1.2.

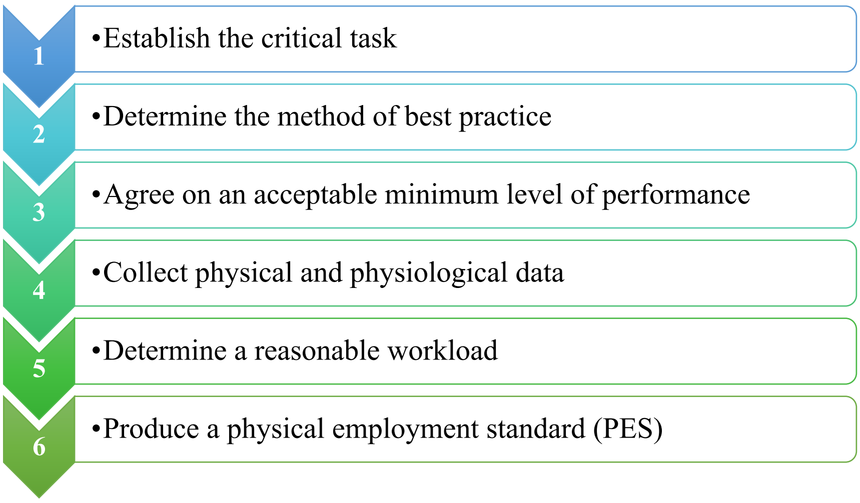


Figure 1.2 The PES methodology

The six-stage methodology to develop physical employment standards as described by Tipton et al. (81)

The six-stage PES methodology has been used to determine physiological demands in similar roles to paramedics working in Australian ambulance services. For example, Milligan et al. analysed the pulling of a rescue sled by members of the United Kingdom Coastguard (85). The study recruited Coastguard members ranging from new and inexperienced members though to members who possessed extensive experience in performing the defined task to determine relative workload (85). Further, in a recent study developing PES for specialist paramedics, members of the Hazardous Area Response Teams (HART) in the United Kingdom demonstrated high maximal aerobic capacity and high relative physiological workloads (19). Such high physical demands may have some bearing on employee health status, and an opportunity exists to further investigate this relationship. To facilitate this, the PES methodology could be readily applied to assess the physically demanding nature of paramedic work in Australasian ambulance services, and the results compared to the diet, cardiometabolic, and physical activity metrics previously mentioned.

1.1.3 Structures and career progression in Australian ambulance services

(Note: other than where specifically referenced, this information is sourced from the author's experience working in or observing the function of jurisdictional ambulance services in Australia).

In Australia, out-of-hospital care is primarily provided by state-based ambulance services. An example of a large state-based ambulance service is in the Australian state of Victoria, which comprises an area of approximately 237,629 km^2 encompassing the metropolitan city of Melbourne, major regional cities, and remote and difficult-to-access terrain, including more than 2,000 km of coastline. AV is the single provider of emergency medical service (EMS) to the nearly 6.4 million inhabitants. Almost 4200 paramedics are employed by AV. Similar to most other Australasian ambulance services, AV is a two-tiered service incorporating a group of general duties paramedics, and a smaller group of specialist clinicians. Most paramedics in AV are termed Advanced Life Support (ALS) Paramedics, and they represent approximately 85% of the workforce. These paramedics are the major providers of generalist primary and emergency health care and are the backbone of ambulance services.

Paramedics in Australasia are required to complete a Bachelor's degree in paramedicine before applying for an intern or graduate year with an ambulance service (excepting New South Wales where the vocational Diploma of Paramedicine is an accepted qualification). A paramedic who has completed their university degree and has commenced their first year of practice is usually termed a graduate ambulance paramedic (GAP) or similar. If they successfully complete the academic and practical requirements of the graduate year, GAPs will qualify as an ALS Paramedic (or equivalent term, dependent on the service). In AV, during the first year of practice, GAPs are allocated to a location in regional (rural) Victoria or a major metropolitan area. All paramedics at AV and in most other services are required to undertake rotating shift work to varying degrees, however most paramedics at AV work a shift pattern that follows a consecutive four days "on" and then four days "off" structure. The "on" shift section starts with two ten-hour consecutive day shifts, one 10–12-hour afternoon shift, and then one 12–14-hour night shift. This is followed by four consecutive days off (this pattern may vary slightly across AV). Consultation with other paramedics in Australia suggests most other ambulance services would have roster patterns somewhat similar to this.

In most Australian ambulance services GAPs and ALS (or their respective equivalent) paramedics are supported by specialist intensive care paramedics (ICPs) to provide support for critically unwell patients. In AV, such paramedics are termed MICA Paramedics and represent approximately 14% of the workforce. Before applying to the ICP role, ALS Paramedics are generally required to possess several years' experience in the generalist role. If successful in gaining an ICP position, paramedics undertake postgraduate study and a clinical internship. At the time of qualification, ICPs will generally have at least five years' clinical experience in addition to their university training.

A subspecialty of ICPs are those paramedics who staff the helicopter emergency medical services (HEMS), which are well-established across Australia. In AV these paramedics are termed intensive care flight paramedics (ICFPs), locally referred to as MICA Flight Paramedics. Before applying to the ICFP role, paramedics are generally required to be qualified as ICPs for two years, although it would be uncommon to be successful in gaining an ICFP position with less than four to five years' ICP experience. If successful in gaining an ICFP position, paramedics undertake further postgraduate education, followed by a clinical internship. At the time of qualification, most ICFPs in Australasia will have been an operational paramedic for a minimum of nine to 10 years in addition to their university training. In AV, ICFPs represent 1% of the total paramedic workforce.

Most HEMS in Australia require the ICFP to perform helicopter-based rescue tasks. In addition to being trained in advanced clinical practice, ICFPs also perform physically demanding land and water-based winch rescue. HEMS across Australia undertake winch rescue operations by deploying the ICFP to incidents via an external hoist/winch. An air crew officer operates the winch control from the helicopter whilst the ICFP goes "down the wire" to the ground or water whilst the pilot flies the helicopter. ICFPs are some of the most senior and experienced clinicians in Australian ambulance services. The HEMS operations in AV specifically (including the winch rescue component) have been described in detail in previous work (86, 87).

1.2 Statement of the problem

There has been little work undertaken to assess core elements of health including diet, cardiometabolic health and physical activity to measure the overall health status of paramedics. Similarly, there is little work investigating the physical demands of paramedics' work and how it impacts health status. This chapter has outlined the current concerns regarding paramedic health and wellbeing and indicates multiple key areas for research that will be addressed in this thesis.

The studies in this thesis undertake a multidisciplinary approach to the assessment of paramedic health and wellbeing, combining assessments of diet, cardiometabolic health, physical activity levels (which are all addressed in Chapters Three and Four), and the physical demands of specialist paramedics' work (Chapters Five, Six, Seven and Eight). These investigations provide insight into the causes of compromised health in paramedics, with a view to improved paramedic health and the development of novel, targeted intervention programs.

1.3 Research aim and objectives

1.3.1 Research aim

The overall aim of this thesis is to examine the cardiometabolic, dietary and physical health of paramedics, and gain an understanding of the specific physical performance demands of paramedics and how they affect health.

1.3.2 Research objectives

To achieve this aim, the following research objectives will be addressed:

1. i) Assess cardiometabolic health and physical activity in paramedics at the commencement of their careers.
   ii) Assess cardiometabolic health and physical activity in senior specialist paramedics with extended careers.
2. Explore health and the physical demands of occupational tasks in senior specialist paramedics with extended careers in paramedicine.

1.4 Thesis overview

This thesis is presented as a *thesis including published works*. It consists of nine chapters featuring seven publications. Building on the Introduction, Chapter Two includes an editorial piece published in *Occupational Medicine* that summarises the current health concerns for paramedics and identifies that to improve health in the profession, further multidisciplinary work is required.

Chapters Three and Four include two papers, both published in *Prehospital Emergency Care*. The first paper describes a longitudinal study that monitored several key markers of cardiometabolic, physical and dietary health in graduate paramedics during the first 12-months practice. The second paper reports on a cross-sectional research design used to measure the same key markers of health, but this time in senior specialist paramedics. Both papers align with research objective one.

Further exploring the health status of the senior specialist paramedics, Chapters Five, Six, Seven and Eight utilise processes from the science of PES to analyse the physical demands of these helicopter rescue paramedics. Firstly, in Chapter Five, a case report published in the *Journal of Special Operations Medicine* describes the physically demanding nature of a live rescue operation. Based on the information from Chapter Five, in Chapter Six, a study published in *Applied Ergonomics* describes the use of historical rescue case data and a SME focus group to define the physically demanding tasks that helicopter rescue paramedics undertake. Then, in Chapter Seven, to establish maximum physiological capacity in senior specialist paramedics, a study published in *Ergonomics* describes the development of a novel, water-based maximal aerobic capacity test for helicopter rescue paramedics and compares it to the criterion land-based assessment. To complete the analysis of physical demands via the PES methodology, the study described Chapter Eight uses the results from Chapters Six and Seven to describe the physical demands of helicopter winch rescue. These papers align with research objective two.

Finally, in Chapter Nine, the results of these studies are summarised and discussed, and conclusions drawn. In addition, recommendations are made regarding how the profession of paramedicine, employers of paramedics and paramedics themselves can improve health and wellbeing, and suggestions for research protocols and further research projects are detailed.

The core research areas are summarised and grouped as depicted in Figure 1.3. To provide the reader with ongoing reference to the overall theme of the thesis, this figure reappears at the beginning of each chapter. There, the link between the specific chapter and the core research area is indicated by a red highlight.

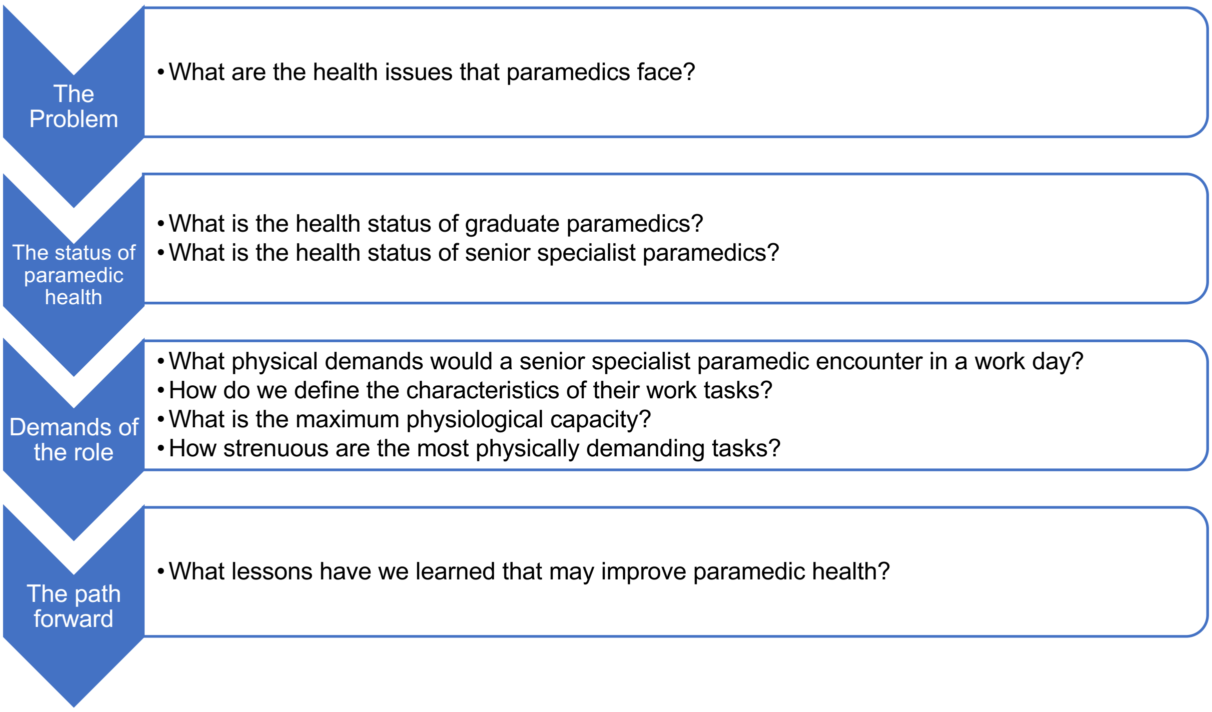


Figure 1.3 Core chapter content and flow

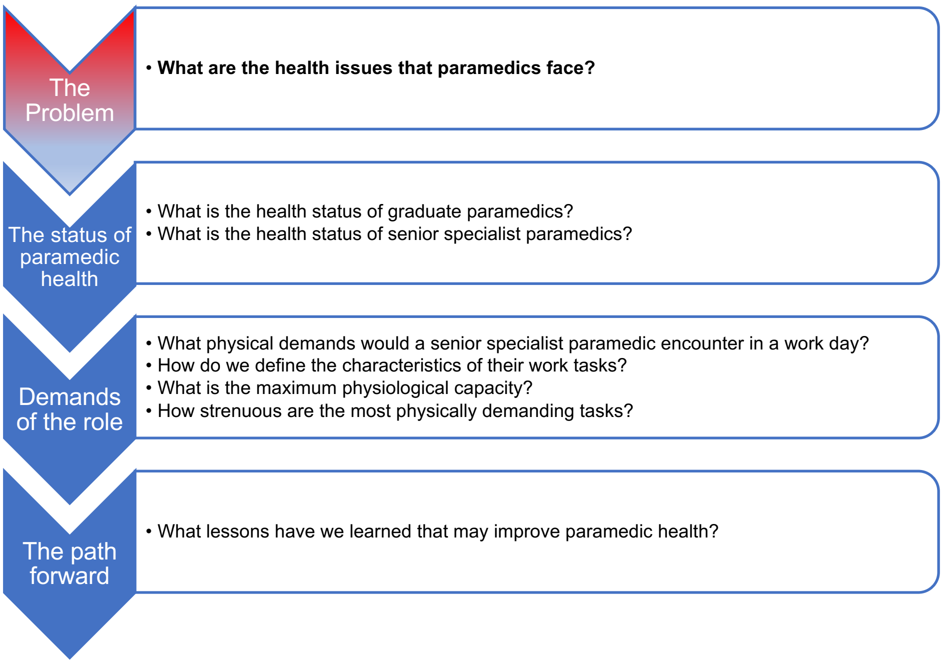
1.5 Summary of Chapter One

This chapter has provided detailed information regarding the status of paramedic cardiometabolic and physiological health, identified gaps in the research and suggested methods for which to assess health in this unique workgroup. The next chapter is an editorial piece summarising these health concerns for paramedics.

Chapter Two: The health and wellbeing of paramedics

2.1 Preamble

For ambulance services and other organisations that employ paramedics to deliver high quality out-of-hospital care, it is vital that staff be in a state of optimal heath. Unfortunately, paramedics face barriers to maintaining good health. Previous research investigating the health and wellbeing of paramedics has mostly focused on discrete aspects of health in isolation; for example, mental or dietary health, and has failed to define the barriers to good health of paramedics in the context of the whole person. Moreover, there is limited research with multidisciplinary teams collaborating to achieve a common goal of improving paramedic health. The human body is a complex interaction of many systems which should be studied together. This editorial piece provides a foundation for further exploration of the health status of different groups of paramedics and the physical demands of their jobs, to ultimately develop effective health promotion interventions for this vulnerable part of the workforce.



2.2 Manuscript

Meadley B, Caldwell J, Perraton L, Bonham M, Wolkow A, Smith K, Williams B, Bowles K. The health and well-being of paramedics - a professional priority. Occupational Medicine. 2020;70(3):149–51. (Quartile 2, Impact factor 1.611)

Occupational Medicine 2020;**70:**149–151
doi:10.1093/occmed/kqaa039

EDITORIAL

The health and well-being of paramedics - a professional priority

The health and well-being of paramedics is central to a successful ambulance service and provision of the highest level of clinical care. The Paramedic Health and Wellbeing Research Unit (PHAWRU) at Monash University (Victoria, Australia) is a newly formed unit that comprises a collaborative team of researchers, emergency service end-users and paramedic representatives, aiming to better understand and minimize the negative health impacts of a career in paramedicine. Together, the research team looks to ensure there are evidence-based strategies to improve musculoskeletal, physiological, metabolic, nutritional, mental and sleep health in paramedics.

Paramedics are registered health professionals in numerous countries. Paramedicine, the contemporary term for professional paramedic practice, has an established clinical research profile demonstrating that evidence-based practice can contribute to an improvement in patient outcomes. Whilst ambulance services must prioritize their patients, they also require personnel to be healthy to perform at their utmost in order to provide optimal patient care. Yet, there is concern regarding health outcomes in paramedics. It is vital that research focuses on optimizing the health and well-being of paramedics, thus enabling ambulance services to meet their duty of care to provide a safe and healthy workplace, whilst delivering high-quality patient care.

Ambulance services provide care 24 h a day, 7 days a week, and shift work is known to be a risk factor for poor health [1–4]. Working unsociable hours has detrimental consequences on the health and well-being of healthcare workers and can ultimately result in compromised patient care. Ambulance service utilization rates are high, with paramedics working in unpredictable environments, and undertaking complex clinical and manual handling tasks whilst caring for critically unwell patients; thus, there are several reasons postulated for poor health in this professional group. These include mental health problems, sleep disturbances, poor nutrition, limited physical activity and high rates of musculoskeletal injury [4].

There is increasing awareness of the psychological effects of long-term exposure to emergency service work. This was highlighted in a recent Australian study conducted by the mental health advocacy group 'Beyond Blue'. The report on mental health in emergency services, *Answering the Call*, surveyed 21 014 Australian emergency services personnel, highlighting significant issues including that 39% of employees reported having been diagnosed with a mental health condition compared to 20% of all adults in Australia [5]; emergency services employees report having suicidal thoughts two times more often than the general population and are over three times more likely to have a suicide plan [5]; over half of all employees reported having experienced a traumatic event that significantly affected them during their work [5], and one in four former employees experiences probable post-traumatic stress disorder, and one in five experiences very high psychological distress [5].

There are a number of initiatives from ambulance services aimed at mitigating work-related mental health issues for paramedics. However, we believe all factors of health and well-being must be addressed. There is a gap in the research regarding systemic health, and improvements in mental health can be achieved by acknowledging the multitude of factors that influence well-being.

It is recommended that a typical adult should have 7–9 h sleep per night for optimal health and function [6]. For paramedics, however, getting adequate quantity and quality sleep can be challenging due to overnight and early morning work. These schedules require personnel to work through the circadian nadir when alertness is low and sleep propensity high, then attempt to sleep when alertness is at maximum, resulting in misalignment of the sleep–wake cycle, reduced sleep duration and quality, and sleepiness. High rates of sleep disturbances, including short sleep, sleep disorders and sleepiness have been reported among paramedics [4]. Importantly, shift work schedules can vary widely within and between ambulance services. Further research is needed to determine the specific aspects of shift work, as well as other stressors and individual factors that make paramedics vulnerable (or resilient) to sleep problems. Our understanding of how sleep affects paramedics' physical and mental health is also limited. Accordingly, additional longitudinal research assessing sleep and health outcomes in paramedics as they progress through their career is needed to determine if and how sleep patterns relate to chronic health outcomes among personnel.

The role of high-quality nutrition in the prevention of disease, and its contribution to overall wellness is well known. Studies have also examined the impact of shift work on the ability to access high-quality nutrition [1]. This is especially relevant to paramedics and other health and emergency service workers. Shift workers are at a higher risk of suffering from conditions such as obesity, Type II diabetes, cardiovascular and inflammatory diseases [7].

Paramedic crews are constantly mobile, the workload is unpredictable, as such, the ability to plan a meal is often challenging. In one study, paramedics reported a number of barriers to accessing high-quality nutrition [3]. These include mobility of the role, reliance on easily accessible food (e.g. take away food), leaving pre-prepared meals at the ambulance station and then being out on jobs all shift, lack of meal breaks and influence of other paramedics on meal choices [3]. In isolation, intermittent consumption of low-quality nutrition may seem insignificant; however, chronic consumption of poor-quality foods can be insidious, especially as cumulative fatigue from shift work amounts, leading to a lack of motivation to seek high-quality meals. Acknowledging the identified difficulties in planning and accessing nutritious food in a time-poor world, it is still important to consider the impact of diet and nutrition on paramedic well-being.

In an attempt to ensure timely treatment for their patients, paramedics often place their bodies in high-risk situations. This means paramedics make choices to lift, pull or push heavy loads at any time of the day or night. As a result, paramedics have one of the highest overall risks for musculoskeletal injuries among healthcare workers, with Roberts *et al.* [8] finding paramedics had between 3.5- and 13-times greater risk of lower back injury compared to nurses. Of additional concern is the resultant insurance claim rates from these injuries are increasing for paramedics, while other healthcare occupations are seeing a decrease [8].

Regular physical activity has a proven role in the prevention of disease and contributes to improved health outcomes. Recent large-scale studies demonstrate the significant positive effect regular physical activity has on a number of areas of overall well-being, including a reduction in mental health symptoms [9]. Although it is evident that regular physical activity improves health outcomes across the population, the impact of shift work on access to regular physical activity is uncertain and is likely to be important in improving overall paramedic health.

Ambulance services have a responsibility to ensure that paramedics are physically fit for their role and should institute objective physical employment standards (PES). For example, Ambulance Victoria (Australia) uses a PES for its graduate paramedics [10], but paramedics are only assessed at the commencement of employment. Assessing fitness for duty at the start of career is insufficient to ensure safe performance of complex tasks. Ongoing assessment of physical capacity via formalized PES may impact not only a paramedic's ability to perform their role, but whether it further reduces injury rates, and/or improves overall health and well-being.

Although the focus of paramedic education in undergraduate and postgraduate programmes is appropriately clinically focused, informing and educating paramedics on self-care is essential for emergency service professionals where there is known risk of poor health outcomes linked to their vocation. Evidence-based, proactive and preventive health strategies should be implemented early in the academic programme and linked to measurable learning outcomes and meaningful assessments.

Several important projects are currently underway by our group to identify and mitigate the effects of a career in paramedicine on whole-body health. To attend to high injury rates, we are conducting investigations into musculoskeletal health, including analysis of lower back movement patterns of paramedics during a shift. Additionally, having identified significant deficiencies in initial and recurrent assessment of paramedics' physical capacity, we have commenced a project to establish PES for helicopter search and rescue paramedics, with priority projects planned to expand this to the wider paramedic population.

Little data exist to demonstrate how soon health may be affected by a career in paramedicine. We are conducting urgently needed prospective studies that monitor nutrition, cardiometabolic and mental health, and sleep and physical activity levels of paramedics during their first year of practice, with the intention to conduct long-term follow-up studies. Finally, in an effort to implement preventive measures, we are mapping undergraduate paramedic curricula to explore the effectiveness of intervention strategies early in the educational journey.

Occupational physicians and researchers must acknowledge mounting evidence indicating paramedics and other emergency service workers are at risk of significantly poor health outcomes [1,2,4,5,7]. Research aimed at reducing this burden should involve a whole-body approach, with a focus on areas additional to mental health. We anticipate that the work of the PHAWRU serves to improve outcomes not only in paramedics, but across the emergency services and health professions.

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doi:10.1093/occmed/kqaa051

After careful consideration of the rapidly changing situation relating to the Coronavirus outbreak

After careful consideration of the rapidly changing situation relating to the Coronavirus outbreak, the Society of Occupational Medicine and the Faculty of Occupational Medicine have taken the decision to postpone the Occupational Health 2020 Conference and Exhibition and provisionally re-schedule to 19–21 October 2020.

2.3 Summary of Chapter Two

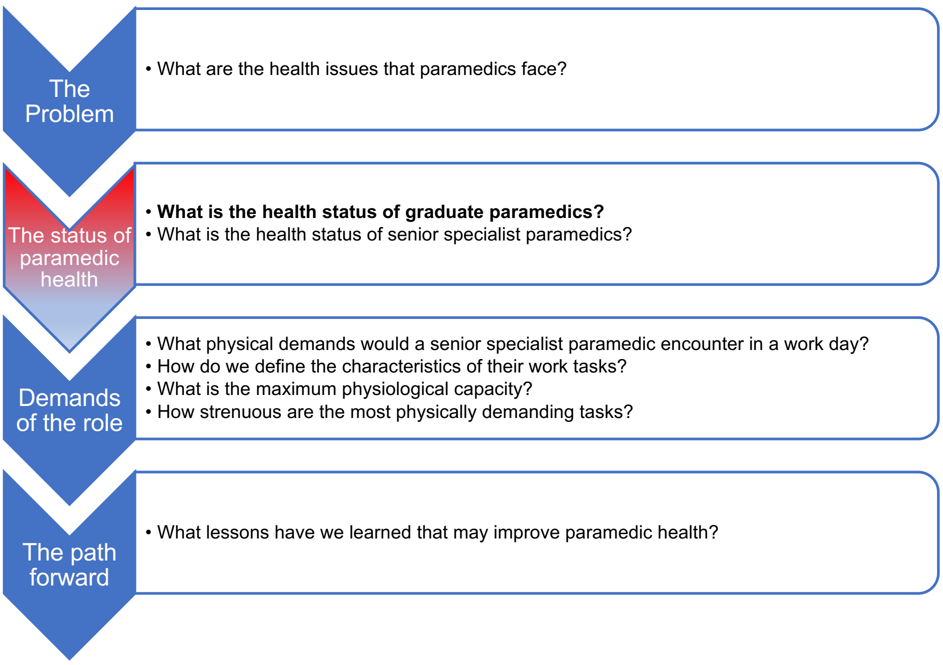
Coupled with Chapter One, this editorial identifies that there are number of concerns regarding paramedic health and wellbeing. These include mental health, sleep, diet and nutrition, physical activity, and the physically demanding nature of paramedic work.

To enhance paramedic health and wellbeing there is a need to bring together multi-disciplinary teams across a range of areas including clinical practice, research, behavioural science, process improvement and systems design to ensure that health improvement strategies are evidence-based and readily implementable. A multi-faceted approach to collaborative research is essential. Paramedics are an integral component of our health system, and we must support their function by improving their health. Given the current healthcare landscape, never has this been more apparent. Little work has been undertaken to investigate critical health areas including the role of physical activity, diet, cardiometabolic health and the physical demands of this occupation. The gaps in these areas have informed the development of the studies undertaken in this thesis.

Chapter Three: Cardiometabolic, dietary and physical health in graduate paramedics during the first 12-months of practice

3.1 Preamble

Chapters One and Two of this thesis identified the need to investigate the adverse health effects of a career in paramedicine. The study in this chapter follows graduate ambulance paramedics during one of the most challenging periods of a paramedic's career; their first year of practice. This longitudinal study investigated changes in health outcomes in 56 graduate paramedics commencing their careers with AV. Assessments included: dietary health; sampling of biomarkers to determine cardiometabolic health risk; maximal aerobic capacity assessment via treadmill running; physical activity tracking; and assessment of health-related quality of life (HRQoL).



3.2 Manuscript

Meadley B, Wolkow AP, Smith K, Perraton L, Bowles KA, Bonham MP. Cardiometabolic, dietary and physical health in graduate paramedics during the first 12-months of practice-a longitudinal study. Prehospital Emergency Care. 2021; Jul 7:1-13.

(Quartile 1, Impact factor 3.077)

Cardiometabolic, Dietary and Physical Health in Graduate Paramedics during the First 12-Months of Practice – A Longitudinal Study

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Abstract

Objective: Shift work is an established risk factor for poor health yet is necessary for paramedics to provide continuous care to the public. It is unknown how early into a career shift work may begin to impact health. This study sought to identify changes in cardiometabolic health, diet, aerobic capacity, physical activity and health-related quality of life (HRQoL) in graduate paramedics during the first 12-months of their career. **Methods:** Fifty-six paramedics with no history of regular shift work (28 female, 28 male; median age 24.5, IQR 23-26 years) were recruited for this study. Dietary patterns (food frequency questionnaires) and HRQoL (36-Item Short Form Questionnaire) were assessed at baseline, 6- and 12-months. Body weight, body mass index (BMI) and blood samples (fasting lipids, glucose, insulin and C-reactive protein) were measured at baseline and 12-months to ascertain cardiometabolic health risk. A subset of participants (n = 19; 10 female, 9 male) wore a physical activity monitor for 12 months and completed baseline and 12-month maximal aerobic capacity assessments (VO_{2max}). **Results:** Body weight and BMI decreased in males and increased in females (-0.7% versus 1.7%, p = 0.02). HRQoL and dietary intake did not change over 12-months, except for a small decrease in fat intake (−1%). Consumption of core/healthy foods was lower than recommended at all timepoints. Biomarkers of cardiometabolic health were within normal range and did not change over 12-months, excepting insulin where a small non-significant increase was seen (+0.5 mIU/L, p = 0.61). Baseline VO_{2max} was 41.4 (37.1-49.1) $ml.kg^{-1}.min^{-1}$, with no change noted at 12-months. Comparison of quarterly physical activity data showed no difference in steps per day (p = 0.47) or moderate to vigorous physical activity (MVPA, p = 0.92) across the 12-months. Paramedics completed less MVPA on day shifts compared to rostered days off (−14.68 minutes, p = 0.04). **Conclusions:** Dietary patterns, HRQoL, cardiometabolic health, aerobic capacity and physical activity levels did not change meaningfully in the first year of practice. Some dietary behaviors and physical activity levels could be improved and may mitigate health effects of exposure to shift work. Long-term follow-up of this group may aid in developing programs to enhance health for paramedics and other health workers. **Key words:** emergency medical services; cardiometabolic; nutrition; physical activity; ambulance

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BM is an operational paramedic with Ambulance Victoria but was not involved in recruiting participants to the study. Ambulance Victoria had no influence on study design, protocol development or reporting of results. All other authors have no competing interests to declare.

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Introduction

Negative effects on health and wellbeing can manifest if work is performed in opposition to circadian rhythms over extended periods (1, 2). Adverse effects of shift work can include impaired health-related quality of life (HRQoL), increased incidence of cardiovascular disease, weight gain, Type II diabetes mellitus, and poor mental health (3–5). However, due to a lack of longitudinal research in this area, little is known about when the signs of these adverse health outcomes first appear in new shift workers. One of the most challenging periods of a new paramedic's career is their first year of practice. Junior paramedics are exposed to many new experiences, including the steep learning curve faced during the transition from university education to clinical practice, and the lifestyle changes that occur when commencing shift work in healthcare. It is reasonable to propose that some of the negative health consequences associated with long term shift work may manifest in this early phase of the career.

A number of factors have been proposed to contribute to the incidence of long-term poor health in paramedics and other shift-workers including chronic exposure to unwell and injured patients, sleep disturbance, circadian misalignment, poor diet, low levels of physical activity and musculoskeletal injury (3, 4, 6, 7). The incidence of metabolic, cardiovascular and inflammatory diseases reported in those performing shift work for extended periods (including paramedics) is concerning (3, 4, 7, 8). There is a need to identify the elements of health and wellbeing that can be modified in order to improve paramedic health and build a resilient emergency medical service (EMS) workforce.

Optimizing wellbeing requires attention be paid to the key components of health, such as physical activity, which has an established role in the prevention of a range of disease states. The positive effect regular physical activity has on a number of health and wellbeing elements has been demonstrated in large cohort studies (9, 10). Improvements in cardiovascular or cardiometabolic health in particular are aligned to certain physical activity metrics, namely steps per day and minutes per day of moderate to vigorous physical activity (MVPA) (11). Recent updates to physical activity guidelines consolidate the important role frequent MVPA has in improving health (12), and previous work investigating physical activity levels in paramedics indicates that shift work as a paramedic may impede access to regular vigorous, non-occupational physical activity (13).

A nutritious diet is another key component of health. For paramedics, the high workload and unpredictable nature of emergencies, and mobile workplace means it can be difficult for personnel to plan for, prepare and source nutritious meals. Indeed, paramedics in Australia and overseas have reported a number of obstacles to maintaining a nutritious diet, including reliance on non-core (e.g., take away) foods, multiple back-to-back cases and insufficient meal breaks (14, 15). At present, little is known about the composition of paramedics' diet, but it can be reliably assessed with tools such as food frequency questionnaires (FFQ) to detect longitudinal change (16). To build a complete profile of dietary and cardiometabolic health, biomarkers (such as lipid profile, inflammatory markers such as C-reactive protein (CRP) and insulin resistance scores), body composition and anthropometric data can be combined (17, 18). Coupled with physical activity metrics, these data may be useful to identify risks to health and assist in the development of programs early in the career to improve the wellbeing of EMS personnel. This study sought to i) identify changes in HRQoL, cardiometabolic health and dietary patterns, and ii) identify changes in cardiovascular fitness, and the influence of shift type on physical activity levels in a sample of graduate ambulance paramedics working their first year of a career in EMS.

METHODS

Study Design and Setting

This was a 12-month longitudinal study of graduate ambulance paramedics (GAP) commencing employment with a state EMS. Paramedics in Australasia are registered health professionals and are required to complete a Bachelor's degree in paramedicine before applying for an intern or graduate year with an ambulance service. During the undergraduate degree, student paramedics undertake clinical placements with an ambulance service, but in this jurisdiction, placements only occur on day and afternoon shifts, and do not include overnight shifts. The study was conducted at Ambulance Victoria (AV), the single provider of EMS to the nearly 6.4 million inhabitants of the state of Victoria, Australia. At the time of the study, almost 4200 paramedics were employed by AV. GAP are well remunerated and secondary employment to supplement income is uncommon. In their first year, GAP are allocated to a location in regional (rural) Victoria or a major metropolitan area. The general shift pattern follows a consecutive four days "on" and then four days "off" structure. The "on" shift section starts with two ten-hour consecutive day shifts, one 10–12-hour afternoon shift, and then one 12–14-hour night shift. This is followed by four consecutive days off (this pattern may vary slightly). In this study, the term "first day off" represents the day immediately following the end of the final shift of the roster cycle, which is usually a night shift, and the term "rostered day off" refers to days where paramedics did not attend work at all.

Participants

Participants were recruited from groups of newly employed GAP via a 30-minute presentation given by members of the research team on the first day of

Table 1. Summary of assessments and associated timepoints

	Timepoint		
Standard assessments (n = 56)	Baseline	6 months	12 months
Anthropometry	*		*
Biomarkers	*		*
Food frequency questionnaire	*	*	*
SF-36 HRQoL survey	*	*	*
Additional assessments (n = 19)	Baseline		12 months
Body composition	*		*
Maximal aerobic capacity ($\dot{V}O_{2max}$)	*		*(n = 11)†
Physical activity monitoring	Continuous		

†8 of 19 participants were unable to complete 12-month $\dot{V}O_{2max}$ assessments due to cessation of exercise testing during the COVID-19 pandemic when the laboratory was forced to close.

the AV induction program. The presentation was delivered to five separate induction groups between January and June 2019. The single inclusion criterion was employment by AV as a graduate paramedic. Exclusion criteria were previous employment as a qualified paramedic in another service, shift work in other emergency services or the defense forces, a history of prior full-time overnight/shift work experience in the last three months. Full-time overnight work was defined as working (on average) ≥2 overnight shifts (defined as work hours between 10 pm to 8am) per week in the last three months. Written informed consent to participate in all aspects of the study was obtained from each individual participant. This study was approved by the Monash University Human Ethics Research Committee (Project numbers 15285 & 17784) and the Ambulance Victoria Research Governance Committee.

Measurements

Table 1 details the assessments and related timepoints. Funding for the project limited recruitment to a maximum of 60 overall and 20 for the physical activity monitoring.

All participants (n = 56) undertook the following assessments:

Baseline Assessment

Baseline testing occurred at either the AV training facility or the laboratory at the Be Active, Sleep and Eat (BASE) facility at Monash University. All participants were required to avoid strenuous exercise for the preceding 24 hours, be well-rested, free from illness for the preceding 14 days, have not worked a nightshift prior to the assessments, and to have fasted for the previous 10 hours. Participants were required to complete a form that detailed basic demographics. All assessments were conducted between 0700-1000 hours.

Pre-assessment preparation for the 12-month follow-up assessments was the same as baseline. However, some GAP were placed at regional or rural AV locations outside the metropolitan area, and 15 of the 56 participants were unable to attend the laboratory or AV training facility. AV provided the research team with a decommissioned ambulance to use as a mobile laboratory to enable off-site 12-month assessments in these 15 participants.

Anthropometry and Blood Pressure

For each of the following assessments, the value was measured twice, and the mean recorded: After 5 minutes sitting at rest, blood pressure was measured on the right arm using an ABN Aneroid Professional Sphygmomanometer (Padalarang, Indonesia) and a Littmann Classic II SE Stethoscope (3 M, Saint Paul, Minnesota, USA). Waist circumference was measured using a metric fabric tape measure at the level of the umbilicus (19). Height was measured using a SECA 213 portable stadiometer (SECA, Hamburg, Germany). Participants were weighed using calibrated SECA 813 Digital Flat Scales (SECA, Hamburg, Germany).

Biomarkers of Cardiometabolic Health and Inflammation

All participants had blood sampled via venepuncture of the antecubital vein using a 21-gauge butterfly needle, extension tube and tube connector (Grenier Bio-one, Kremsmunster, Austria). If difficulties were encountered, ultrasound-guided venous access was performed (GE VScan Dual Probe, GE Healthcare, Chicago, Illinois, USA). Three blood tubes were used to collect blood samples: two BD K2E Plus EDTA (plasma; glucose, insulin) and one BD SSTII Advance Plus (serum; lipid profile) (Becton Dickinson, Franklin Lakes, New Jersey, USA). EDTA and SSTII tubes were inverted eight times immediately post blood collection. SSTII tubes were left to stand at room temperature (20-22 degrees) and allowed to clot.

When sampled off-site, EDTA tubes were stored at 4 °C in a temperature controlled Dometic Waeco CFX3 35 Compressor Fridge Freezer (Dometic, Solna, Sweden). The samples were then transported back to the laboratory for processing with a maximum of 40 minutes (baseline) and 120 minutes (12-month) from sample time to laboratory arrival. For all samples, EDTA tubes were centrifuged at 1500 g for 15 minutes at 4 °C. After a minimum of 30 minutes post-sampling, SSTII tubes were centrifuged at 1300 g for 10 minutes at 22 °C (Eppendorf

5702 R centrifuge, Eppendorf, Hamburg, Germany). After centrifugation, samples were aliquoted to micro-tubes and stored at −80 °C. At the end of the study, all samples were transported from −80 °C freezer storage via polystyrene cooler with dry ice to an external laboratory for batch analysis (Monash Health Pathology, Clayton, Victoria, Australia).

Fasting plasma glucose, fasting plasma insulin, total cholesterol, LDL, HDL and triglycerides were measured via automated analyzer according to the manufacturer's instructions as described in previous work (20). High sensitivity C-reactive protein (hsCRP) was measured via the near infrared particle immunoassay rate methodology using a Beckman Coulter Synchron LX system Chemistry Analyzer, with standard reagents and calibrators (Beckman Coulter Diagnostics, Mount Waverley, Victoria, Australia). The homeostatic model assessment of insulin resistance (HOMA-IR) is an established metric to estimate insulin resistance. HOMA-IR was calculated as a product of fasting plasma glucose ((mmol.L^{-1} × 18.0182) = G_0, mg/dl) and fasting plasma insulin (I_0, mIU/L) divided by the constant 405: HOMA-IR = (G_0 x I_0)/405 (21).

Health-Related Quality of Life (HRQoL)

At the baseline, 6- and 12-month timepoints, all participants completed the RAND 36-Item Short Form Health Survey (SF-36), a validated, self-reported assessment of mental and physical health domains (22, 23). We did not analyze sub-domains and only reported on Physical and Mental Health summary outcomes to estimate HRQoL. The resultant summary scores for Physical and Mental health are presented as a value out of a maximum possible score of 100.

Dietary Health

At the baseline, 6- and 12-month timepoints, dietary intake was assessed using the validated Australian Eating Survey (AES) Food Frequency Questionnaire (FFQ) (16). The AES assesses intake of 120 commonly consumed foods, alongside 15 behavioral and demographic questions pertaining to the previous six months. The questionnaire is categorized according to the food groups of drinks, breads and cereals, main meals, fruit and vegetables, dairy products, sweets and snacks. Adult portion sizes are standardized and are determined from data of the Australian National Nutrition Survey (16). Overall energy intake, and food group contribution to average energy intake is calculated. The AES report output groups foods into core (i.e., non-processed and fresh foods) and non-core foods (i.e., take-away and highly processed foods). Additionally, the AES produces a diet quality index, termed the Australian Recommended Food Score (ARFS). The ARFS is a tool used to score overall diet quality, and scores for six food group categories (24). Results of the ARFS are compared against a maximum score and total ARFS is ranked as: "needs work", "getting there", "excellent", or "outstanding".

Maximal Aerobic Capacity and Physical Activity

Nineteen of the 56 participants undertook the following additional assessments:

Maximal Aerobic Capacity

Prior to the assessment of maximal aerobic capacity (VO_{2max}), all participants were required to complete the Sports Medicine Australia/Exercise and Sports Science Australia Pre-Exercise Screening Tool to exclude risks to completing a maximal exercise test (25). VO_{2max} was estimated by indirect calorimetry (Vmax Encore Metabolic Cart: Carefusion, San Diego, California, USA) during continuous incremental exercise test to volitional exhaustion on a motorized treadmill (MyRun, Technogym, Seattle, Washington). We used our standard laboratory protocol described previously (26).

Physical Activity

Participants were instructed to wear a wrist mounted activity monitor as much as possible for 365 days (Versa, FitBit, San Francisco, California, USA). As an incentive to participation, participants were permitted to keep the physical activity monitor at the end of the 12-months (∼$200AUD value). Activity monitors were synchronized to a central database (Fitabase, San Francisco, California, USA), and participants were blinded to their detailed physical activity data. A member of the research team monitored the database daily and contacted participants by email or SMS if their device did not synchronize with the database for more than five days, which we set as the acceptable threshold *a priori* to prevent loss of data from the device's internal memory. To determine participant compliance, data were excluded if <100 steps per day were recorded. We analyzed the remaining data for steps per day, minutes per day of sedentary time and light activity, and minutes per day and per week of moderate-vigorous physical activity (MVPA). These metrics are derived from a combination of individual participant data (e.g., weight, height, age), heart rate, accelerometry and the proprietary algorithm that is not divulged by the manufacturer. AV provided shift roster data for each participant which included

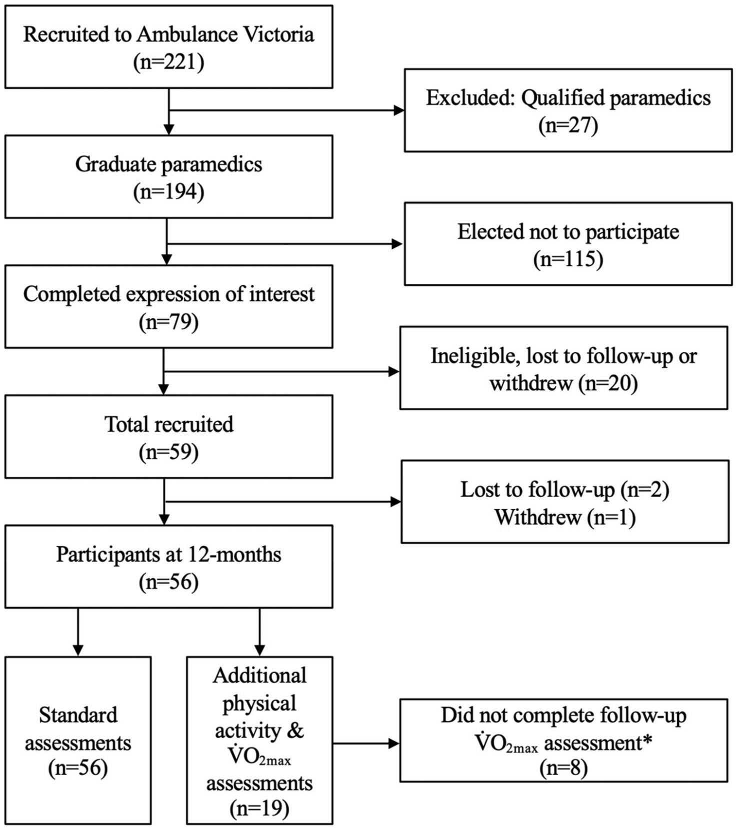

FIGURE 1. Flow chart for recruitment of participants.
*due to closure of the laboratory during the COVID-19 pandemic.

all rostered shifts for the 12 months, including additional shifts completed on rostered days off. The roster data did not allow for differentiation between regular rostered days off and vacation time or sick leave. We aligned physical activity data with each shift worked (day shift, afternoon shift, night shift, the first day off and other rostered days off).

Effect of the COVID-19 Pandemic on this Study

COVID-19 restrictions in Melbourne, Victoria, resulted in closure of research laboratories close to the 12-month mark of the study. Although this had minimal impact on physical activity data collection, eight of the 19 participants who participated in the sub-study were unable to undertake the 12-month VO_{2max} test, but all other assessments were completed.

STATISTICAL ANALYSIS

Data were assessed for normality using visualization of histograms and Shapiro-Wilk tests. For data that was found to be normally distributed, parametric tests were used and data presented as mean and standard deviation. For data that was found not to be normally distributed, non-parametric tests were used and data presented as median and IQR. Specific tests are detailed in the footnotes of the respective tables. Spearman's correlations were run to assess the relationship between baseline body mass index (BMI) and change in weight, and baseline BMI and change in waist to height ratio. For participants that wore physical activity monitors, Spearman's correlations were run to assess the relationship between baseline BMI and steps per day, and baseline BMI and minutes per day of MVPA. To assess physical activity over the 12-months (steps per day and minutes of MVPA per day) data were grouped per quarter and compared using a one-way repeated measures ANOVA. To investigate the association between shift type and physical activity (number of steps and MVPA per day) we aligned physical activity data with shift type. Steps per day and MVPA were then grouped by shift type to allow further descriptive analysis, and simple linear regression was performed to investigate the relationship between steps and shift type, and MVPA and shift type. Within the regression analyses, robust standard errors were used to address the fact that the data was not independent and identically distributed. Statistical analysis was performed using Stata version 16.1 (StataCorp, College Station, Texas, USA), and statistical significance was determined *a priori* at $p < 0.05$.

TABLE 2. Descriptive characteristics of participants (n = 56)

Demographics	n	%
Male	28	(50.0)
Female	28	(50.0)
	Median	(IQR)
Age, years	24.5	(23-26)
Metropolitan region[‡]	31	(55.4)
Rural region[‡]	25	(44.6)
Living status	Median	(IQR)
At home with family (i.e., with parents)	11	(19.6)
Solo	2	(3.6)
Share house	27	(48.2)
Partner ± dependents	16	(28.6)

[‡]denotes region where graduate paramedic was assigned to work for the 12-month period.

RESULTS

Figure 1 details participant recruitment and participation. During the study period, 194 GAP were recruited by Ambulance Victoria, and 79 GAP expressed interest in the study. Screening for inclusion and exclusion was performed via telephone by two researchers (BM and APW). At the 12-month timepoint, 56 paramedics (28.9% of AV GAP recruits from January to June 2019) had completed the study. Table 2 details participant characteristics for all 56 participants. There were equal numbers of males and females, mostly in their early twenties with slightly more GAP assigned to work in the metropolitan region of AV compared to rural areas. Most GAP lived in a share house, with a significant other or with their parents.

Changes in anthropometry and markers of cardiometabolic health are shown in Table 3, with

TABLE 3. Baseline and 12-month, and difference over time for anthropometry, markers of cardiometabolic health (n = 56) and maximal aerobic capacity (n = 11). Data are presented as median (IQR)

	Change						Percent change						
Cardiometabolic health (n = 56)	Baseline		12 months		p[#]	Ref	All (n = 56)		Male (n = 28)		Female (n = 28)		p[#]
Weight, kg	75.0	(63.9-87.6)	76.6	(63.3-87.7)	0.26	–	1.1	(−2.2-3.5)	−0.7	(−3.7-2.6)	1.7	(−0.2-3.8)	0.02*
Body Mass Index, $kg.m^{-2}$	23.7	(21.1-26.4)	24.0	(21.3-27.2)	0.23	18.5-24.9	1.1	(−2.0-3.5)	−0.7	(−3.7-2.6)	1.7	(−0.2-3.8)	0.02*
Waist: Height ratio	0.45	(0.42-0.50)	0.46	(0.42-0.52)	0.54	<0.50	0.6	(−3.8-1.6)	−0.1	(−1.3-1.6)	0.8	(0.1-1.5)	0.13
BP systolic, mmHg	121	(115-130)	124	(113-135)	0.70	<129	0.9	(−5.0-7.9)	2.5	(−5.0-7.4)	−0.4	(−4.9-9.2)	0.85
BP diastolic, mmHg	75	(68.5-80.0)	75	(70-83)	0.55	<80	0.0	(−8.4-16.0)	−1.2	(−8.4-16.0)	1.9	(−8.9-15.6)	0.55
Fasting glucose, $mmol.L^{-1}$	5.1	(4.7-5.5)	5.3	(5.1-5.7)	0.43	3.6-6.0	5.9	(0-13.5)	5.7	(0-13.9)	6.3	(2-13.4)	0.41
Fasting insulin, mIU/L	4.9	(3.3-6.1)	5.4	(3.1-7.0)	0.61	3.0-8.0	3.3	(−20.8-31.4)	0.0	(−31.7-28.3)	6.7	(−9.5-32.5)	0.31
Total cholesterol, $mmol.L^{-1}$	4.6	(3.9-5.2)	4.8	(4.25-5.4)	0.17	<5.2-6.2	6.7	((0-15.5)	6.0	(−6.15-12.2)	8.1	(3.1-19.0)	0.13
HDL, $mmol.L^{-1}$	1.4	(1.2-1.7)	1.5	(1.2-1.7)	0.62	09-1.5	1.2	(−6.4-11.5)	0.7	(−11.3-11.9)	1.5	(−3.7-10.8)	0.45
LDL, $mmol.L^{-1}$	2.6	(2.0-3.1)	2.8	(2.3-3.4)	0.11	0-4.5	9.1	(−1.5-20.9)	7.7	(−8.2-19.75)	11.8	(1.4-32.2)	0.20
Triglycerides, $mmol.L^{-1}$	0.9	(0.7-1.3)	0.9	(0.7-1.3)	0.77	0.6-2.0	7.1	(−12.5-37.5)	0.0	(−17.8-38.8)	12.5	(−12.5-31.3)	0.65
C-reactive protein, $mg.L^{-1}$	0.8	(0.4-1.9)	0.7	(0.3-2.5)	0.96	0-5	0.0	(−25.0-51.9)	0.0	(−23.2-45.0)	8.4	(−25.4-54.2)	0.88
HOMA IR	0.9	(0.7-1.57)	1.3	(0.7-1.8)	0.32	0.5-1.4	14.0	(−17.0-41.5)	6.0	(−29.0-39.5)	22.0	(−4.3-43.2)	0.22
Maximal aerobic capacity (n = 11)[‡]							All (n = 11)		Male (n = 7)		Female (n = 4)		p[#]
VO_{2max}, $ml.kg^{-1}.min^{-1}$	41.4	(37.1-49.1)	42.6	(36.8-44.4)	0.41	–	−8.1	(8.6-3.4)	−1.5	(−8.5-4.8)	−8.4	(−10.9-4.1)	0.35

[#]Wilcoxon rank-sum test.
*p= <0.05.
[‡]Due to the inability to undertake maximal aerobic capacity testing during the COVID-19 pandemic, only 11 of 19 participants who undertook baseline VO_{2max} testing completed the 12-month follow-up assessments.

TABLE 4. Quarterly physical activity data for steps per day and minutes per day of MVPA (n = 19). Data are presented as mean (±SD)

	Quarter 1		Quarter 2		Quarter 3		Quarter 4		
	Mean (±SD)	95% C.I.	Mean (±SD)	95% C.I.	Mean (±SD)	95% C.I.	Mean (±SD)	95% C.I.	p*
Steps per day	7259 (±1227)	[6668, 7850]	7192 (±1909)	[6272, 8112]	7464 (±1982)	[6509, 8419]	6918 (±2578)	[5675, 8161]	0.47
Minutes MVPA per day	29 (±22)	[18, 40]	27 (±16)	[19, 35]	29 (±19)	[20, 38]	30 (±22)	[19, 41]	0.92

*one-way repeated measures ANOVA.

reference values based on international recommendations and laboratory-provided thresholds. At baseline, median BMI and waist to height ratio were within normal range. However, approximately 46% of male and 28% of female GAP commenced their careers with a BMI >25kg.m^2, thus were considered overweight (27). For both males and females, approximately 18% started with a waist to height ratio above the threshold of 0.5 which indicates cardiometabolic health risk (28). Whilst group median BMI and waist to height ratio did not significantly change over the 12-month study period, there was a different pattern between female and male GAP. Median (IQR) BMI for males fell by 0.7% (-3.6-2.3), whilst female GAP reported a 1.7% (-0.2-3.8) increase in BMI. Whilst this difference was statistically significant ($p = 0.02$), it is unlikely to be clinically relevant. For other indicators of cardiometabolic health, baseline blood pressure and biomarker values were within normal limits. Over the 12-month study period, there was little change in all values except HOMA-IR, where there was a median (IQR) 14% (-17.0-41.5) increase. For all biomarkers of cardiometabolic health, there was no difference between males and females. There were very weak correlations between baseline BMI and change in weight (r_s = 0.0039, $p = 0.98$) and change in waist to height ratio (r_s = 0.1897, $p = 0.16$)

Table 3 shows change in VO_{2max} for the 11 GAP able to complete a follow-up assessment prior to the COVID-19 pandemic leading to closure of the laboratory. Demographic profile and baseline anthropometry for these 19 participants were similar to the wider group of 56 (10 female, 9 male, median (IQR) age 26 (24-29) years, weight 77 (64.9-87.4) kg, BMI 24.1 (21.7-26.3) kg.m^2). Baseline aerobic capacity within the sub-group was of a moderate to good standard with median (IQR) 41.4 (36.3-47.6) ml.kg^{-1}.min^{-1}. As anticipated, there was a difference between male and female VO_{2max} (male, median (IQR) 45.3 (39.3-48.9) versus female, 38.1 (34.1-48.0)), but this finding was not statistically significant ($p = 0.11$). For those who completed the 12-month follow-up VO_{2max} assessment, no clinically or statistically significant change was noted, nor was there a difference between males and females. Physical activity monitoring showed mean (±SD) device compliance was 93.7% (±5.4%).

Table 4 shows quarterly physical activity data for the 19 participants that elected to wear a physical activity monitor. Over 12 months, there was no evidence to indicate a difference between quarters for the amounts of both steps per day (F (3, 54) = 0.86, $p = 0.47$) or minutes of MVPA per day (F (3, 54) = 0.16, $p = 0.92$), and there were weak correlations between baseline BMI and steps per day (r_s = −0.2298, $p = 0.34$) and minutes per day of MVPA (r_s = 0.2634, $p = 0.28$). Regarding the effect of shift type on physical activity, descriptive analysis showed that participants recorded the lowest mean values for steps per day on rostered days off, and lowest mean minutes of MVPA per day on day shifts. We elected to utilize rostered day off as the reference variable for both linear regression models. This effectively assessed the difference between day shift, afternoon shift, night shift and first day off compared to rostered day off for the physical activity variables. As seen in Table 5, both models demonstrated no significant association between shift type and amount of physical activity, except for MVPA where an effect was noted for day shift only ($p = 0.037$). This finding indicated GAP completed significantly less MVPA (nearly 15 minutes) on day shift when compared to rostered days off (ß = −14.68, 95% C.I. [−28.44, −0.93]).

Compared to baseline levels, the HRQoL Mental Health domain dropped by nearly 5% at 6 months and did not recover to baseline levels at 12 months. This change did not however reach statistical significance ($p = 0.29$). There was a small (1.2%) decrease in the Physical Health domain of the HRQoL at 6 months, but this had returned to within 0.2% of baseline at 12 months. Baseline data revealed moderately high fat consumption as percentage of total energy intake, lower than recommended median (IQR) percent energy intake from core foods at 72.5% (63.0-78.8) and higher than recommended non-core food as a percentage of energy intake at 27.5% (21.3-38.0). Furthermore, at baseline, paramedics consumed a median (IQR) 2.3 (0.63-5.0) standard drinks of alcohol per day and 68.5 (61.8-

TABLE 5. Linear regression output for association between physical activity (steps per day, MVPA) and shift type in GAP who wore a physical activity monitor (n = 19). Note: Rostered day off shift is the reference variable for both analyses

Shift Type (ref = Rostered day off)	ß	SE	t	p	[95% CI]
Steps					
Day	345.00	553.10	0.62	0.53	[−753.82, 1443.82]
Afternoon	596.58	678.35	0.88	0.38	[−751.08, 1944.23]
Night	433.53	596.47	0.73	0.47	[−751.47, 1618.52]
First day off	121.79	619.84	0.20	0.85	[−1109.63, 1353.21]
Constant	7412.42	488.98	15.16	0.00	[6440.98, 8383.86]
MVPA					
Day	−14.68	6.93	−2.12	0.04	[−28.44, −0.93]
Afternoon	−10.37	7.36	−1.41	0.16	[−24.99, 4.25]
Night	−8.58	7.26	−1.18	0.24	[−23.00, 5.84]
First day off	−10.32	6.33	−1.63	0.11	[−22.89, 2.25]
Constant	37.47	4.86	7.71	0.00	[27.81, 47.13]

186.2) mg per day of caffeine. The ARFS diet quality index showed most GAP were within the "getting there" and "excellent" categories, but few were "outstanding" or "needs work" (median 33, IQR 27.0-37.3). For macronutrients, alcohol, caffeine, percent energy intake and ARFS, there were no changes seen across the baseline 6- and 12-month timepoints. For percentage fat intake, however, there was a median 1% decrease between 6- and 12-months (p = 0.02).

DISCUSSION

This study found that in a sample of shift work naïve graduate paramedics, markers of cardiometabolic health (BMI, blood pressure, glucose, insulin, lipids and CRP) were within normal reference ranges at baseline and did not change in the first 12 months of their careers. However, some anthropometric measures and physical activity behaviors were identified that could lead to poor health outcomes if not addressed.

Although there were concerns regarding some baseline anthropometric measures for the male GAP in particular (48% with a BMI > 25.0 kg.m^2 at baseline), overall the group had a median BMI well below values seen in studies of North American EMS providers (8, 29), Australian paramedics and in other studies of both paramedics and the wider population (27, 30, 31). There was a statistically significant difference between males and females regarding BMI change over the 12-month period (males −0.7% versus females +1.7%). This 1.7% increase in weight for females (and the 1.1% increase weight for all participants) could result in substantial weight gain if that trend was to continue, as seen in other studies of young adults with similar age and demographics (32, 33). Longer term follow-up would help clarify if there is in fact a greater risk of weight gain for male or female paramedics. Baseline waist to height ratio in paramedics was less than the threshold of 0.5 that indicates increased cardiometabolic risk (28), and did not change in the study period. However, 18% of all participants were >0.5 at baseline. Waist to height ratio is increasingly recognized as a predictor of cardiometabolic health (28, 34), however few studies report waist to height ratio in paramedics or other health care workers. Given BMI and waist to height ratio were above normal levels among paramedics in the current study and these are simple and inexpensive assessments, they could be used widely in EMS to monitor staff health and provide data for longitudinal studies. However, it should be acknowledged that over the 12 months there were weak correlations between baseline BMI and change in weight, and baseline BMI and waist to height ratio.

Biomarkers of cardiometabolic disease risk in paramedics, including fasting lipids and C-reactive protein, did not change over the 12-month period and remained mostly within their respective reference ranges at each timepoint. The exception was for the glucose and insulin-derived metric HOMA-IR, where a ∼14% increase was noted between baseline and 12 months. This was primarily driven by a ∼9% increase in insulin. Although similar trends have been reported in other health care workers completing shift work (35), median HOMA IR was still less than the upper threshold reported in early work examining the utility of this metric (21), and fasting insulin was within the pathology laboratory determined reference range. Whilst shift workers are at risk for Type II diabetes, this small change is unlikely to be clinically significant at this stage of

TABLE 6. Health related quality of life and dietary characteristics of participants derived from the Australian Eating Survey Food Frequency Questionnaire (n = 56). Data expressed as median (IQR)

	Baseline		6 months		12 months		p[#]	Reference value
Health related Quality of Life (SF-36)								
Physical Health (/100)	85.4	(79.0-89.6)	84.2	(77.2-89.1)	85.2	(78.2-88.4)	0.75	76.7[†]
Mental Health (/100)	83.1	(73.0-88.2)	78.7	(72.5-84.3)	81.4	(74.2-87.0)	0.29	76.2[†]
Diet - Energy and Macronutrients								
Energy, kJ.day^{-1}	8695	(6940, 10563)	8415	(6987, 10669)	8739	(6751, 10292)	0.70	Male: 10,800-13,000[‡] Female: 8100-10,500[‡]
Carbohydrate, g.day^{-1}	234.9	(159.5, 276.8)	222.2	(184.4, 279.7)	227.2	(176.8, 275.5)	0.64	–
Sugar, g.day^{-1}	91.3	(65.4, 118.6)	91.9	(71.6, 118.8)	85.0	(65.8, 109.4)	0.85	–
Protein, g.day^{-1}	89.2	(68.4, 109.7)	86.0	(67.9, 119.3)	83.9	(63.4, 111.6)	0.40	–
Fat, g.day^{-1}	78.6	(65.1, 94.9)	78.8	(54.8, 103.0)	75.6	(55.5, 95.0)	0.24	–
Saturated fat, g.day^{-1}	27.2	(21.5, 33.7)	28.4	(18.6, 37.5)	26.5	(19.0, 35.9)	0.26	–
Dietary Fiber, g.day^{-1}	29.8	(23.0, 35.1)	30.2	(20.9, 37.7)	27.3	(22.1, 37.5)	0.50	28-38
Alcohol, drinks per day	2.30	(0.63, 5.0)	2.50	(0.6, 5.1)	2.40	(0.7, 7.4)	0.36	2-4
Caffeine, mg.day^{-1}	68.5	(61.8, 186.2)	74.3	(61.9, 185.6)	67.5	(62.4, 186.0)	0.79	<400
Diet - Percent energy intake								
Carbohydrate	45.0	(39.8, 49.0)	44.0	(40.0, 48.8)	45.5	(43.0, 49.8)	0.13	45-65
Protein	18.0	(16.0, 19.0)	17.0	(16.0, 20.0)	17.0	(16.0, 18.0)	0.32	15-25
Fat	36.0	(32.0, 40.0)[a]	36.0	(32.0, 38.8)[a]	35.0	(31.3, 37.8)[b]	0.02*	2-35
Saturated fat	13.0	(11.8, 14.0)	13.0	(10.3, 14.0)	12.5	(10.3, 14.0)	0.29	–
Alcohol	1.0	(0.0, 2.0)	1.0	(0.0, 2.0)	1.0	(0.0, 2.0)	0.33	<5
Core (healthy) foods	72.5	(63.0, 78.8)	70.5	(62.3, 77.0)	69.5	(63.3, 74.8)	0.62	85-90
Non-core (discretionary) foods	27.5	(21.3, 38.0)	29.5	(23.0, 37.8)	30.5	(25.3, 36.8)	0.62	0-15
ARFS[§]	33.0	(27.0-37.3)	33.0	(26.0-40.5)	34.5	(28.3-39.0)	0.38	>47

Dietary reference values: Nutrient reference values for Australia and New Zealand.

[‡]References for energy intake are intended as a guide only, and are based on 19-30 year old sedentary-to-moderately active males and females: https://www.nrv.gov.au/dietary-energy.

[#]Friedman test result (for data captured over three time points).

[a,b]Indicates significant differences between groups (Wilcoxon Signed-Rank test, Bonferroni correction), where a is significantly different from b.

*$p < 0.05$.

[†]Indicates reference for HRQoL from study of 747 Australian paramedics: MacQuarrie AJ, Robertson C, Micalos P, Crane J, High R, Drinkwater E, Wickham J. Fit for duty: the health status of New South Wales paramedics. Irish Journal of Paramedicine. 2018 Dec 10;3(2).

[§]Australian Recommended Food Score: (<33 "needs work", 33-38 "getting there", 39-46 "excellent", ≥47 "outstanding").

the career and does not insinuate increased insulin resistance per se. Nonetheless, close monitoring over the long-term may allow for early detection.

Maximal aerobic capacity among paramedics in the current study was moderate-to-good, but not excellent. Results were comparable to those seen in normative data for similar age groups (36), but lower than that seen in a study of older helicopter rescue paramedics (median (IQR) age 45 (42-48) years, VO_{2max} 47.0 (43.0-54.6) ml.kg^{-1}.min^{-1}) from the same EMS (20). By comparison, a longitudinal study of student paramedics in Finland showed similar baseline VO_{2max} values to GAP, however small increases in aerobic capacity were noted in that study (male +3.0%, female +5.9%) (37), whereas male and more so female GAP in the present study demonstrated a small decline (male −1.5%, female −8.4%). Cardiorespiratory fitness has been demonstrated to be inversely proportional to incidence of metabolic syndrome in firefighters (38), and is associated with improved cardiometabolic health and pancreatic beta cell function, hence decreased risk for Type II diabetes (39). Thus, VO_{2max} may be a useful metric for longitudinal monitoring in paramedics, but also an area of health to focus on to improve long term health outcomes in new recruits. However, to monitor cardiorespiratory fitness long-term, the laboratory-based methods used in the current study may be logistically and financially prohibitive. Therefore, simple and accurate surrogate tests of maximal aerobic capacity, such as the 6-minute walk test, may be more appropriate for use in this population (40, 41).

Previous work investigating activity levels in paramedics indicated that they face many impediments to undertaking regular physical activity (13). The cohort of GAP who wore activity monitors did not meet minimum recommendations for steps per day (42), but recommended minutes of MVPA per week were exceeded (12). However, both steps and MVPA in paramedics were lower than seen in recent study of Canadian nurses (43). There were no statistically significant differences in the amounts of essential physical activity when compared to shift type, but GAP still completed fewer absolute amounts of steps per day and minutes of MVPA on the first day off after a nightshift. Post-night shift fatigue appears to have had an effect on physical activity volume in the current study. Although previous work has demonstrated shift workers undertake similar amounts of leisure time physical activity as the general population (44), paramedics may benefit from encouragement to maintain consistency across the on/off work cycle, especially when in a state of relative fatigue and possibly low motivation. Roster data provided by AV did not allow for differentiation between physical activity undertaken whilst performing job-related tasks, other physical activity that may be undertaken at work, or activity undertaken outside of rostered hours (e.g., commuting, exercise before or after the shift), but enabled general reporting of how active paramedics are when on or off duty. Further work is needed to investigate whether GAP occupational tasks and other activities lead to high levels of essential physical activity, and to ascertain if GAP physical activity levels play a role in decreasing cardiometabolic health risk as the career advances.

When compared to a study of experienced rural paramedics from another Australian EMS, participants in this study reported HRQoL that was 8.5% higher for physical health and 5.2% higher for mental health. However, the paramedics in that study had mean (±SD) 9.98 (±6.12) years' experience and were significantly older (43.51 ± 9.42 years). Longitudinal surveillance of HRQoL may allow for early detection of deterioration in quality-of-life measures and early intervention. Additionally, in our study there was a 5% decrease in the mental health score at 6 months, and the 12-month score did not recover to baseline. The decrease at 6 months did not reach statistical significance, but the finding presents an opportunity for further work to explore if this was a clinically significant change.

Dietary assessment via the FFQ revealed a normal energy intake among paramedics at each timepoint when compared to recommendations for daily energy intake in moderately active young adults in Australia, and macronutrient consumption was distributed appropriately and within recommended values (45). Macronutrient distribution and macronutrient percentage of total energy intake were similar to that seen in physically active Australian firefighters, but daily energy intake was noticeably lower (14). Daily energy intake in GAP aligns with moderate levels of occupational and personal time physical activity discussed previously. Whilst dietary profile indicated even distribution of macronutrient consumption, non-core/discretionary foods (defined as highly processed or take-away/fast food) was almost double the recommended percentage of energy intake at each timepoint (16). As such, the ARFS indicated the majority of GAP were in the "getting there" category for diet quality at each timepoint (baseline 33.0, 6-months 33.0 and 12-months 34.5). This is comparable to a study of Australian university students who had a similar mean (±SD) age of 26.9 (±10.5) years and similar ARFS of 33.0 (±10.3) (46). Conversely, a study in male military personnel of similar mean (±SD) age 28.7 (±8.9) years recorded an ARFS of 37.6 (±7.7) (47), and older helicopter rescue paramedics working in the same service as our cohort scored an ARFS of median (IQR) 38 (30-45) (20). Behavioral traits, environmental and lifestyle factors from participants in these comparison studies may inform strategies to improve diet quality, and indices such as the ARFS and may be useful to track dietary changes in longitudinal studies in EMS personnel.

The summary profile of cardiometabolic health, dietary patterns and physical activity levels in GAP showed that although baseline health was reasonable and no significant changes occurred in their first year, there are some areas where targeted interventions may help prevent declines in health that may occur as paramedics' careers progress. Further work is required to gain a deeper understanding of how EMS organizations and educational institutions (i.e., universities providing undergraduate paramedicine programs) can prepare their junior workforce for the rigors of shift work in health care. Such work may include studies of interventions including meal preparation education and physical activity promotion that can assist student paramedics and new staff with their transition to shift work. These need to be targeted to a young audience who may not have an awareness or concerns regarding health decline during their careers.

STRENGTHS AND LIMITATIONS

This was a longitudinal study with a large amount of novel and important data. We recruited equal numbers of women and men, which aids generalizability of the results to both sexes. The study had relatively small loss to follow-up, especially considering the COVID-19 pandemic was declared in the last 3-6 months of data collection. Although our sample size was small, it represented nearly 29% of GAP recruited to the EMS during the study period. As all GAP personnel perform similar duties and most will commence their careers soon after degree completion, participants in the current study are of a similar demographic profile to the wider population of GAP in this EMS. However, the sample size limits inferences that can be made regarding GAP in other jurisdictions. There was a risk of selection bias in that highly motivated GAP may have been more inclined to participate in the study. This appeared to be minimized however, with a wide range of baseline health and physical activity levels. Another limitation was the limited reference data available from similar occupational populations. However, we were able to compare results with published reference ranges from the wider general population. We acknowledge the limitations of BMI in certain cohorts (e.g., very muscular people), and future work should consider additional measures of body composition (e.g., body fat percentage). As this study recruited participants via purposive and convenience sampling methods, the relatively small sample size means that detailed analyses of subgroups (e.g., those that started their careers with higher body weight) would not be meaningful. Further validation of these results in a larger sample would be useful and allow for detailed subgroup analyses.

Conclusion

In this sample of graduate paramedics with no prior exposure to shift work, dietary patterns, HRQoL, cardiometabolic health, aerobic capacity and physical activity levels did not change meaningfully in the first year of practice. However, baseline BMI, physical activity levels and some dietary behaviors were suboptimal. Programs that optimize these factors prior to, and at the point of career commencement, may better prepare paramedics to combat the negative health effects of shift work. Long-term longitudinal studies of paramedics from the beginning of employment may identify at which point in a career negative health effects may manifest.

Author Contributions

Ben Meadley: Conceptualization, Methodology, Investigation, Validation, Data curation, Formal analysis, Writing- Original draft preparation, Writing-Reviewing and Editing, Project Administration, Funding Acquisition. **Alexander P. Wolkow:** Investigation, Writing- Reviewing and Editing. **Luke Perraton**: Methodology, Investigation, Writing-Reviewing and Editing, Supervision. **Karen Smith:** Resources, Writing- Reviewing and Editing, Supervision, Funding acquisition. **Kelly-Ann Bowles:** Investigation, Writing- Reviewing and Editing, Supervision. **Maxine P. Bonham:** Conceptualization, Methodology, Investigation, Validation, Formal analysis, Writing- Reviewing and Editing, Supervision, Project Administration.

Data Availability

Deidentified data is available upon reasonable request from the corresponding author (BM).

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3.3 Summary of Chapter Three

This is the first study to quantify baseline health status and change in health outcomes in graduate ambulance paramedics as they start their careers in paramedicine. Over the 12 months of studying these 56 paramedics, body weight and BMI decreased in males and increased in females. There was a small decrease in self-reported mental health at 6 months, but overall, quality of life and dietary intake did not change. Biomarkers of cardiometabolic health were within normal range and did not change, except for a small increase in insulin. Baseline aerobic capacity was good, with no change noted at 12-months. Paramedics completed less than recommended steps per day, but levels of moderate to vigorous physical activity were slightly higher than recommended.

3.3.1 Supplementary findings

In addition to the results presented in Chapter Three, further measures were taken as part of this longitudinal study. Although these results and findings were not presented within the manuscript, their implications are significant for future research. In the study described in Chapter Three, the glucose results were reported from the venous blood samples collected via BD K2E Plus EDTA 4.0mL tubes, (Becton Dickinson, Franklin Lakes, New Jersey USA) and formal pathology laboratory analysis. As a failsafe and given the ease of measuring glucose via commercial glucometer, we elected to measure point of care glucometer-derived glucose in addition to the venous blood tube samples. Notably, our comparisons indicated that mean (±SD) values did not differ between the venous laboratory derived glucose and the portable glucometer measured value (5.5 (±1.5) versus 5.4 (±1.5) mmol.L^{-1}, p=0.67, paired t-test).

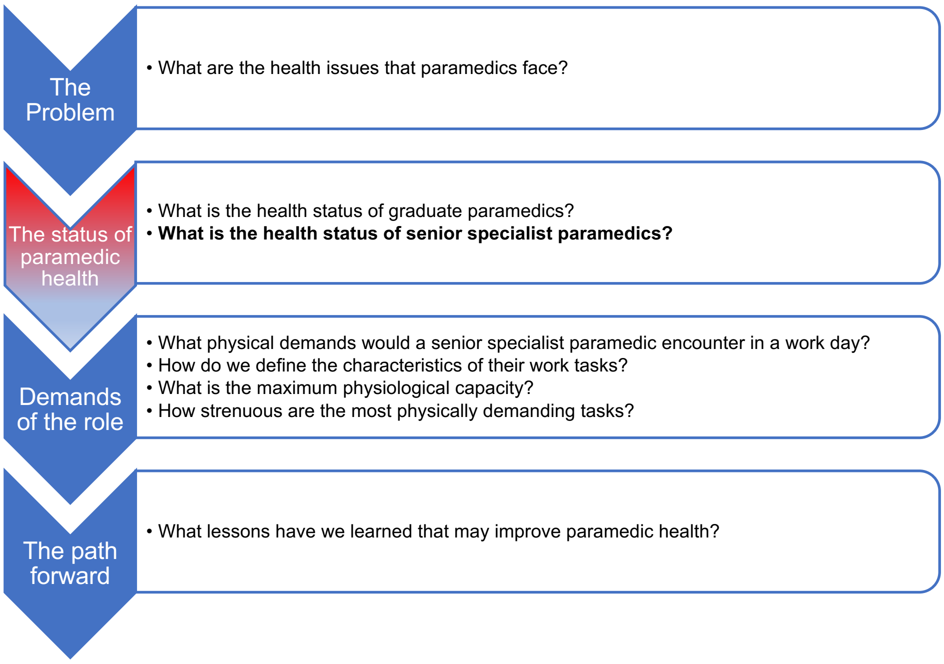
Additionally, when outside the laboratory for extended periods, the stability of the EDTA tube samples, and other tubes used (e.g., fluoride oxalate tubes) to collect and measure plasma glucose may vary (88, 89). For 15 of the 56 participants described in Chapter Three, 12 month follow up assessment including blood collection occurred at a location greater than 30 minutes from the laboratory. To ensure the accuracy of the follow-up glucose assessments, we added BD FX 2.0mL Fluoride Oxalate tubes (Becton Dickinson, Franklin Lakes, New Jersey USA) to the EDTA and glucometer assays. We found no significant difference between EDTA tube, FX tube and glucometer derived blood glucose ($F(2, 42) = 1.67$, $p=0.21$, one way repeated measures ANOVA). A commercial glucometer-derived blood glucose level appears to be an acceptable surrogate for venous sampling compared to either the EDTA or FX tube venous samples and the associated pathology laboratory analysis. Glucometer use may decrease cost, logistical burden and provide rapid results. For its ease of access, cost-effectiveness, reliability to detect metabolic changes and to prompt further investigation for insulin resistance, glucose assessment via commercial glucometer is a practical biomarker assay for population wide research and monitoring of cardiometabolic health risk in paramedics.

In summary, Chapter Three demonstrated that there were no changes in dietary patterns, quality of life, cardiometabolic health, aerobic capacity, or physical activity levels, but some dietary behaviours and physical activity levels could be improved. From this study, it appears no significant changes to cardiometabolic and physiological health manifest in the first year of practice. Long term follow-up of this cohort is essential to detect if and when markers of poor health appear. The studies outlined in Chapter One indicate that it is reasonable to assert that paramedics with extended careers in paramedicine will demonstrate some signs of poor systemic health after many years of shift work. As such, to examine whether a subgroup of the paramedic population with extended careers in paramedicine show signs of poor health, the next chapter investigates dietary and cardiometabolic health, aerobic capacity, HRQoL and physical activity in a sample of experienced helicopter rescue paramedics (ICFPs).

Chapter Four: Assessment of Cardiometabolic health and physical activity in helicopter rescue paramedics

4.1 Preamble

The research reported in Chapter Three indicated that there was little change in graduate paramedic health status during the first year of practice; a finding that was surprising but welcomed. However, the small changes that were seen may indicate the start of a trend. Long term follow-up (beyond the scope of this thesis) is required to detect such trends. Additionally, there were some health behaviours that could be considered sub-optimal, such as, levels of physical activity and some dietary behaviours. Long-term data from previous studies in paramedics have demonstrated poor health outcomes, therefore it would seem prudent to undertake health assessments in paramedics who have worked in the profession for an extended period. In a cross-sectional study detailed in this chapter, 15 experienced and senior specialist paramedics (ICFPs) working for Ambulance Victoria's helicopter emergency medical service underwent the same assessments as the graduate paramedic group described in Chapter Three. The study aimed to ascertain whether an experienced, specialist sub-group of the paramedic profession showed indications of poor health after an extended career in paramedicine.



4.2 Manuscript

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Assessment of Cardiometabolic Health, Diet and Physical Activity in Helicopter Rescue Paramedics

Ben Meadley, GradDipEmergHlt, Luke Perraton, PhD, Karen Smith, PhD, Maxine P. Bonham, PhD and Kelly-Ann Bowles, PhD

Abstract

Objective: Shift work is an established risk factor for weight gain, cardiovascular disease, Type II diabetes mellitus, and impaired health-related quality of life (HRQoL). Prolonged exposure to shift work is common in paramedics and other emergency medical service (EMS) providers. Sub-populations of EMS workers may have varying health outcomes when exposed to shift work, but the reasons for this have not been investigated. We sought to describe cardiometabolic health, dietary patterns, physical activity, and health-related quality of life (HRQoL) in a sample of experienced intensive care flight paramedics (ICFPs) working for a Helicopter Emergency Medical Service (HEMS). **Methods:** Fifteen paramedics (median age 45, IQR 42–48 years) were recruited to undertake a range of health assessments. These included a food frequency questionnaire to assess dietary patterns, sampling of biomarkers to determine cardiometabolic health risk, maximal aerobic capacity assessment via treadmill running and assessment of HRQoL via the SF-36 survey. In an extension of the study protocol, ten of the fifteen participants wore a physical activity monitor for one year. **Results:** Median (IQR) weight was 79.9 (72.3–89.3) kg, body fat percentage 23.3 (21.9–26.5) %, body mass index (BMI) 25.1 (21.9–27.4) kg.m^2, and waist to height ratio 0.48 (0.45–0.54). Dietary analyses showed high discretionary food intake. Biomarkers of cardiometabolic health risk were all within normal range. HRQoL was 86.2/100 for physical health and 85.1/100 for mental health. VO_{2max} was 47.0 (43.0–54.6) mL.kg^{-1}.min^{-1}. The ten participants that wore activity monitors completed 11,235 (8334–15,380) steps per day and undertook 50 (12–98) minutes per day/350 (84–686) minutes per week of moderate to vigorous physical activity. The least amount of physical activity was conducted on day shifts. **Conclusions:** For ICFPs included in this study, HRQoL, cardiometabolic and physical activity outcomes are representative of good health. Although shift work influences the amount of physical activity, ICFPs exceeded minimum recommendations even when rostered to duty. Despite lengthy careers in EMS, ICFPs demonstrate an excellent health profile that is likely due to high physical activity levels and healthy BMI. This information may be useful in guiding health interventions in the wider EMS workforce.
Key words: paramedic; emergency medical services; cardiometabolic; nutrition; physical activity

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BM is an operational ICFP with Ambulance Victoria. Ambulance Victoria had no influence on study design, protocol development or reporting of results. All other authors have no competing interests to declare.

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Deidentified data is available upon reasonable request from the corresponding author (BM).

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INTRODUCTION

When work is performed in opposition to our circadian rhythms, detrimental effects on health and wellbeing can manifest (1, 2). Shift work is an established risk factor for weight gain, cardiovascular disease, Type II diabetes, impaired health-related quality of life (HRQoL), and mental health (3–5).Yet, shift work is necessary for the delivery of an emergency medical service (EMS). A number of mechanisms are proposed for long-term poor health in paramedics and other shift workers, including chronic exposure to critically unwell and injured adults and children, circadian biological rhythm misalignment, sleep disturbance, poor nutrition, limited physical activity, and musculoskeletal injury (3, 4, 6, 7). These factors are likely contributors to the high incidence of obesity and metabolic, cardiovascular and inflammatory diseases reported in chronic shift workers, including paramedics (3, 4, 7, 8). It is important to investigate the specific elements of health that can be targeted to minimize the effects of chronic shift work on the EMS workforce.

There are many elements of good health, with a key pillar being a balanced diet. Shift workers report a number of barriers to accessing healthy foods, including reliance on take away food, and lack of meal breaks (9, 10). Recent work has indicated that manipulation of meal timing (e.g., limited eating overnight) and altering macronutrient composition may have a role in reducing the excursions in plasma glucose and insulin that are seen in shift workers (11–13), Little is known about the macronutrient composition of paramedics' diet, but it can be assessed via instruments such as food frequency questionnaires (FFQ) (14). In addition, biomarkers of cardiometabolic health (such as lipid profile and insulin resistance scores), body composition and anthropometric data can be combined with dietary information to build a cardiovascular and metabolic health profile (15, 16), which may be useful for identifying disease risk and developing strategies to improve the health of EMS personnel.

Specific forms of physical activity including steps per day and minutes per day of moderate to vigorous physical activity (MVPA) have a proven role in the prevention of disease and contribute to improved cardiometabolic health (17–20). Self-reported data from an Australian EMS suggests that paramedic work could be a barrier to regular physical activity (21). To capture and analyze physical activity data, modern consumer-level wearable fitness trackers have demonstrated cost-effectiveness, validity and reliability (22–24), and such work has been conducted in other health professionals (25). It is important to gain a greater understanding of these various elements of health in occupations such as EMS, to target interventions aimed at enhancing health-related quality of life (HRQoL), increasing physical activity and decreasing cardiometabolic health risk. Improvements in these areas may lead to decreased rates of job-related health problems, workers compensation claims, and employee attrition.

Paramedics working in specialist helicopter teams represent a small proportion of the EMS workforce. Their roles require extensive EMS experience prior to commencement thus extended exposure to shift work. Additionally, their roles are considered physically demanding (26), requiring the satisfaction of specific physical standards. We sought to report HRQoL, nutritional and cardiometabolic health, aerobic capacity, and physical activity levels in a sample of helicopter rescue paramedics who have established careers in EMS. Our aims were to (i) describe the HRQoL, cardiometabolic health and dietary patterns of helicopter rescue paramedics, and (ii) describe cardiovascular fitness and the influence of shift type on physical activity levels.

METHODS

Study Setting

We conducted a cross sectional study of helicopter rescue paramedics (termed intensive care flight paramedics, ICFPs) working for a state EMS. The state of Victoria, Australia covers an area of approximately 237,629 km^2 including remote terrain and more than 2000 km of coastline. Ambulance Victoria (AV) is the single EMS, providing care to Victoria's population of nearly 6.4 million people. In addition to ground-based EMS, AV is the provider of Helicopter Emergency Medical Services (HEMS). HEMS responsibilities include emergency medical response, critical care interhospital transfer and physically demanding land and water search and rescue (usually involving deployment to a scene via an external hoist/winch) and overall workload in the service is relatively high and has been reported previously (27). Aircraft are staffed by an ICFP, a pilot and an air crew officer (who provides the ICFP with medical task assistance, operates the winch and performs co-pilot duties). At the time of the study, AV employed 45 ICFPs (approximately 1% of the AV paramedic workforce), who are senior paramedics generally possessing at least ten years' experience as a general duties and ground based intensive care paramedic prior to commencing work as an ICFP. Paramedics in Australasia are tertiary-qualified registered health care professionals meaning they are well remunerated and secondary employment to supplement income is uncommon. ICFPs undertake search and rescue tasks that require them to meet ongoing specific physical standards, however, they do not have a prescribed exercise regime per se. The ICFPs shift pattern is two day shifts from 0700–1700 hours, followed by two night shifts from 1700–0700 hours, followed by 4 days off. AV HEMS operations has been described in detail in previous work (27, 28).

Participants

Participants were recruited from the operational workforce of AV ICFPs via an email sent to all members of staff. Inclusion criteria required current employment as an ICFP. Written informed consent to participate in all aspects of the study was obtained from each individual participant. This study was approved by the Monash University Human Ethics Research Committee (Project numbers 16340, 17784) and the Ambulance Victoria Research Committee (Project numbers R18-023, R18-033).

Fifteen ICFPs (13 male, 2 female) volunteered to participate in the study (33.3% of all AV ICFPs), which included assessments of anthropometry, body composition, heart rate and blood pressure, biomarkers of cardiometabolic health, HRQoL, dietary patterns, and aerobic capacity. Ten of those 15 ICFPs (9 male, 1 female) volunteered to participate in an extension of the study (22.2% of all AV ICFPs), which added the wearing a physical activity monitor for 12 months. Of note, at the time of the study, only two females were qualified as ICFPs at this HEMS, with a further two in training. To ensure that confidentiality of participants was maintained and to abide by the project's ethical approval, anthropometric and body composition data was not separated by sex.

Measurements

All participants (n = 15, 2 female, 13 male) undertook the following assessments:

Pre-Assessment Preparation

Prior to reporting to the laboratory at the Be Active, Sleep and Eat (BASE) facility at Monash University, all participants were required to avoid strenuous exercise for the preceding 24 hours, be well-rested, free from illness for the preceding 14 days, and fasted for the previous 12 hours. Participants were required to complete a form that described basic demographics and paramedic experience. All assessments were conducted between 0700–1000 hours.

Anthropometry, Body Composition, Heart Rate, and Blood Pressure

For each of the following assessments, the value was measured twice, and the mean recorded: Heart rate and blood pressure was measured on the left arm using the Welch Allyn Connex 3400 ProBP Automatic Blood Pressure Machine (Welch Allyn Skaneateles Falls, New York, USA) after five minutes sitting at rest. Waist circumference was measured using a metric fabric tape measure at the level of the umbilicus (29, 30), height was measured using a SECA 213 portable stadiometer (SECA, Hamburg, Germany), and waist to height ratio was calculated from these values. Body composition was assessed using a validated bioelectrical impedance device (31) (SECA 515 mBCA body composition analyzer, SECA, Hamburg, Germany), and variables recorded were: weight, fat mass, fat free mass, and body mass index.

Biomarkers of Cardiometabolic Health

All participants had blood sampled via venipuncture of the antecubital vein using a 21-gauge butterfly needle, extension tube and tube connector (Grenier Bio-one, Kremsmunster, Austria). If difficulties were encountered, ultrasound-guided venous access was performed (GE VScan Dual Probe, GE Healthcare, Chicago, Illinois, USA). Three blood tubes were used to collect blood samples: two BD K2E Plus EDTA (plasma; glucose, insulin) and one BD SSTII Advance Plus (serum; lipid profile) (Becton Dickinson, Franklin Lakes, New Jersey, USA). EDTA and SSTII tubes were inverted eight times immediately post blood collection. SSTII tubes were left to stand at room temperature (20–22 degrees) and allowed to clot. EDTA tubes were immediately centrifuged at 1500 G for 15 minutes at 4 °C. Thirty minutes after sampling, SSTII tubes were centrifuged at 1300 G for 10 minutes at 22 °C (Eppendorf 5702 R centrifuge, Eppendorf, Hamburg, Germany). Samples were aliquoted and stored at −80 °C. Samples were transported from −80 °C freezer storage via polystyrene cooler with dry ice to an external laboratory for analysis (Monash Health Pathology, Clayton, Victoria, Australia).

Fasting plasma glucose was measured by a standard commercial rate assay via the oxygen rate method using a glucose oxygen electrode on a Beckman Coulter DXC800 Analyzer, with standard reagents and calibrators (Beckman Coulter Diagnostics, Mount Waverley, Victoria, Australia).

Fasting plasma insulin was measured via the Access/DXI Ultrasensitive Insulin assay, a simultaneous one-step immuno-enzymatic assay (Beckman Coulter Diagnostics, Mount Waverley, Victoria, Australia). Total cholesterol, LDL, HDL, and triglycerides were measured by a standard commercial enzymatic assay using a Beckman Coulter LX20PRO Analyzer, with standard reagents and calibrators (Beckman Coulter Diagnostics, Mount Waverley, Victoria, Australia). The homeostatic model assessment of insulin resistance (HOMA-IR) is an established metric to estimate insulin resistance, and was calculated as a product of fasting plasma glucose ((mmol.L^{-1} $\times$ 18.0182) = G_0, mg/dL) and fasting plasma insulin (I_0, mIU/L) divided by the constant 405: HOMA IR = $(G_0 \times I_0)/405$ (32).

Health-Related Quality of Life (HRQoL)

All participants completed the Rand 36-item Health Survey (SF-36), a validated, self-reported assessment of mental and physical health domains (33, 34). We did not analyze sub-domains and only reported on Physical and Mental Health summary outcomes to estimate HRQoL. The resultant summary scores for Physical and Mental health are presented as a value out of a maximum possible score of 100.

Dietary Patterns

Dietary intake was assessed using the validated Australian Eating Survey (AES) Food Frequency Questionnaire (FFQ) (14). The AES assesses intake of 120 commonly consumed foods, alongside 15 behavioral and demographic questions pertaining to the previous six months. The questionnaire is categorized according to the food groups of drinks, breads and cereals, main meals, fruit and vegetables, dairy products, sweets, and snacks. Adult portion sizes are standardized and are determined from data of the National Nutrition Survey (14). Overall energy intake, and food group contribution to average energy intake is calculated. Additionally, the FFQ produces a diet quality index, termed the Australian Recommended Food Score (ARFS). The ARFS is a tool used to score overall diet quality, and scores for six food group categories (35). Results of the ARFS are compared against a maximum score and total ARFS is ranked as: "needs work," "getting there," "excellent," or "outstanding."

Aerobic Capacity

Prior to the assessment of maximum oxygen uptake ($\dot{V}O_{2max}$), all participants were required to complete the Exercise and Sports Science Australia Pre-Exercise Screening Tool to exclude risks to completing a maximal exercise test (36). $\dot{V}O_{2max}$ was estimated by indirect calorimetry (Vmax Encore Metabolic Cart: Carefusion, Sand Diego, California, USA) during continuous incremental exercise test to volitional exhaustion on a motorized treadmill (MyRun, Technogym, Seattle, Washington, USA). We used our standard laboratory protocol (including equipment calibration) that has been described previously (37). Briefly, participants were familiarized with the test protocol then completed a 3 min warm up at a self-determined pace. The protocol commenced at 6 km.hr^{-1} with an incline of 1.5%, with speed increased every 3 min up until 14 km.hr^{-1}, after which incline was increased by 2.5% until exhaustion. Heart rate was measured continuously via a Polar FT1 watch and H10 heart rate monitor strap (Polar Electro Oy, Kempele, Finland). Tests were terminated at volitional exhaustion, and the $\dot{V}O_{2max}$ recorded.

Physical Activity

Ten of the 15 participants (1 female, 9 male) volunteered to wear a wrist-mounted activity monitor (Versa, FitBit, San Francisco, California, USA) as much as possible for 365 days. Activity monitors were synchronized to a central database (Fitabase, San Francisco, California, USA), and participants were blinded to their detailed physical activity data. A member of the research team monitored the database daily and contacted participants by email or text message if their device did not synchronize with the database for more than five days (the threshold for loss of data from the device's internal memory). The threshold for activity data inclusion and, therefore, participant compliance was if ≥100 steps per day were recorded in a 24-hour period. All days where <100 steps were recorded were excluded from the analysis. We analyzed the remaining data for steps per day, minutes per day of sedentary time, minutes per day of light activity and minutes per day and per week of MVPA. AV provided shift roster data for each participant, and we aligned physical activity data with each shift (day shift, night shift, the first day off after the second/final night shift and other rostered days off). The ICFPs in this study generally worked a fixed roster of two 10-hour day shifts (0700–1700 hours), followed by a 24-hour break, then two 14-hour night shifts (1700–0700 hours). After the end of the second night shift ICFPs would commence four rostered days off. For our analysis first day off represents the time commencing 0700 at the end of the second night shift. On rostered days

TABLE 1. Descriptive characteristics, markers of cardiometabolic health, physical activity levels, and health-related quality of life (HRQoL)

Demographics			ICFP Group§
Male†	13	(86.6)	43 (95.5)
Female†	2	(13.4)	2 (4.5)
Age, years	45	(42–48)	48 (43–52)
Paramedic experience, years	18	(15–23)	21 (16–27)
Intensive care experience, years	12	(9–17)	16 (11–21)
ICFP experience, years	6	(3–10)	8 (5–15)
Cardiometabolic health (n = 15)			Reference range
Weight, kg	79.9	(72.3–89.3)	–
FFM, kg	61.8	(57.2–67.7)	–
Body Fat, %	23.3	(20.0–26.5)	–
Body Mass Index, $kg.m^{-2}$	25.1	(21.9–27.4)	18.5–24.9
Waist: Height ratio	0.48	(0.45–0.54)	<0.50
BP systolic, mmHg	136	(124–139)	<129
BP diastolic, mmHg	81	(79–84)	<80
Fasting glucose, $mmol.L^{-1}$	5.7	(5.4–6.0)	3.6–6.0
Fasting insulin, mIU/L	3.5	(3.1–5.7)	3.0–8.0
Total cholesterol, $mmol.L^{-1}$	5.7	(5.6–6.4)	<5.2–6.2
HDL, $mmol.L^{-1}$	1.4	(1.2–1.6)	09–1.5
LDL, $mmol.L^{-1}$	3.9	(3.3–4.4)	0–4.5
Triglycerides, $mmol.L^{-1}$	1.1	(0.9–1.7)	0.6–2.0
HOMA IR	0.9	(0.7–1.6)	0.5–1.4
Physical activity			Reference
Maximal aerobic capacity (n = 15)			
VO_{2max} ($mL.kg^{-1}.min^{-1}$)	47.0	(43.0–54.6)	–
Physical activity monitoring (n = 10 of 15)			
Device compliance (%, ≥100 $steps.day^{-1}$) *	97.4%	(±4.8)	>75%
$Steps.day^{-1*}$	11,912	(±2162)	≥10,000
Sedentary time, $min.day^{-1*}$	684	(±90)	–
Light activity, $min.day^{-1*}$	284	(±28)	–
MVPA, $min.day^{-1*}$	65	(±25)	–
MVPA, $min.week^{-1*}$	455	(±173)	>150
Health-related Quality of Life (n = 15)			
Physical health (/100)	86.2	(81.2–87.8)	††73.6
Mental health (/100)	85.1	(68.6–90)	††68.0

Data are expressed as median (IQR), except where † indicates number (%) and * indicates mean (SD).
§indicates reference demographic data for entire ICFP population provided by AV.
††indicates reference for HRQoL from study of 747 Australian paramedics: MacQuarrie AJ, Robertson C, Micalos P, Crane J, High R, Drinkwater E, Wickham J. Fit for duty: the health status of New South Wales paramedics. Irish J Paramed. 2018;3(2).

off, ICFPs may complete additional shifts to fill vacancies and/or for mandatory training. The shift data provided by AV included all rostered shifts including additional shifts but did not allow for differentiation between regular rostered days off and vacation time or sick leave.

STATISTICAL METHODS

Data were assessed for normality using Shapiro-Wilk tests and via visualization of histograms. For data that was found to be normally distributed, parametric tests were used and data presented as mean and standard deviation. For data that was found not to be normally distributed, non-parametric tests were used and data presented as median and IQR. As physical activity data were collected prospectively, we were able to match these data to shift type, and, therefore, investigate association between shift type and essential physical activity (number of steps and MVPA per day). Steps per day and MVPA were grouped by shift type to allow further descriptive analysis. Simple linear regression was performed to investigate the relationship between steps and shift type, and MVPA and shift type. Statistical analysis was performed using Stata version 16.1 (StataCorp, College Station, Texas, USA), and statistical significance for the longitudinal physical activity data was determined *a priori* at $p < 0.05$.

RESULTS

Table 1 outlines participant demographics, cardiometabolic health, physical activity and HRQoL with reference to international recommendations where

TABLE 2. Dietary energy, macronutrient intake, alcohol and caffeine intake, and percentage of energy intake derived from the Australian Eating Survey Food Frequency Questionnaire

	Median (IQR)	Recommended values
Energy and macronutrients		
Energy intake (kJ.day^{-1})	12,586 (8602–14,611)	8000–9000
Energy intake (kCal.day^{-1})	3008 (2056–3492)	1900–2150
Protein (g.day^{-1})	116.8 (70.0–139.0)	–
Carbohydrates (g.day^{-1})	288.2 (219.0–351.2)	–
Sugar (g.day^{-1})	148.0 (100.4–160.9)	–
Dietary fiber (g.day^{-1})	31.1 (26.7–41.7)	28–38
Fat (g.day^{-1})	117.8 (67.7–125.9)	–
Sat fat (g.day^{-1})	38.0 (20.6–46.4)	–
Alcohol (standard drinks)	1.4 (0.6–2.5)	0–2
Caffeine (mg.day^{-1})	187.0 (69.9–198.5)	≤400
Percent energy intake		
Protein (% EI#)	16 (14–19)	15–25
Carbohydrate (% EI#)	44 (42–46)	45–65
Fats (% EI#)	33 (31–38)	20–35
Alcohol (% EI#)	5 (3–13)	<5
Core foods (% EI#)	70 (56–74)	85–90
Non-core/discretionary foods (% EI#)	30 (26–44)	0–15
ARFS§	38 (30–45)	>47

#EI = energy intake.
§Australian Recommended Food Score: (<33 "needs work", 33–38 "getting there", 39–46 "excellent", ≥47 "outstanding").

possible. Participants were predominantly in their fifth decade with a median (IQR) age of 45 (42–48) years and had extensive EMS experience with 18 (15–23) years' as a paramedic including 6 (3–10) years in the ICFP role. For measures of anthropometry and body composition, median (IQR) body mass was 79.9 (72.3–89.3) kg, and body fat percentage was 23.3 (21.9–26.5) %. Median (IQR) body mass index (BMI) was 25.1 (21.9–27.4) kg.m^{-2}, and waist to height ratio was 0.48 (0.45–0.54).

Hemodynamic assessment showed resting heart rate was median (IQR) 64 (60–72) bpm, systolic blood pressure was 136 (124–139) mmHg and diastolic blood pressure was 81 (79–84) mmHg. For cardiometabolic health biomarker assessments, lipid profile indicated total cholesterol was 5.7 (5.6–6.4) mmol.L^{-1}, high density lipoprotein (HDL) 1.4 (1.9–1.6) mmol.L^{-1}, low density lipoprotein (LDL) 3.9 (3.3–4.4) mmol.L^{-1}, and triglycerides 1.1 (0.9–1.7) mmol.L^{-1}. Fasting glucose was 5.7 (5.4–6.0) mmol.L^{-1} and fasting insulin 3.5 (3.1–5.7) mIU/L^{-1}. Median HOMA IR was calculated from these values and demonstrated low incidence of insulin resistance at 0.89 (0.7–1.57). For self-reported HRQoL, physical health was median (IQR) 86.2/100 (81.2–87.8), and mental health was 85.1/100 (68.6–90). Maximal aerobic capacity was high (relative to age) with a median (IQR) VO_{2max} of 47.0 (43.0–54.6) mL.kg^{-1}.min^{-1}.

Table 2 details the dietary information from the FFQ. Estimated daily energy intake was median (IQR) 12,586 (8602–14,611) kJ, with 70% from "core" (healthy) foods and 30% from discretionary (unhealthy) foods. Based on normative data used in the AES FFQ (14), percent energy intake (%EI) was within normal ranges for all macronutrients. Paramedics consumed a median (IQR) 1.4 (0.6–2.5) standard drinks of alcohol per day and 187.0 (69.9–198.5) mg per day of caffeine. The ARFS diet quality index showed most ICFPs were within the "getting there" and "excellent" categories, but none were "outstanding" or "needs work" (median 38, IQR 30–45).

Table 1 details physical activity data for the 10 participants that wore a physical activity monitor. Mean (±SD) device compliance was 97.4% (±4.8%), paramedics completed 11,912 (±2162) steps per day and undertook 65 (±25) minutes per day/455 (±173) minutes per week of MVPA. Of all recorded daily physical activity data, sedentary time represented 64.4%, light activity 30.5% and MVPA 5.1%.

Regarding the effect of shift type on physical activity, descriptive analysis showed that ICFPs recorded the lowest mean values for both steps per day and MVPA per day on day shifts. Therefore, day shift was used as the reference variable for both linear regression models. This effectively assessed the difference between night, first day off and rostered day off compared to day shift for the physical activity variables.

As seen in Table 3, both models demonstrated a significant association between shift type and amount of physical activity ($p < 0.001$). People on day shift had a mean step count of 10,577 steps per

TABLE 3. Linear regression output for association between physical activity (steps per day, MVPA) and shift type in ICFPs who wore a physical activity monitor (n = 10)

Shift type (ref = Day)	ß	SE	t	p	[95% C.I.]
Steps					
Night	1093	270.44	4.04	0.000	[563.20, 1623.66]
First day off	781	335.82	2.33	0.020	[122.64, 1439.46]
Rostered day off	2347	223.58	10.49	0.000	[1908.10, 2,784.81]
Constant	10,577	179.57	58.90	0.000	[10,224.77, 10,928.92]
MVPA					
Night	14.95	3.42	4.37	0.000	[8.24, 21.67]
First day off	11.37	4.25	2.67	0.008	[3.04, 19.71]
Rostered day off	32.58	2.83	11.51	0.000	[27.03, 38.13]
Constant	46.51	2.274	20.45	0.000	[42.05, 50.96]

Note: Day shift is the reference variable for both analyses.

day, with all other shift types recording significantly more steps (night $p < 0.001$, first day off $p = 0.020$, rostered day off $p < 0.001$). The least number of additional steps were observed on first day off, ($ß = 781$, 95% C.I. [122.64, 1439.46]), with the greatest number of additional steps seen on rostered days off ($ß = 2347$, 95% C.I. [1908.10, 2784.81]).

ICFPs on day shift completed a mean of 46.5 minutes per day of MVPA, with all other shift types recording significantly increased minutes per day of MVPA (night; $p < 0.001$, first day off $p = 0.008$, rostered day off, $p < 0.001$). Again, the least amount of additional MVPA minutes were observed on the first day off, ($ß = 11.37$, 95% C.I. [3.04, 19.71]), with the greatest number of additional MVPA minutes seen on rostered days off ($ß = 32.58$, 95% C.I. [27.03, 38.13]).

DISCUSSION

Our study found that in this sample of ICFPs, despite prolonged exposure to shift work markers of metabolic health (blood pressure, glucose, insulin, and lipids) were within normal reference ranges and BMI was within a healthy weight range. Dietary intake was within recommended macronutrient ranges. Unlike other shift working populations of similar age and time in a shift work role, elite ICFPs appeared to be metabolically healthier, have higher HRQoL and aerobic capacity compared to other paramedics, and physical activity above recommended levels. Amounts of essential physical activity (steps per day and minutes per day of MVPA) were above recommendations but varied according to shift type, with the least amount of physical activity undertaken on day shifts, and the most physical activity undertaken on days off.

Participants in this study were senior, experienced paramedics who had extended shift work careers. Studies in firefighters with similar length careers have demonstrated a negative association between age, career length and cardiorespiratory fitness and other markers of cardiometabolic health (38), and a study in Australian firefighters with similar participant characteristics to this study showed high BMI and significant weight gain since career commencement (9). Further, cohort studies investigating the health and physical capacity of the wider paramedic workforce demonstrate concerning levels of obesity and limited aerobic capacity particularly in older, predominantly male paramedics (8, 39, 40).

Median ICFP BMI (25.1 $kg.m^2$) was just above the threshold of 25.0 $kg.m^2$ for classification as overweight, but was still considerably lower than values published in other studies that report on Australian paramedics (21), EMS providers in North America (8, 39), and larger studies of both paramedics and the general population (8, 39, 41–43). The majority of ICFPs were below the waist to height ratio threshold of ≥ 0.50 for increased risk of cardiometabolic disease (44), but it is worth noting that 46.6% of participants (all who were males > 40 years) showed a degree of central adiposity with values exceeding 0.50. This may be an area to target for improvement in cardiometabolic health in ICFPs and other paramedics.

Maximal aerobic capacity was substantially higher than that seen in normative data for similar age groups (combined average VO_{2max} for male and female ~13 $mL.kg^{-1}.min^{-1}$ higher) (45). When compared to a study of Western Australian paramedics, ICFPs were on average ~7 years older, yet had a ~2 $mL.kg^{-1}.min^{-1}$ higher VO_{2max} (46). This relatively high aerobic capacity is likely to be an important factor in the somewhat favorable cardiometabolic health profile seen in ICFPs. A study in US firefighters demonstrated that cardiorespiratory fitness was inversely proportional to incidence of metabolic syndrome (47), and there is strong evidence in studies of the wider population associating high levels of cardiorespiratory fitness with improved cardiometabolic health and increased pancreatic beta cell function, therefore, decreased risk for Type II diabetes (48).

Whilst shift work has been reported to impact physical activity in other populations, the cohort of ICFPs who wore activity monitors exceeded minimum recommendations for steps per day (by ∼16%) (49) and minutes of MVPA per week (by more than three times) (50). Even though there were significant differences in the amount of essential physical activity compared to shift type, ICFPs still completed high amounts of steps per day and minutes of MVPA for each shift type when compared to international recommendations. Additionally, when compared to data from a study that measured step count in general duties paramedics from AV, ICFPs undertook ∼39% more steps per day, and a similar effect on the number of steps per day according to the type of shift worked was noted (51). The high levels of essential physical activity in ICFPs can help to explain the healthy BMI reported by participants, and the association with improved cardiometabolic health (20). This is in opposition to other work investigating paramedics and physical activity which suggests paramedics face many impediments to undertaking regular physical activity (21). Our study was not designed to differentiate between physical activity undertaken whilst performing job-related tasks, physical training at work, or activity undertaken outside of rostered hours (e.g., commuting, pre/post shift exercise) but was to generally report how active paramedics are when on or off duty. Further work is needed to investigate whether ICFP occupational tasks and/or physical standard requirements lead to high levels of essential physical activity, however, it is apparent that ICFP physical activity levels play an important role in decreased cardiometabolic health risk.

ICFP dietary assessment via the FFQ revealed a ∼31% higher energy intake than average adult daily energy intake in Australia, however, percent energy intake for each macronutrient was distributed appropriately and within recommended values (52). Daily energy intake, macronutrient distribution and macronutrient percentage of total energy intake were similar to that seen in physically active Australian firefighters (9). The increased energy intake is likely to be associated with high levels of physical activity discussed previously and/or may relate to the physical demands of the ICFP role. Although in general dietary profile indicated even distribution of macronutrient consumption, non-core/discretionary foods (defined as highly processed or take-away/fast food) was double the recommended percentage of energy intake (14). As such, the ARFS indicated that whilst the diet quality of ICFPs was in the "getting there" category, few had an ARFS higher than this. These diet quality indices may be useful to track changes in diet quality in longitudinal studies in EMS personnel and other shift workers.

An abnormal fasting lipid profile is associated with increased risk of cardiovascular disease (53), but ICFP results for biomarkers of cardiometabolic disease (including lipid profile) were almost universally within normal ranges. At the median, glucose and insulin-derived HOMA IR was less than the upper threshold reported in early work examining the utility of this metric (32), and only one participant had a HOMA IR value that indicated insulin resistance when compared to data from a large study investigating HOMA IR cut off values and their association with metabolic syndrome (54). This finding opposes data reported in other health care workers completing shift work (55) where insulin resistance was more prevalent, and further highlights differences in our group of specialist elite paramedics when compared to the wider population of EMS personnel.

The cardiometabolic and physical activity profiles of ICFPs indicates that their role perhaps requires them to be more physically active, and as such physical activity patterns, weight and metabolic parameters are superior to those of other shift working populations. The health status of ICFPs indicates that it is possible to undertake shift work for a number of years and remain healthy, and this group may be useful as health and wellness role models for other EMS personnel. Anecdotally, this group appears to prioritize health and fitness, but further quantitative and qualitative studies are needed to gain a deeper understanding of the drivers that influence health-related behaviors in this group. These may include assessing the nature and physical demands of the tasks ICFPs are required to undertake in their role, the minimum physical standards that are required to be met, or personality types that are attracted to the role. This information may then be used to drive innovative strategies to improve the health of paramedics, other EMS providers, and health care and shift workers.

STRENGTHS AND LIMITATIONS

Our sample size was small yet was a reasonable proportion of the wider ICFP workforce. As all ICFPs perform the same duties and must meet the same standards, participants in the study may be representative of ICFPs in this service. However, the sample size limits inferences that may be made regarding helicopter rescue paramedics in other jurisdictions. Additionally, statistical analysis methods were limited by the sample size, for example, simple linear regression compared to more advanced analyses. There was a risk of selection bias in that highly motivated ICFPs may have been more inclined to participate in the study. This appeared to be minimized, however, with a wide range of age, experience, and participants volunteering from all areas of the service. Another limitation was the cross-sectional nature of the study design (for all assessments excepting the physical activity monitoring), and the limited reference data available from similar populations. However, we were able to compare results with published reference ranges from the wider population. For participants that wore physical activity monitors, we intended to repeat the maximal aerobic capacity assessment at the end of the 12 months to align with the physical activity data and explore reasons if there were differences. This was not able to be completed due to the closure of the laboratory during the COVID-19 pandemic.

Conclusion

Despite extended exposure to shift work and contrary to data reported from the wider EMS workforce, ICFPs demonstrate good dietary health, good cardiometabolic health, excellent HRQoL and aerobic capacity, and physical activity well above recommended levels irrespective of the shifts worked. ICFPs are likely to be healthier than the wider paramedic and shift working populations due to their lower body weight, better diet, high amounts of physical activity and a physically active job. This information may be useful at guiding health interventions in the wider EMS workforce. Further work is required to investigate the drivers of good health in this group.

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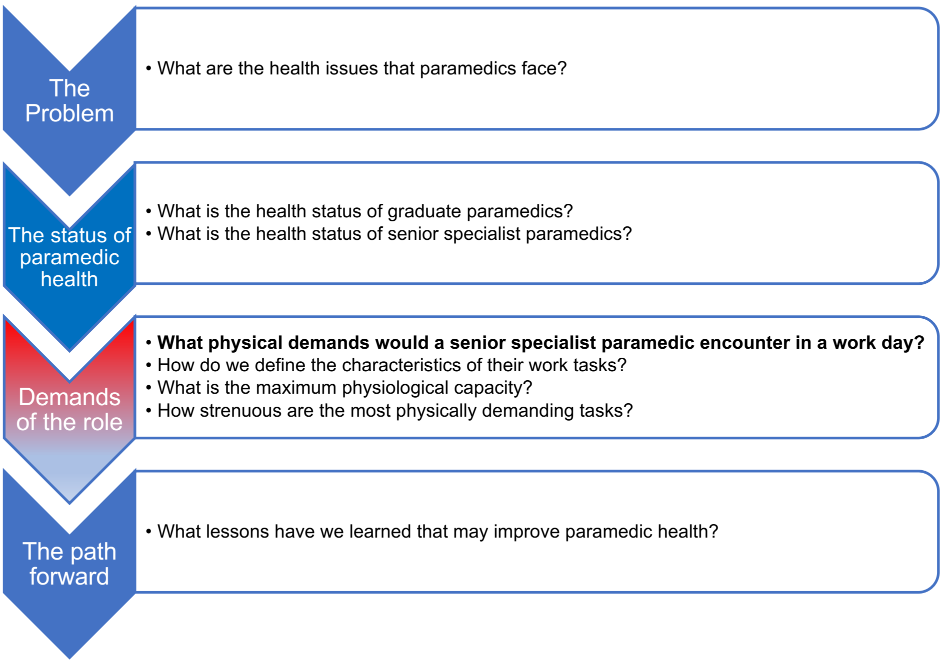
4.3 Summary of Chapter Four

The research reported in Chapter Four of this thesis revealed that a cohort of senior and experienced ICFPs with long term exposure to shift work demonstrated high HRQoL, cardiometabolic indicators within healthy ranges and physical activity outcomes exceeding those recommended in guidelines. Given their long careers in paramedicine, a median age of 45 years and based on the information presented in Chapters One and Two, this was unexpected. As was seen in the graduate ambulance paramedics described in Chapter Three, this study indicated that shift work influenced the amount of physical activity undertaken. However, the ICFPs exceeded minimum recommendations for physical activity, even when rostered to duty. Despite lengthy careers in paramedicine, these specialist paramedics demonstrated an excellent health profile, specifically regarding biomarkers of cardiometabolic health and physical activity. However, little is known about the physically demanding nature of ICFP work, and the question remains as to whether the job tasks may play a role in the excellent health profile of this group.

Chapter Five: Physiological response in a specialist paramedic during helicopter winch rescue

5.1 Preamble

The research reported in Chapter Four revealed that ICFPs with extended careers in paramedicine have relatively good health compared to their junior colleagues. Whilst factors such as normal biomarkers for cardiometabolic health, low BMI and high levels of physical activity may contribute to this paradoxical finding, little is known about the physical demands of helicopter rescue paramedic work, specifically in search and rescue roles that are intuitively very strenuous. As such, it is unclear whether the nature of the physical tasks performed as a part of the job are sufficiently strenuous and frequent to contribute to the positive ICFP health profile. Whilst anecdotally, the work undertaken by ICFPs may appear physically demanding, formal analysis of the most physically demanding tasks has not been reported in published research. In this chapter, a case report details the physiological strain encountered during a live helicopter rescue and suggests some of the methods and indices that may be used to scientifically quantify the most physically demanding tasks of the ICFP role.



5.2 Manuscript

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(Quartile 3, Impact factor N/A)

Physiological Response in a Specialist Paramedic During Helicopter Winch Rescue in Remote Wilderness and Extreme Heat

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ABSTRACT

Tasks performed by search and rescue (SAR) teams can be physically demanding. SAR organizations are faced with mounting challenges due to increased participation in recreation in remote locations and more frequent extreme weather. We sought to describe the physiological response and the methods for data collection during helicopter emergency medical service (HEMS) winch rescue from remote wilderness in extreme heat. A flight paramedic sustained 81% of maximum heart rate ($\dot{V}O_2$ ~44.8 mL/kg/min) for ~10 minutes at a rate of perceived exertion of 19/20, and a relative heart rate of 77.5% in 37.1°C. Maximal acceptable work time for this task was calculated at 37.7 minutes. Our data collection methods were feasible, and the data captured demonstrated the level of physiological strain that may be encountered during HEMS SAR operations in austere environments and hot climate. It is essential that SAR teams that perform physically demanding tasks use a scientific approach to adapt and evolve. This is necessary to ensure personnel are appropriately selected, trained, and equipped to respond in an era of increasing demand and extreme environments.

KEYWORDS: *search and rescue; helicopter emergency medical services; paramedic; eerobic capacity; human performance*

Introduction

Personnel working in military and civilian Special Operations units such as helicopter emergency medical services (HEMS) may be categorized as tactical athletes. These staff perform physically demanding tasks that may include rescue from remote wilderness, vessels, or marine environments.[1] Specialist units usually develop physical employment standards (PES) when recruiting team members, and these should arise from evidence-based and validated processes to identify those suitable for the role.[2] Scientifically validated PES may reduce the risk of employees suffering injury and ensure the ability of personnel to perform their required duties. Additionally, a validated PES provides a barrier to legal challenges should an applicant be unsuccessful when applying to a specialist unit.[3]

One of the most physically demanding tasks performed by helicopter rescue paramedics is rescue via external winch (also known as a hoist) from the helicopter. The frequency of utilization of this rescue technique in civilian SAR varies.[1,4] However, in the modern era, organizations and personnel working in specialist rescue teams face mounting challenges. In regions that have undergone extended lock-down periods to abate the progression of the COVID-19 pandemic, there have been substantial increases in participation in outdoor recreational pursuits in remote areas, placing added demand on emergency services.[5–7] Additionally, the progression of climate change and increased frequency of extreme weather events mean that organizations must appropriately select and train their specialist personnel in the context of both an increasing workload and volatile climate.[8]

Our multidisciplinary research group is developing a scientifically validated PES for helicopter rescue paramedics. As part of primary work to investigate methods for data capture in the HEMS SAR environment, we describe the in-field assessment of physiological parameters in a specialist paramedic conducting a land winch rescue. The data provide insight into the physical demands of contemporary civilian SAR operations by specialist paramedics working in HEMS, and we suggest considerations for research, role equipment, and selection of personnel.

Setting

The state of Victoria, Australia, covers an area of approximately 237,629 km^2 including remote and difficult-to-access terrain and more than 2,000 km of coastline. Ambulance Victoria (AV) is the provider of HEMS in Victoria, and an intensive care flight paramedic (ICFP) may be deployed to an incident via winch. AV HEMS operations have been described in previous work.[1,4] Written informed consent was obtained from the individual participant described in this report. Capture of data was approved by the Monash University Human Ethics Research Committee (Project Nos. 16340 and 17784) and Ambulance Victoria Research Committee (Project R18-033). Anthropometric, body composition, and maximal aerobic capacity data

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are drawn from the larger body of work (not yet published) conducted under the auspices of the aforementioned approvals, with consent from the participant.

Intensive Care Flight Paramedic (ICFP) Characteristics

The ICFP was 44 years of age. He had 23 years of experience as a paramedic, with 12 years in the HEMS SAR role. Demographics, anthropometric, body composition, and maximal aerobic capacity are shown in Table 1.

TABLE 1 *Demographics, Anthropometric, and Physical Activity Data for the ICFP*

Age (years)	44
Sex	Male
Paramedic experience (years)	23
ICFP experience (years)	12
Height (cm)	183
Body mass (kg)	72
Fat free mass (kg)	60.6
Body fat (%)	18.0
Body mass index (kg/m^2)	21.6
Run $\dot{V}O_2$ (mL/kg/min)	55.3

ICFP = intensive care flight paramedic.

$\dot{V}O_{2peak}$ was determined by incremental treadmill running to volitional exhaustion per the method described in Costa et al. Influence of timing of postexercise carbohydrate-protein ingestion on selected immune indices. *Int J Sport Nutri Exer Metabol*. 2009;19(4):366–384.

Description of the Task

Background

Ambient temperature on the day of the case was 37.1°C, and this was the second day in a row of temperatures > 35°C and low relative humidity. The aircrew and ICFP completed a 13-hour shift in similar conditions the previous day and responded to four cases with ~5 hours of cumulative flight time. The crew had 11 hours of rest in between shifts, and the case described in this report occurred 5.5 hours into the new shift (with no other strenuous work performed prior). The HEMS aircraft was dispatched by the AV Flight Coordination Centre to a remote wilderness environment to retrieve a patient with a medical condition. Ground-based resources would have taken up to 2 hours to reach the patient, and transport of the patient back to ground vehicles would require paramedics and the patient traversing steep, rocky, and uneven terrain. Delivery of the ICFP to the scene to assess the patient and recover to the helicopter was considered the most rapid method to deliver patient care and transport to a medical facility.

On arrival at the scene, the patient was located ~720 m along a remote walking track from the nearest access point. During scene reconnaissance, the patient was noted to be located in an area where there was a significant number of tall trees with dead branches that could be dislodged by the helicopter downwash. Furthermore, there was a steep slope, thus insertion via helicopter winch was deemed as high risk. Given there was some risk to the patient and bystanders during winch insertion, the aircrew delivered the ICFP and equipment to the nearby clearing via a hover exit (exit from the aircraft while it is still running and wheels touching land). Once the aircraft departed, the ICFP loaded the 25 kg of specialist equipment (e.g., radios, extraction harness, flight helmet, and medical gear) to commence the 720-m walk to the patient. The ICFP was clothed in a two-piece fire-retardant Nomex flight suit (Sisley Clothing, https://www.sisleyclothing.com.au/), with a jacket fabric weight of 160 g/m^2 (GSM) and pants fabric weight of 200 GSM and a cotton undershirt. The ICFP was wearing a physical activity monitor watch equipped with wrist-based heart rate monitor and global positioning system (GPS) tracking (https://buy.garmin.com/en-US/US/p/541225). Recording was started at the commencement of the walk and stopped on arrival at the patient, and data were downloaded to the Garmin Connect web platform after case completion. The ICFP was familiar with the Borg rate of perceived exertion scale ($RPE_{6\text{-}20}$) from involvement in previous research within the scope of the PES development and therefore was able to self-rate and record physical exertion after the task.[9]

Physiological Demands of the Task

The helicopter remained circling in the area whilw the ICFP walked to the patient. With limited fuel, timely access to the patient and a prompt decision regarding extraction was essential. Table 2 summarizes the environmental and physiological characteristics of the walk. The 720-m walk carrying 25 kg of equipment to the patient took 10 minutes 3 seconds at an average speed of 4.6 km/h in 37.1°C ambient temperature. These conditions, coupled with an average track gradient of 14%, induced substantial physiological strain. The ICFP self-rated the task difficulty as $RPE_{6\text{-}20}$ = 19, and average heart rate (HR) was 81% of predicted maximum, with the highest recorded HR at 95% of predicted maximum. Relative heart rate (RHR) is one of a number of reliable indices to determine workload and associated fatigue, with values > 33% signifying the point of increase of physical workload.[10] It is calculated from the formula $RHR = HR_{work} - HR_{rest}/HR_{max} - HR_{rest.}$[11] The RHR of 77.5% for this task further demonstrates the substantial physiological strain of the walk to the patient. As per the method described by Wu and Wang, we were able to calculate maximum acceptable work time (MAWT) for this task from the RHR via the formula MAWT (hours) = $26.12 \times e^{(-4.81 \times RHR)}$, $R^2 = 0.87 = 0.6281045$; therefore, MAWT (min) = MAWT * 60 (min) = 37.7.[10]

TABLE 2 *Weather, Climate, Topographic, and Physiological Data for Case*

Ambient temperature	37.1
Relative humidity (%)	16
Ambient air pressure (hPa)	999.1
Equipment weight (kg)	25
Walk distance (m)	720
Average track gradient (%)	14
Time (min:sec)	10:03
Average speed (km/h)	4.3
Average moving speed (km/h)	4.6
Maximum speed (km/h)	5.7
Maximum heart rate (bpm)	180
% Maximum heart rate	95
Average heart rate (bpm)	153
% Average maximum heart rate	81
Perceived exertion (6–20)	19
Relative heart rate (%)	77.5
Estimated energy expenditure (kcal)	100
MAWT (min)	37.7

bpm = beats per minute, MAWT = maximum acceptable work time.

Outcome
Once assessment and initial care were completed, the patient was relocated to a safe location away from the overhanging tree canopy in which winch extraction to the aircraft was performed. The patient was then transported to hospital. After completion of this task, the aircrew and ICFP were immediately tasked to two further back-to-back non–physically demanding cases; however, this did limit opportunity for recovery.

Discussion

This report details data collection methods in rescue personnel and demonstrates the level of physiological strain that may be encountered during HEMS SAR operations in remote wilderness and extreme heat. With increasing participation in outdoor recreational pursuits and the increased frequency of extreme weather events, it is essential that special operations teams performing physically demanding tasks adapt and evolve.[12] This will ensure personnel are appropriately selected, trained, and equipped to respond in these conditions.

The physical status of this ICFP was comparable to that seen in other studies investigating SAR professionals and specialist paramedics.[13,14] Some authors have proposed a minimum $\dot{V}O_{2peak}$ of 40–45 mL/kg/min for specialist rescue roles (e.g., mines rescue personnel and fire fighters), and the ICFP in this case exceeded this threshold.[15,16] Possessing well-developed aerobic capacity, high physical activity levels, and good overall health may be important factors when designing PES and ongoing strength and conditioning programs for physically-demanding occupations. However, the concept of a minimum $\dot{V}O_{2peak}$ for selection to this ICFP role requires investigation in formal studies that examine a range of physiological and performance demands of winch rescue.

The ICFP was required to sustain 81% of maximum HR (an approximate $\dot{V}O$ of 44.8 mL/kg/min, based on $\dot{V}O_{2peak}$) for just over 10 minutes at an $RPE_{6\text{-}20}$ of 19 and RHR of 77.5% in 37.1°C. This high physiological strain must be placed in the context of the fact that ICFPs must be able to deliver clinical care once they reach the patient. A study in male Soldiers demonstrated that nonacclimated personnel suffered greater cognitive impairment when exposed to exertional heat stress when compared to those who were acclimatized to heat.[17] Calculated MAWT for this task was 37.7 minutes, and although this individual task was less than one-third the duration of MAWT, it is possible that further similar or more demanding tasks may have to be completed by the ICFP during the same shift. Additionally, repeated incidences of high physiological workload (especially in hot climates) should factor into workforce and response planning, PES development, and determination of appropriate shift duration. Of note, the method we used to calculate MAWT is based on heart rate (RHR), and although it is well established that there is good agreement between RHR and relative $\dot{V}O_2$, direct assessment of oxygen consumption is considered the most accurate method.[10] Formal physiological assessment of this population should measure relative $\dot{V}O_2$ to determine MAWT.

To limit physiological strain and enable performance of postexertion cognitive tasks (such as delivery of advanced clinical care), rescue services should pursue strategies to minimize physiological stress in hot environments. Increased rates of exertional heat illness are reported in the military setting, and this has led to the development of a number of novel methods to enhance performance in these environments.[18] Garment technology for physically demanding work has evolved predominantly through military research. Modern fabrics allow for more effective heat dissipation and may include active cooling elements, thus reducing core temperature, heat stress, and physiological demand.[19] Novel cooling strategies such as arm immersion in cold water, ice vests, and ingestion of energy drink ice slurries demonstrate value for temperature reduction in the post exertion recovery phase.[18,20–22] Some of these strategies may be particularly useful in HEMS SAR operations, in which personnel may be required to undertake multiple physical demanding tasks during a shift.

Load carriage during physically demanding tasks is known to modify metabolic demand and increase physiological strain, yet it is an essential component of specialist team response.[23] Lightweight technical rescue and medical equipment is an ever-evolving area with a wide range of proprietary offerings. Organizations requiring significant load carriage in physically demanding specialist response roles should ensure equipment is restricted to the most essential items. It should also be adaptable to extreme environments and high temperatures to minimize physiological strain.[24] Organizations deploying specialist rescue personnel to remote and hostile environments should consider long-term monitoring of physiological workload during rescues. These organizations should also initiate continuous quality improvement programs to review PES, garments, equipment, employee readiness, and adaptability to deliver services in an ever-changing response environment.

Limitations

We acknowledge that data such as HR, RPE, and MAWT from a single participant completing a physically demanding task may not reflect the physiological responses in other ICFPs completing a similar task, and studies in a representative sample of the occupational group are required. Additionally, we acknowledge that the wearable technology used in this study may have variable accuracy and reliability, whilst appreciating the usefulness of such devices to capture physiological data in the environments described.[25]

Conclusion

This report highlights that HEMS SAR operations may require specialist personnel to be exposed to high physiological demands in remote wilderness and extreme climatic conditions. Assessment of physiological parameters during HEMS SAR operations is viable, but future work to develop PES should include assessment of additional elements. One example is oxygen consumption during task simulations as a method of enhancing scientific validity. Coupled with the progression of climate change and increasing participation in outdoor pursuits, organizations must ensure that staff are selected to the role via scientifically valid and reliable PES. Specialist rescue organizations should initiate continuous quality improvement programs to review and adapt selection processes, physical readiness programs, and specialist equipment to suit the dynamic operational response environment.

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The authors have indicated they have no financial relationships relevant to this article to disclose.

Author Contributions

BM and EH conceived the study concept and design. BM acquired the data. BM and EH analyzed the data. BM, EH and LP drafted of the manuscript. LP, KS, and KAB provided critical revision of the manuscript. All authors approved of the final manuscript.

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5.3 Summary of Chapter Five

This is the first published case study to demonstrate the physical demanding nature of HEMS search and rescue work performed by ICFPs. In addition to good cardiometabolic health, high levels of physical activity and low BMI identified in Chapter Four, strenuous tasks undertaken as part of core work duties may, in-part, explain the excellent overall health profile of ICFPs. This chapter has also identified that formal and detailed assessment of physiological parameters during HEMS search and rescue operations is viable and may include measurements of physiological parameters such as heart rate, expired air for determination of oxygen consumption (VO_2), rate of perceived exertion (RPE), and maximal acceptable work time or duration (MAWD). However, a single case is insufficient evidence for the physical demands of HEMS rescue work as whole. Further work should be undertaken to accurately quantify the physiological demands of the most strenuous tasks in a representative sample of the ICFP group, and should use an evidence-based, systematic process such as the criterion physical employment standards (PES) methodology described by Tipton et al. (81).

Chapter Six: Defining the characteristics of physically demanding winch rescue in helicopter search and rescue operations

6.1 Preamble

The study in Chapter Four determined that ICFPs have an excellent health profile, which could be related in part to the physically demanding nature of their specialist work. Chapter Five then provided broad insight into the strenuous nature of an ICFP rescue task. To understand more deeply the physically demanding nature of ICFP specialist tasks, further work is required. This chapter details the first stage in the established PES methodology (81) to determine the characteristics of the physically demanding tasks ICFPs undertake.

The information detailed below was not included in the published manuscript but provides a background summary of how the work tasks of land and water winch rescue were determined to be the most physically demanding tasks in ICFP practice, above and beyond routine paramedic duties.

Supplementary information

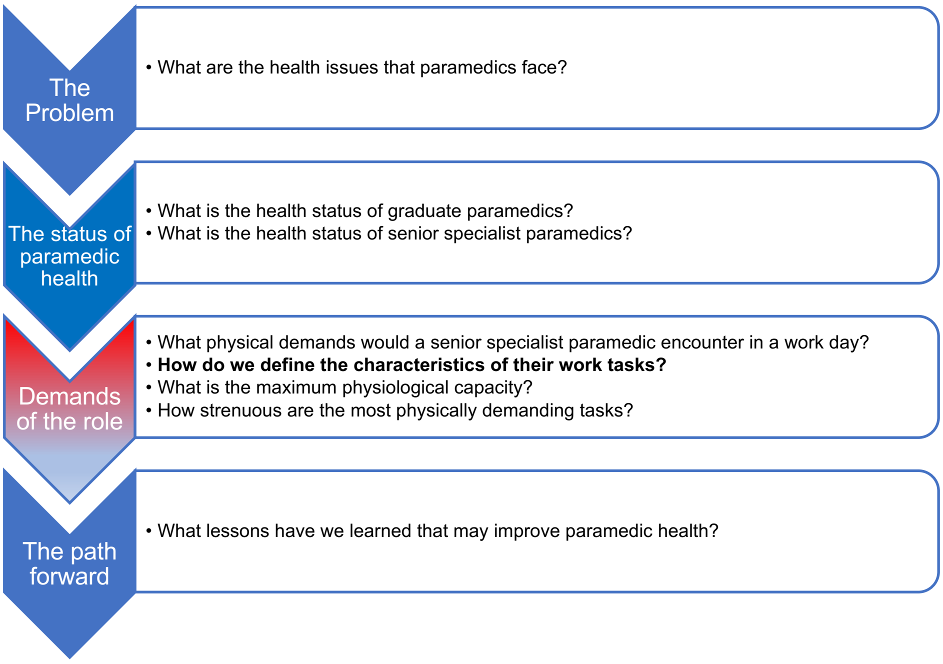
A one-day SME focus group was held with 16 ICFPs from AV. The SMEs were given short presentation by a specialist physiologist, introducing the concept of PES and its development, and the purpose and aims of the SME focus group. SMEs were then invited to discuss and identify common tasks completed during a typical day at work for an ICFP, with the aim to generate a critical task list. Following generation of the list, each individual task was assigned a Task Code. Once the task list was generated (Table 6.1), participants were invited to engage in a discussion to achieve consensus regarding the *most* physically demanding tasks from the task list. SMEs unanimously agreed that land winch rescue (Task Code: HM13) and water winch rescue (Task Code: HM14) from the helicopter are the most physically demanding tasks when compared to the other tasks in the list, of which most may be undertaken by any paramedic.

Table 6.1: Critical tasks performed by intensive care flight paramedics.

The most physically demanding work tasks identified by intensive care flight paramedics subject matter experts are in the shaded boxes.

Task Code	Task description
HM1	Start of shift equipment checks that may take up to 1 hour including significant physical effort for 5-10 minutes of that hour (e.g., moving equipment in and out of the helicopter)
HM2	Moving equipment in and out of internal drawers
HM3	Repeated entry and exit of the aircraft
HM4	General duties, including changing of linen skips, tidying common areas
HM5	Replenishing stores
HM6	Training, including but not limited to clinical scenario/simulation-based training, online clinical and aviation training packages (sitting for extended periods)
HM7	Winch training at 6 weekly, 3-monthly, 6 monthly (land) and 12 monthly (water) intervals during live flying exercises
HM8	Completing training and operational cases in extremes of temperature, and high/medium/low/no ambient light environments with additional challenges like getting into and out of life-rafts.
HM9	Snow survival/rescue training (every 2-3 years) over 2 days
HM10	Helicopter Underwater Escape Training every 2-3 years
HM11	Complex operational clinical cases such as climbing into a car wreck, trapped patient
HM12	Moving patient around to stretcher/loading device, and managing patients into aircraft
HM13	**Operational winch rescue over land in remote and/or austere environments**
HM14	**Operational winch rescue in swift and/or open water**

Ultimately, the aim was to generate task descriptions for the most physically demanding ICFP tasks of land and water winch rescue, as the foundation for the development of task simulations to assess physiological workload (detailed in Chapter Eight). The manuscript details the qualitative consensus study where a SME focus group reviewed four years of historical HEMS rescue case data with an aim to agree on definitions for the characteristics of these strenuous tasks.



6.2 Manuscript

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Defining the characteristics of physically demanding winch rescue in helicopter search and rescue operations

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ABSTRACT

Helicopter emergency medical service search and rescue (HEMS SAR) paramedics perform physically demanding winch rescues. Rescue organisations require valid physical employment standards (PES) to ensure personnel can adequately perform duties. There are no studies describing validated PES for HEMS SAR. We convened a subject matter expert (SME) focus group to review historical case data and generate task descriptions for land and water winch rescue as the basis for development of task simulations to assess physiological workload. Sixteen helicopter rescue paramedics with a mean age of 47 (range, 36–52) years and 8 (2–20) years' experience in helicopter rescue participated in a SME focus group. When provided with data from historical cases, SMEs achieved consensus (≥80%) when generating descriptions of winch rescue. This method may be useful to develop simulations for assessment of physiological demands of winch rescue and similar tasks, and to enhance validity and reliability of PES for rescue organisations.

1. Introduction

1.1. Background

Emergency services personnel working in specialist teams such as helicopter emergency medical services (HEMS) are often required to perform physically demanding tasks (Fischer et al., 2017). These services usually develop physical employment standards (PES) that are required to be met for initial employment (Petersen et al., 2011). This is due to the high physical demand of tasks performed by HEMS staff, such as rescue from remote wilderness or open water (Meadley et al., 2016). However, if standards are arbitrary, they may discriminate against capable persons or fail to eliminate those unsuitable for the role. Employees may then be exposed to risk of injury and inability to deliver the service they are chartered to provide, and failed applicants may challenge the standard (Milligan et al., 2016).

Specialist teams such as HEMS, military special forces and civilian search and rescue (SAR) teams require PES distinct from the general workforce due to the high physical demand and complexity of tasks required to satisfactorily perform these roles (Carlson and Jaenen, 2012; Hunt et al., 2013; Milligan et al., 2017). For example, when selecting new staff for HEMS SAR positions, Ambulance Victoria (AV) only assesses specific tasks that are over and above regular ambulance service operations, e.g., helicopter winch rescue from land or water. If not adequately prepared for the rigors of selection, training and the ongoing role, personnel undergoing selection to specialist teams such as HEMS SAR are at risk of physical and psychological injury, unsuccessful course completion and organisational burden (Hunt et al., 2013). As such, organisations should ensure PES for groups performing physically demanding roles are particularly robust to maximise staff safety and operational performance. Methods to develop scientifically validated PES are well established, and the criterion process is described by Tipton et al. It identifies the following six stages to be undertaken to establish defensible physical standards for employment (Tipton et al., 2013):

Abbreviations: AV, Ambulance Victoria; ePCR, electronic Patient Care Record; HEMS, Helicopter Emergency Medical Service; ICFP, Intensive Care Flight Paramedic; PES, Physical employment standards; SAR, Search and Rescue; SME, Subject Matter Expert.

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i. Establish the critical task
ii. Determine the method of best practice
iii. Agree on an acceptable minimum level of performance
iv. Collect physical and physiological data
v. Determine a reasonable workload
vi. Production of a PES

Summarily, the process involves the determination of critical job tasks, identifying the interaction between individuals, the environment, specialist equipment and the physiological demands of the role. The analysis can include common and routine tasks but, importantly, also those infrequent yet critical emergency tasks (Tipton et al., 2013) such as high-skill emergency procedures performed by specialist military and civilian rescue teams. This current study focuses on describing the high-skill, low frequency tasks of land and water winch rescue performed in the HEMS SAR operational environment by undertaking the first stage of the PES process, with adaptation to this specific occupation.

A number of approaches have been reported to describe physically demanding tasks. Data is lacking to indicate which, if any, is superior (Beck et al., 2016; Tipton et al., 2013). A method detailed by Rayson involves recruiting subject matter experts (SMEs) whom possess intricate knowledge of the tasks, with broad representation of the employee group including junior staff through to senior managers (Rayson, 2000). Such a group of SMEs are able to separate the routine and emergency tasks, challenge opinions, and feel ownership of the process and the outcome (Rayson, 2000), and should meet predetermined criteria with regard to their experience and expertise (Blacklock et al., 2015). Focus groups of SMEs may use a range of analyses and materials to determine critical tasks and define best practice, including interviews, surveys, SMEs and existing records (Beck et al., 2016). There is a gap in the literature regarding formal analysis of the physical requirements for personnel performing HEMS SAR winch rescue. This study utilised a SME focus group to undertake the first stage of the PES process, specifically targeting winch rescue tasks.

1.2. Study setting

The state of Victoria, Australia covers an area of approximately 237,629 km^2 including remote and difficult-to-access terrain and more than 2,000 km of coastline. AV is the provider of HEMS in Victoria, and aircraft are staffed by an intensive care flight paramedic (ICFP), an air crew officer, and a pilot. The 45 ICFPs employed by AV are senior, experienced paramedics who in addition to being trained in advanced clinical practice are the sole staff member deployed from the aircraft to perform land and water-based SAR. AV HEMS is a multi-role service, and responsibilities include emergency medical response (e.g., motor vehicle accidents), interhospital transfer of critically unwell patients and rescue of patients via deployment to remote and difficult to access scenes via external winch. AV HEMS differs when compared to HEMS in other jurisdictions. For example, other Australian HEMS often deploy two or more personnel to winch rescue scenes, European HEMS may deploy a specialist mountain rescuer or rescue swimmer rather than a paramedic, and HEMS in the United Kingdom do not perform winch rescue, rather it is performed by specialist coast guard teams. AV HEMS operations are described in more detail in previous work (Andrew et al., 2015; Meadley et al., 2016).

In general, emergency medical response and critical care transfer work performed by ICFPs does not involve physical tasks different to the wider AV paramedic population. Physical capacity to perform common paramedic tasks is not examined during selection to the ICFP role. Physically demanding land and water SAR operations are unique to HEMS, and thus physical capacity for this role must be assessed during selection. Existing assessments for SAR tasks are not developed from a scientific PES process and have remained largely unchanged for more than a decade. Additionally, ICFPs are not currently formally reassessed to ascertain if they remain physically capable of performing the SAR role, but they do perform regular task-specific training exercises. To date, there are no studies indicating that a formal PES process has been undertaken for civilian HEMS SAR operations, potentially exposing organisations, employees and patients to risk. The aims of this study were to convene an ICFP SME focus group to i) analyse and discuss historical case data from operational rescues, and ii) generate task descriptions for which to base simulations for analysis of physiological demands.

2. Materials and methods

2.1. Focus group participants

Eligibility for the study required current employment by AV as an ICFP, with authorisation to undertake winch rescue. Convenience sampling via corporate email was utilised due to varied roster patterns and geographical work locations. Participants were required to complete a form that described basic demographics, total paramedic experience and ICFP experience, and they were invited to attend a one-day focus group. Written informed consent was obtained from all individual participants included in the study. This study was approved by the Monash University Human Ethics Research Committee (Project number 12323) and Ambulance Victoria Research Committee (Project R18-016).

2.2. Preparation of materials for the focus group - collation of historical rescues

At the completion of an operational winch rescue over land or water, ICFPs are required to complete a HEMS winch debrief form in addition to an electronic clinical patient care record (ePCR). The HEMS winch debrief form requires the ICFP, pilot and air crew officer to detail the non-clinical aspects of a winch rescue including weather, terrain, the specific rescue equipment utilised, the load carried, and an estimate of distance walked/swum. These descriptors may be replicated or supplemented in the ePCR. Complete HEMS Winch Debrief Forms and case-matched ePCRs for period January 2014 to December 2018 were made available by AV. A total of 105 land winch rescues and 14 water winch rescues were described.

Prior to review of the HEMS winch debrief forms and ePCRs, we established a method of categorising the tasks by i) the terrain or environment (land or water), the standardised rescue equipment for the task type (as determined by AV HEMS standard operating procedures) and iii) the information that could be garnered from both the HEMS winch debrief forms and associated ePCR. Specialist equipment described in this process was weighed using calibrated scales (SECA 813 Digital Flat Scales, SECA, Hamburg, Germany). The template for categorisation of tasks is shown in Table 1.

Prior to the focus group, one member of the research team reviewed the HEMS winch debrief forms and the associated ePCR, categorising the data according to the template seen in Table 1. Recorded physical demands were placed into one of three criterion that denoted the described physical demands of the task (distance walked or swum, patient weight, number of patients). Rescues were then further allocated to levels (two levels for water, three for land) that described the items and total weights of specialist equipment required to be carried by the ICFP. For land winching only, data was further divided into categories of individual (the ICFP had no on-ground assistance) or team (the ICFP had at least one person on the ground to assist with load carriage). The resultant Tables 2 and 3 were provided to SMEs in the focus group. It is important to note that HEMS in other jurisdictions may allow their rescue personnel to disconnect from the winch cable during water rescue. AV policy prohibits this, thus there are no circumstances in the water rescue data where there is insertion only, no patient extraction, as occurs in land winch rescue.

Table 1
Template for categorisation of the winch rescue tasks during review of HEMS winch debrief forms and electronic patient care records.

	Category allocation	
Terrain/environment	Land	Water
Rescue equipment (Level)	**Level 1:** Insertion only, no patient extraction **Level 2:** Winch harness & connector, medical pack, rescue harness, radios, lifejacket, Helmet – **28 kg** **Level 3:** Winch harness & connector, medical pack, stretcher + tagline, radios, lifejacket, flight helmet – **43 kg**	**Level 1:** Winch harness & connector, strop, wetsuit + fins, lifejacket, water helmet – **15 kg** **Level 2:** Winch harness & connector, strop, immersion suit + fins, lifejacket, water helmet – **16 kg**
Physical characteristics of the task (Criterion)	**Criterion 1:** Insertion close to patient and/or single patient **Criterion 2:** Patient weight >90 kg and/or distance >100 m under load and/or 2 patients **Criterion 3:** Significant exertion and/or distance >500 m under load and/or patient >100 kg and/or 3 or more patients	**Criterion 1:** Insertion close to patient and/or single patient **Criterion 2:** Patient weight >90 kg and/or swim distance >10 m under load and/or 2 patients **Criterion 3:** Significant exertion and/or swim distance >50 m under load and/or patient >100 kg and/or 3 or more patients

2.3. *SME focus group*

Prior to attendance, all SMEs were required to be current with regard to AV winch rescue procedures, but no further pre-reading materials were provided. Participants attended the one-day focus group in-person (n = 13) or via video conference (n = 3). Firstly, to ensure all participants were afforded the same opportunity to contribute to discussions, SMEs were reacquainted with the AV code of conduct, with specific reference to the concept of respectful behaviour. This was followed by a 2-h presentation by the specialist physiologist (JC), introducing the concept of PES and how it was developed, and examples of where PES have been developed in other similar occupations. The purpose of the focus group was then explicitly stated as the aforementioned aims of this study. SMEs were then given the opportunity to ask questions, and any queries were resolved.

As a method of an introduction to discussion around physical tasks, JC invited SMEs to identify common tasks completed during a typical day at work for an ICFP, however we did not report results from this discussion of standard paramedic tasks. JC then asked participants to focus the discussion on physically demanding tasks that are supernumerary to regular paramedic duties, specifically land and water winch rescue. After a short break, participants were then presented with the collated historical land and water winch data (Tables 2 and 3). The methods for generation of collated data and the results were explained in detail. SMEs were then asked to review the tables. Over the next 2 h, SMEs were asked to recall their personal experiences of winch rescue in the context of the collated data. For the last hour of the focus group, the SMEs were then asked by JC to form consensus descriptions of land and water winch rescue. Once descriptions for land and winch rescue were generated, consensus was defined as ≥80% agreement via a show of hands, similar to the method described by Skulmoski et al. (2007). The total focus group duration was ~5.5 h.

3. Results

Sixteen male ICFPs volunteered to participate, representing 35.5% of the workforce. At the time of the study, no females were qualified as ICFPs (four were in training). The response rate was higher than expected, and staff in attendance thoroughly engaged in the focus group. ICFPs in the group represented a wide range of experience and seniority and were comparable to the wider ICFP population (Table 4).

For land winch rescue, SMEs agreed that ICFPs would be expected to be able to perform the maximum categorised task (Table 3: Criterion 3,

Table 2
Frequency and categorisation of tasks by equipment and physical demands for land winch rescues conducted between 2014 and 2018 (n = 105).

Personnel	Equipment	Criterion 1 n (%)	Criterion 2 n (%)	Criterion 3 n (%)
Individual (Lone ICFP)	Level 1	0 (0)	1 (0.95)	1 (0.95)
	Level 2	6 (5.7)	5 (4.8)	0 (0)
	Level 3	2 (1.9)	0 (0)	0 (0)
Team (ICFP + ≥ one other on ground)	Level 1	15 (14.3)	5 (4.8)	0 (0)
	Level 2	21 (20)	9 (8.6)	1 (0.95)
	Level 3	21 (20)	12 (11.4)	6 (5.7)

Criterion 1: Insertion close to patient and/or single patient.
Criterion 2: Patient weight >90 kg and/or distance >100 m under load and/or 2 patients. Criterion 3: Significant exertion and/or distance >500 m under load and/or patient >100 kg and/or 3 or more patients.
Level 1: Insertion only, no patient extraction.
Level 2: Winch harness & connector, medical pack, rescue harness, radios, lifejacket, Helmet – 28 kg. Level 3: Winch harness & connector, medical pack, stretcher + tagline, radios, lifejacket, flight helmet – 43 kg.

Table 3
Frequency and categorisation of tasks by equipment and physical demands for water winch rescues conducted between 2014 and 2018 (n = 14).

Equipment	Criterion 1 n (%)	Criterion 2n (%)	Criterion 3n (%)
Level 1	3 (21.5)	4 (28.5)	3 (21.5)
Level 2	0 (0)	0 (0)	4 (28.5)

Criterion 1: Insertion close to patient and/or single patient.
Criterion 2: Patient weight >90 kg and/or swim distance >10 m under load and/or 2 patients.
Criterion 3: Significant exertion and/or swim distance >50 m under load and/or patient >100 kg and/or 3 or more patients.
Level 1: Winch harness & connector, strop, wetsuit + fins, lifejacket, water helmet – 15 kg.
Level 2: Winch harness & connector, strop, immersion suit + fins, lifejacket, water helmet – 16 kg.

Table 4
Demographic data from subject matter experts (SMEs) who participated in the focus group compared to the wider ICFP population.

	Focus Group SMEs (n = 16)	ICFP Population (n = 45)
Age[a] (yrs)	47 (36–52)	48 (36–62)
Total experience[a] (yrs)	20 (13–31)	23 (12–38)
ICFP experience[a] (yrs)	8 (2–20)	11 (2–24)
Collective ICFP experience (yrs)	126	465

[a] Data expressed as mean (range).

Level 3). Even though there were no incidences of an individual ICFP undertaking a Criterion 3, Level 3 rescue for the four years of data (defined as significant exertion and/or distance >500 m under load and/or patient >100 kg and/or 3 or more patients, carrying 43 kg of equipment, no assistance on ground), SMEs were in agreement (≥80%) that this situation could and likely has occurred outside the defined data capture period.

Similarly, for water winch rescue, SMEs agreed (≥80%) that ICFPs should be expected to be able to perform the maximum described task (Table 4 Criterion 3, Level 2) despite a low incidence (28.5%) in the recorded data in the defined time period. SMEs detailed that water rescue situations are highly variable due to a number of factors, including patient compliance, sea state/swell, weather, temperature, location of patient (e.g., rescue from a life-raft versus in-water), and the distance required to swim. Participants also noted that perceived exertion/level of effort is highly subjective between ICFPs and that some efficiencies would be gained by experienced staff when compared to junior staff.

SMEs discussed the fact that there would be significant physical and cognitive load (leading to physiological stress) in the timeframe immediately prior to performing land winch rescue and water winch rescue (due to donning rescue clothing and equipment in anticipation of rescue, reconfiguring aircraft cabin, winching out of a helicopter at up to 90 m). Acknowledging that as part of this project, any future physiological testing would not include live winch operations due to the prohibitive cost of helicopter operations, SMEs indicated that donning specialist rescue clothing and equipment (such as a wetsuit and a winch harness) immediately prior to assessment would serve as an acceptable surrogate for the cognitive and physiological demand of the preparation phase of real-world rescue. After an extended discussion in collaboration with the research team, SMEs reached consensus (100%, via show of hands) regarding descriptions of the physically demanding tasks in HEMS SAR (Table 5).

4. Discussion

This study found that SMEs in a focus group can use recorded case data to reach a consensus to define physically demanding land and water winch tasks in helicopter search and rescue. Recorded case data may be a useful addition to SME focus groups when establishing physically demanding tasks during the development of PES in occupations such military and civilian search and rescue services. The task descriptions from our study resemble those seen in studies of other physically demanding occupations, such as specialist teams such of wildland firefighters (Gumieniak et al., 2018), specialist police teams (Silk et al., 2018b) and other search and rescue services (Milligan et al., 2017; Silk et al., 2018a).

The use of focus groups is well established in health research, but participants must be representative of the population being studied. In our study, SME demographics and experience were comparable to the wider ICFP population, and focus group participants met the criteria for identification as SMEs as defined by Blacklock et al. (2015). Each SME participant had completed land and water winch rescue in both training and operational environments, had performed leadership roles (all ICFPs are senior clinicians with clinical instruction experience), and witnessed the tasks performed both satisfactorily and unsatisfactorily using various techniques. Focus groups members in this study can therefore reliably classed as experts (Baker et al., 2006; Blacklock et al., 2015), and the resultant consensus statements reliable. It is prudent to ensure SME focus groups meet minimum criteria for the definition as experts to increase engagement and acceptance of outcomes by the wider occupational group.

Once presented with the collated land winch rescue data, SMEs expectation was that ICFPs must be capable of the task categories that would be the most extreme situations in HEMS SAR irrespective of historical incidence. This was unexpected given the limited occurrence and/or absence of extreme tasks in the recorded rescue data. This however acknowledges the unpredictable nature of the emergency work, and that such strenuous tasks have or are likely to occur. A similar low incidence of the most demanding recorded task was noted for water winch rescue, yet again SMEs felt that it is reasonable to expect all staff to be capable of the task's performance. Other studies have demonstrated the tendency for specialist team members to set high physical performance expectations for their colleagues, irrespective of operational task frequency (Silk et al., 2018b; Taylor et al., 2012). This highlights the importance of structured, systematic PES to ensure physical assessments are relative to the operational environment (Reilly et al., 2006), especially in high-risk, low frequency tasks such as land and water winch rescue. Our use of historical rescue data allowed SMEs (who had demonstrated their high expectations) to reference real rescues in their discussions when developing consensus descriptions of the physically demanding winch rescue tasks, and this may have reduced recall bias.

When exploring water winch rescue specifically, SMEs detailed that water rescue situations are highly variable due to a number of factors, including patient compliance, sea state/swell, weather, temperature, location of patient (e.g., life-raft versus in-water), and the distance required to swim. This aligns with the variability in physical demand during water-based rescue described in other studies (Prieto Saborit et al., 2010; Salvador et al., 2014). Participants also noted that perceived exertion/level of effort is highly subjective between ICFPs and that some efficiencies would be gained by experienced staff when compared to junior staff. The influence of experience on physical task performance is well reported (Milligan et al., 2017; Tipton et al., 2008). Interestingly, our recorded data indicated 28.5% of water rescues required greater than 50 m of swimming, yet SMEs consensus described a swim distance of a maximum of 50 m in moderate swell. This was discussed by the group in detail. SMEs acknowledged low frequency of water rescue, the fact that they always remain connected to the winch cable, and that recorded swimming distances were greater and lesser than 50 m. SMEs also reported water rescues occurred in calm through to rough sea conditions. Thus, SMEs were willing to compromise on these extremes at a theoretical median of 50 m swimming in a moderate swell. In general, many of these compromises were not seen as applicable to land winch rescue. The level of exposure to land winch rescue was significantly higher, and SMEs were more confident and in discussing demands during land rescues. This highlights that where incidences of tasks are low, results from SME focus groups should be interpreted in the context of task frequency.

Objective quantification of tasks, ideally through direct observation of task performance in the field is seen as the ideal approach, but can

Table 5
Subject matter expert consensus descriptions of the physically demanding tasks of land winch rescue and water winch rescue during helicopter search and rescue operations.

Task: Land winch rescue
From a starting point of enhanced cognitive and physiological load, whilst wearing the ICFP overland rescue personal protective equipment, be lowered (winched) to the ground from a helicopter with the specified equipment, reconfigure equipment for carriage, and then walk, at least 250 m over uneven, steep terrain, whilst navigating any obstacles. Once reaching the patient, recover, provide clinical care, then secure the patient in the winch stretcher. Relocate the patient to a safe position and recover by winch to the aircraft.
Task: Water winch rescue
From a starting point of enhanced cognitive and physiological load, whilst wearing the ICFP water rescue personal protective equipment, the ICFP is lowered (winched) into the water from a helicopter, and then swims, using any stroke, 50 m in moderate swell. Once reaching the patient, the ICFP treads water, and secures the rescue strop around the patient (in water or a life raft). The ICFP then removes the patient to a safe position and is recovered by winch to the aircraft. Repeat immediately once.

encumbered through logistical and financial constraints (Beck et al., 2016). This particularly notable in the case of HEMS SAR, where significant flying costs and the inherent risk of the tasks make this infeasible. As such, methods such as the one described in this paper utilise subjective determination with objective confirmation as a method of offsetting some of the logistical constraints (Beck et al., 2016). Our method served to be effective in achieving the desired outcome and is partially attributable to the presence of the existing data and thus it required minimal resources. For organisations developing PES for specialist roles, we have described methods to use recorded case data to assist SMEs in accurately describing low frequency yet complex physically demanding tasks. In the context of HEMS SAR, these descriptions provide the basis for formulation of simulations and progression of a focused PES for winch rescue tasks. It is important to acknowledge that the specific task descriptions generated in this study may not be directly transferrable to HEMS SAR providers in other jurisdictions due to variations in key operational factors such as staffing and topography for example.

Although this study led to a description of specific physically demanding tasks, SMEs and the research team acknowledged that some components of the task may not be easily assessed in the field. This includes the preparatory phase but may also include clinical care and extraction from the scene via winch, which require varying degrees of physical strain. Our SME focus group represented a wide range of experience and seniority; however, the subjective nature of the process may allow expectations of physical capacity and task performance to vary significantly, thus compromising content validity. The primary reasoning for the use of recorded rescue data in this study was to empower the SMEs to use real incidences to guide their analyses and objectively confirm the incidence of physically demanding rescues, and limit recall bias. The SMEs represented 35.5% of the operational workforce, a higher number than expected, and combined with the range of experience increased the likelihood that SME input was reflective of the greater employee group.

Few studies describe the utilisation of recorded case data to guide SMEs to define the most physically demanding tasks of an occupation. Hughes et al. used a combination of surveys, incident reports and video footage to establish content validity in a study investigating critical job tasks and physical performance tests in corrections officers (Hughes et al., 1989), and Arvey et al. describe a similar method of combining incident reports, SME analysis of task requirements and employee surveys (Arvey et al., 1992). These studies highlight the development of PES in instances of well-resourced, relatively large project teams where the organisation has sought external expertise to conduct the PES process. In our case, the study was initiated from outside the organisation, and was thus resource limited. However, with the cooperation of AV and the ICFP group, researchers were able to access and collate data from prospective, established databases. Additionally, SMEs located in regional areas were able to contribute to the focus group via videoconference, whilst readily viewing the collated recorded rescues data and participating in discussions. This may be valuable in instances where face to face focus groups are not viable, such as during an infectious disease pandemic.

5. Conclusions

Historical case data from operational missions can be used by SMEs in a focus group to reliably describe physically demanding winch rescue tasks in HEMS SAR. This method may be useful for the basis of PES in a number of occupations where employees perform complex low-frequency, physically demanding tasks such as military and civilian search and rescue services and specialist first-responder teams. To enable this process to be undertaken, organisations deploying specialist teams should implement robust systems to prospectively collect detailed in-field data that describes the physically demanding elements of operational cases.

Author contributions

All authors contributed to the study concept and design. BM, JC and KB prepared material for the focus groups and completed the analysis. The first draft of the manuscript was written by BM, JC, KB and LP, and all authors commented on each version of the manuscript. All authors read and approved the final manuscript.

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Data statement

Records analysed in this study contain information that may allow for individuals to be identified. As such raw data are confidential and are not available.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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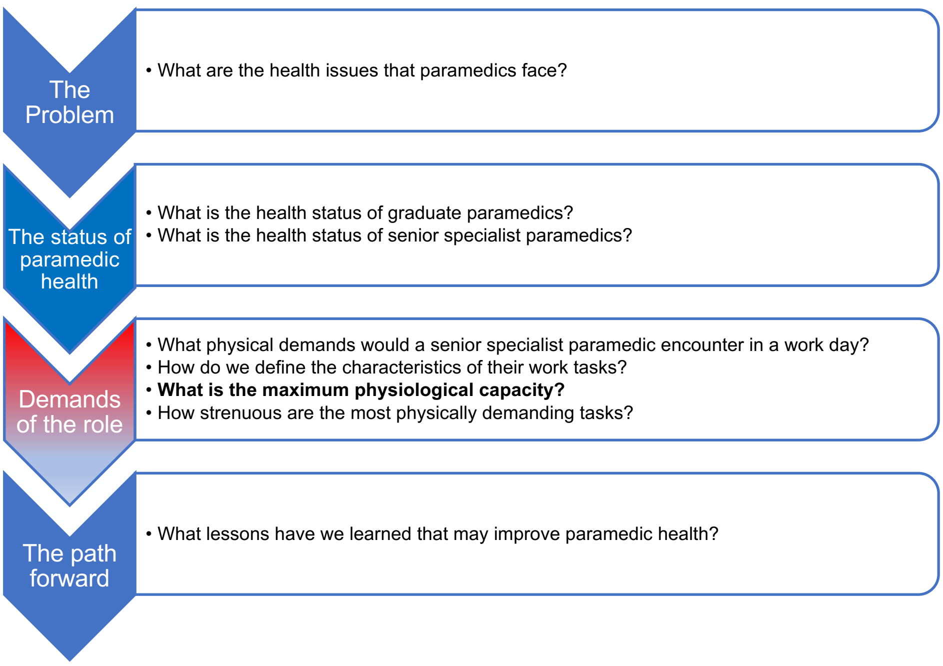
6.3 Summary of Chapter Six

This is the first study to use historical case data within a subject matter expert focus group to identify and describe the most physically demanding tasks in the ICFP HEMS rescue role. The ICFPs included in the focus group were able to review data from historical cases to identify winch tasks as the most physically demanding and achieve greater than 80 percent consensus when defining the characteristics of winch rescue over land and in water. The processes described in this chapter may be useful for the development of task simulations not only in specialist paramedics, but also the wider paramedic and emergency services professions, and others who perform similar roles (e.g., military special operations teams). In the context of this thesis and determining the physical demands of ICFP winch rescue work, this process primarily allows for the development of task simulations for the assessment of relative physiological workload, which will be described in Chapter Eight. However, prior to determination of the relative physical demands of ICFP work, the maximum physiological capacity must be measured.

Chapter Seven: Comparison of swimming versus running maximal aerobic capacity in helicopter rescue paramedics

7.1 Preamble

In Chapter Six, the most physically demanding tasks performed by ICFPs were defined. To ascertain relative physiological workload for those tasks, maximal physiological capacity must first be established. Although protocols for the assessment of maximal aerobic capacity on land are well-established, this is not the case for water-based tasks. Protocols exist to measure maximal aerobic capacity whilst swimming in elite athletes, but these are not suitable for non-elite populations including ICFPs. The quasi-experimental study described in this chapter aimed to measure maximal physiological capacity in 14 ICFPs. Paramedics underwent two maximal aerobic capacity tests. The first was an established treadmill-based maximal aerobic capacity (VO_{2peak}) protocol and the second was a novel pool-based VO_{2peak} assessment. These assessments provided maximal data for oxygen consumption, blood lactate, heart rate and perceived exertion in both water and land-based environments, allowing for assessment of work task demands relative to maximum capacity (Chapter Eight). In addition, this study compared results from each protocol to assess equivalence.



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Comparison of swimming versus running maximal aerobic capacity in helicopter rescue paramedics

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ABSTRACT
Swimming is a critical task for helicopter rescue paramedics and aerobic capacity is assessed in this occupation to determine job suitability. We evaluated one treadmill-based and one pool-based assessment of maximal aerobic capacity (VO_{2peak}) in 14 helicopter rescue paramedics. There was a small absolute difference ($p = 0.11$, $d = 0.46$) between VO_{2peak} in the swim (45.5 ± 7.8 ml.kg^{-1}.min^{-1}) compared to the run (48.5 ± 5.5 ml.kg^{-1}.min^{-1}), with a moderate relationship noted ($r = 0.74$, 95% CI [0.35–, 0.91], $p = 0.0023$). Whilst not interchangeable, run VO_{2peak} was a predictor of swim VO_{2peak}. Maximal blood lactate was similar ($p = 0.93$) in swim (13.4 ± 3.8 mmol.L^{-1}) and run (12.2 ± 3.0 mmol.L^{-1}), and maximal heart rate 13% lower ($p < 0.0001$) in the swim (162 ± 11 bpm) versus the run (186 ± 10 bpm). To estimate swimming VO_{2peak} in paramedics a treadmill test is sufficient but does not replace assessment of swimming proficiency.

Practitioner Summary: We developed a swim protocol to assess maximal aerobic capacity in helicopter rescue paramedics. Compared to a treadmill-based test, our swim protocol generated 20% lower submaximal VO_2 and 6% lower VO_{2peak}. Although not interchangeable, a treadmill VO_{2peak} test is indicative of maximal aerobic capacity in rescue paramedics whilst swimming.

Abbreviations: HEMS: helicopter emergency medical service; PES: physical employment standards; ICFP: intensive care flight paramedic; RPE: rating of perceived exertion

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Human performance; aerobic capacity; exercise performance; emergency medical services

Introduction

Paramedics working in specialist teams such as Helicopter Emergency Medical Services (HEMS) are required to perform physically demanding tasks such as rescue from remote wilderness or open water (Meadley et al. 2016). Specialist rescue services typically develop physical employment standards (PES) for selection to the team (Petersen et al. 2011). PES should be developed from evidence-based and validated processes to ensure they have acceptable accuracy and validity, do not discriminate against capable persons, yet identify those unsuitable for the role. These requirements minimise the risk of employees suffering injury during the course of their duties and ensures the capability of delivering the service they are chartered to provide. Robust and systematic PES also provide a barrier to legal challenges should an applicant be unsuccessful (Milligan et al. 2016).

To assess applicant suitability for selection to specialist teams within large organisations (e.g., military special forces and civilian search and rescue teams), there is a tendency to develop PES that are more stringent than that of the wider workforce (Carlson and Jaenen 2012; Hunt, Orr, and Billing 2013; Milligan, House, and Tipton 2017). Previous work characterising the demands of physically demanding occupations has led to assertions that minimum standards for cardiovascular fitness should be based on maximal oxygen consumption (VO_{2max} or VO_{2peak}) (Gledhill and Jamnik 1992; Siddall et al. 2016). One of the most physically demanding tasks performed by helicopter rescue paramedics is water rescue via winch from the helicopter. Winch rescue is also conducted over land.

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As part of the development of PES for helicopter rescue paramedics, we sought to assess the maximal aerobic capacity of helicopter rescue paramedics in water.

Protocols for measuring VO_{2peak} in non-elite populations undertaking high-performance swimming as part of their occupation are not described in the literature, and accurate assessment of VO_{2peak} while swimming is complex. There is wide variation of VO_{2peak} protocols within the literature, with the majority of studies conducted on sub-elite or elite swimmers (Pelarigo et al. 2017; Pelarigo et al. 2018; Ribeiro, Lima, and Gobatto 2010). Protocols for highly-trained athletes involve a series of short intervals (typically 100-m or 200-m) with short breaks and increasing intensity (Tanner and Gore 2012). It is well established that critical power required to generate VO_{2peak} are not sustainable for an extended duration (Jones et al. 2010), and this is especially relevant to non-elite swimmers. Helicopter rescue paramedics as a group exhibit moderate-to-good levels of swimming capability. The protocol designed for high-performance athletes may not yield an accurate estimate of $VO_{2peak,}$ thus compromising the predictive validity and value of this assessment in PES.

Although surrogate measures such as blood lactate and heart rate can be used to estimate physiological workload during many forms of exercise including swimming (Pyne, Lee, and Swanwick 2001), VO_{2peak} is most accurately assessed via quantification of oxygen consumption during exercise to volitional exhaustion. Proprietary indirect calorimetry devices to assess oxygen consumption during swimming are available, however these are costly and not accessible to many organisations and research teams. Moreover, there are some suggestions that this equipment may underestimate true values of VO_2 (Baldari et al. 2013; Reis 2011). Additionally, anecdotal reports from research teams familiar with this type of equipment highlight some methodological complications that can occur secondary to inadvertent water contamination. However, a recent study reported validated assessment of VO_{2peak} in competitive and recreational swimmers using the Cosmed K4b and AquaTrainer portable respiratory-metabolic system (Cosmed, Rome, Italy) in a controlled pool environment (Nagle et al. 2019).

Other less costly methods are available to assess oxygen consumption during free swimming, including intermittent use of Douglas bags (Di Prampero et al. 1974) or indirect assessment using the backwards extrapolation method (Lavoie and Montpetit 1986). We sought to explore the utility of these methods during the development of a test specifically for helicopter rescue paramedics. Additionally, we sought to compare VO_{2peak} generated during swimming with that during running on a treadmill. Physical assessments in the aquatic environment may present a significant logistical burden to organisations due to water contamination of sensitive equipment, the effects of weather on performance if testing is conducted outdoors, and the paucity of swimming-specific physiology laboratories. Conversely, treadmill-based testing is readily accessible at universities, research facilities or sports institutes where the above-mentioned burdens are eliminated. If results from a treadmill test were sufficiently similar to that seen in a pool-based assessment, this may obviate the need to specifically assess VO_{2peak} in the aquatic environment. The aims of this study were to (i) develop and assess a pool-based maximal oxygen capacity test for non-elite occupational swimmers during free swimming and (ii) compare results from this test with a validated treadmill-based running VO_{2peak} assessment. Limited previous work in this area has identified that a lesser physiological response may be noted in swimming when compared to running (Åstrand and Saltin 1961). We expected that in a sample of helicopter rescue paramedics, our novel pool-based protocol would generate significantly lower cardiorespiratory values than during a criterion treadmill-based VO_{2peak} protocol. We expected that running VO_{2peak} would not predict swimming VO_{2peak}, therefore a separate water-based VO_{2peak} assessment may be required for this occupational group.

Materials and methods

Study population

We employed a repeated measures, cross-over study, of intensive care flight paramedics working for a state ambulance service. The state of Victoria, Australia covers an area of approximately 237,629 km^2 including remote and difficult-to-access terrain, and more than 2,000 km of coastline. Ambulance Victoria is the single provider of HEMS in Victoria and helicopters are staffed by an intensive care flight paramedic (ICFP), an air crew officer, and a pilot. ICFPs are deployed from the aircraft to perform land and water-based winch rescue. Ambulance Victoria HEMS operations have been described in detail in previous work (Andrew et al. 2015; Meadley et al. 2016).

Eligibility for the study required current employment by Ambulance Victoria as an ICFP, with authorisation to undertake all role duties including winch rescue. Convenience sampling via corporate email was utilised given the varied roster patterns and geographical work locations. Participants were required to complete a form that described basic demographics and occupational experience. Written informed consent was obtained from all individual participants included in the study. The study was approved by the Monash University Human Ethics Research Committee (Project number 16340) and Ambulance Victoria Research Committee (Project R18-016). All research in this study was conducted under the framework of the National Health and Medical Research Council Australian Code for the Responsible Conduct of Research.

Participants ($n = 14$, 12 male, 2 female) were 44 ± 5 years of age (mean ± SD) and had 19 ± 5 years' experience as a paramedic, with 7 ± 5 years in the specialist ICFP role. Participants completed a run or swim VO_{2peak} protocol in random order as their first assessment. Prior to reporting to the laboratory or swimming pool, participants were requested to avoid strenuous exercise in the preceding 24 hours, be free from illness for the preceding 14 days, and have had at least seven days between run and swim testing. All participants were required to complete the Exercise and Sports Science Australia Pre-Exercise Screening Tool to identify risks when completing a maximal exercise test (Brickwood et al. 2013). All testing was conducted between 0700-1000 hours.

Measurements

Anthropometry, body composition and cardiometabolic health

Each participant had a comprehensive assessment of haemodynamic status, anthropometry and body composition prior to the run test, with body mass, resting heart rate and blood pressure measured prior to the swim test. Values were measured twice (and the mean value recorded) as follows: after 5 min sitting at rest, blood pressure and resting heart rate was measured on the left arm using the Welch Allyn Connex 3400 ProBP Automatic Blood Pressure Machine (Welch Allyn Skaneateles Falls, New York, USA). Body mass was measured using calibrated SECA 813 Digital Flat Scales (SECA, Hamburg, Germany). Waist circumference was measured using a fabric metric tape measure at the level of the umbilicus (Brown et al. 2018). Height was measured using a SECA 213 portable stadiometer (SECA, Hamburg, Germany). Body composition was assessed via a validated bioelectrical impedance device (Bosy-Westphal et al. 2017) (SECA 515 mBCA body composition analyser, SECA, Hamburg, Germany) including body mass, fat mass, fat free mass and body mass index. Capillary blood (5 µl) was sampled from a fingertip for analysis of resting blood lactate concentration (Lactate Pro2, Arkray, Tokyo, Japan).

Table 1. Maximal oxygen uptake–run protocol.

	Warm up	Start Test	Increment V1	Increment V2
Time	3 min	0 minutes	+3 min	+3 min
Speed	3−15 km.hr^{-1}	6 km.hr^{-1}	+2 km.hr^{-1}	14 km.hr^{-1}
Incline (%)	0	1.5	1.5	+2.5

Increment V1 commenced 3 min after the test started, (at 6 km.hr^{-1} and 1.5% incline) and continued until 14 km.hr^{-1}. After 3 min at 14 km.hr^{-1} increment V2 commenced, where speed was maintained, and incline increased by 2.5% every 3 min until exhaustion.

Maximum oxygen uptake – running protocol

VO_{2peak} was estimated by indirect calorimetry (Vmax Encore Metabolic Cart: Carefusion, San Diego, California, USA) during a continuous incremental exercise test to volitional exhaustion on a motorised treadmill (MyRun, Technogym, Seattle, Washington). A standard laboratory protocol (including system calibration) as described previously (Costa et al. 2009) was used. All tests were performed in a temperature-controlled laboratory set at 22 °C. Participants were familiarised with the test protocol and the Rating of Perceived Exertion (RPE_{6-20}) scale (Borg 1982), then completed a 3 min warm up at a self-determined pace. The protocol commenced at 6 km.hr^{-1} with an incline of 1.5%, with speed increased every 3 min (Increment V1, Table 1) up until 14 km.hr^{-1}, after which incline was increased by 2.5% every 3 minutes until exhaustion as per Increment V2 (Table 1). Heart rate was measured continuously via a Polar FT1 watch and H10 heart rate monitor strap (Polar Electro Oy, Kempele, Finland). Within 30 sec of completion of each 3 min phase and at test termination, participants indicated RPE_{6-20} and 5 µl capillary blood was sampled from a fingertip for analysis of blood lactate concentration. Tests were terminated at volitional exhaustion, and the VO_{2peak} recorded. Protocol details are shown in Table 1.

Maximum oxygen uptake – swimming protocol

Our novel protocol (300-m, 200-m, 100-m swims of increasing intensity, Table 2) was developed in consultation with swimming physiologists from state and national elite swimming programs. The research team attended and observed elite athlete physiological testing sessions and met with a subject matter expert

Table 2. Maximal oxygen uptake – novel swim protocol.

	Stage 1	Stage 2	Stage 3
Distance	300 m	200 m	100 m
Expired air Sampling	End of stage	End of stage	Real time (last 50 m)
Pace	15 RPE (hard)	18 RPE (very hard)	20 RPE (maximal exertion)
Rest period (post-stage)	2 min: 30 sec VO_2 sample, lactate, RPE and HR recorded	2 min: 30 sec VO_2 sample, lactate, RPE and HR recorded	End of test: Lactate, RPE and HR recorded

VO_2, blood lactate, and RPE were sampled within the rest period at the end of stages 1 and 2, and real-time VO_2 was obtained in the last 50 m of stage 3. Heart rate was recorded continuously throughout.

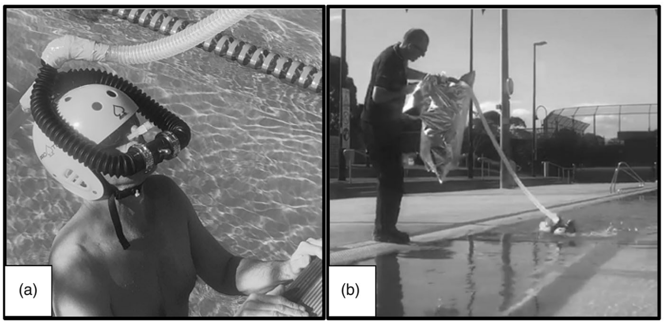

Figure 1. (a) modified diving rebreather circuit connected to rescue helmet for the swim protocol. (b) Sampling expired air during the final 50 m of Stage 3 of the swim protocol. Alt-text: (a) A swimmer standing at the end of a swimming pool wearing a helmet and a breathing apparatus, (b) one person swimming in a pool, whilst another person walks along the pool edge carrying a large bag to collect expired air.

(DP) to describe the characteristics of the study population, the type of work performed by the ICFPs, and how the team could design a pool-based test to replicate the increasing intensity of the run protocol to accommodate the non-elite swimming capability of the participants. Once developed and prior to formal data collection, the research team pilot-tested the novel swim protocol in three ICFPs which revealed minor logistical challenges in the original protocol. Amendments to the pilot protocol included sampling expired air immediately at the end of each stage on the first breath while the participant was still in the pool, increasing the number of researchers to allocate one to each individual measurement (expired air collection, blood sampling and lactate analysis, recording time intervals and $RPE_{6\text{-}20}$), and use of a swimming-specific nose-clip versus a standard laboratory nose clip for the final stage.

Testing was performed at an outdoor 50-m swimming pool (water temperature 26.7 ± 0.2 °C, air temperature 14.5 ± 2.0 °C, barometric pressure 767.2 ± 4.5 mmHg; mean ± SD). Upon arrival participants were familiarised with the test protocol, and resting blood lactate concentration, heart rate and oxygen consumption were measured. A swimming-specific heart rate monitor and chest strap were fitted to the participant (Garmin Forerunner 735XT watch and HRM SWIM strap, Garmin, Olathe, Kansas, USA) and set to record and store continuous heart rate data. These data were downloaded after the test and synchronised with time stamps recorded at each stage. Participants were familiarised with the $RPE_{6\text{-}20}$ scale and trialled a rebreather circuit/helmet setup (Figure 1(a)) over a short 15-m swim (to be used in the final stage of the protocol). The modified diving rebreather circuit (Poseidon Diving Systems AB, Akered, Sweden) was adapted from existing equipment by the research team to allow for in-activity capture of expired air using equipment familiar to the ICFPs. The circuit was secured to the standard issue ICFP water rescue helmet (Classic Full, Pro-tec, Santa Fe Springs, California, USA). Importantly, ICFPs are accustomed to front crawl/freestyle swimming in this helmet with a snorkel and diving mask. The one-way valve and mouthpiece system allowed for watertight inspiration via one arm, and expiration via the other. The inspiratory arm was extended and made watertight to act as a snorkel, and the expiratory arm shortened and modified to be watertight and compatible with standard corrugated ventilation tubing. The tubing was then connected via a three-way tap at the distal end to the Douglas bag (Figure 1(a)). After completion of the familiarisation with the rebreather/helmet apparatus, it was removed, and participants completed a warmup at $RPE_{6\text{-}20}$ 13–15 over 200-m.

Previous work using perceptually regulated exercise training (Molinari et al. 2020) informed the pacing strategy, which was determined by fixed $RPE_{6\text{-}20}$ values. However, participants were instructed to report their actual $RPE_{6\text{-}20}$ at the end of each stage. Stage 1 was a freestyle swim of 300-m at a target $RPE_{6\text{-}20}$ of 15, followed by a 2 min rest. Stage 2 was a freestyle swim of 200-m at a target $RPE_{6\text{-}20}$ of 18, followed by a 2 min rest. At the end of stages 1 and 2, expired air was immediately collected on the first breath for 30 sec using a 120 litre Douglas bag connected to a one-way valve and mouthpiece via corrugated ventilation tubing, with the participant remaining in the water wearing a nose clip. Capillary blood lactate was measured from an earlobe sample (5 µl), heart rate was sampled via pulse oximetry (Nonin PalmSat, Nonin, Minneapolis, Minnesota, USA) in case of failure of the chest heart monitor, and actual $RPE_{6\text{-}20}$ was recorded. Stage 3 was a 100-m freestyle swim with participants required to swim at $RPE_{6\text{-}20}$ of 20, or their maximum effort. Table 2 shows a summary of the swimming protocol.

During Stage 3, participants wore the modified diving rebreather circuit and rescue helmet apparatus. A swimming-specific nose clip was used throughout the final stage to prevent expiration through the nose, and ensure all expired air was collected in the Douglas bag. Expired air was only sampled for the last 50-m of the 100-m final stage due to volume and carriage limitations of the Douglas bag (Figure 1(b)), and sample time was recorded. The test was terminated after completion of Stage 3 and capillary blood lactate, heart rate via pulse oximetry and $RPE_{6\text{-}20}$ were again recorded. For each stage, expired air samples were analysed at the poolside immediately after collection (ML206 Gas Analyser PowerLab 8/30, ML870, AD Instruments, New South Wales, Australia), with sample volume obtained via a dry volumeter. Both protocols fulfilled the requirements of a maximal test for VO_{2max} assessment, namely blood lactate $\sim$8 mmol.l^{-1}, respiratory exchange ratio values $>$1.0, heart rate $>$85% of its maximum values, and an exertion to exhaustion (Fernandes and Vilas-Boas 2012; Howley, Bassett, and Welch 1995). We acknowledge the limitations of our methods to verify VO_2 plateau during the swim assessment. As such, we recorded VO_{2peak} in the run and swim protocols (as opposed to VO_{2max}), thus refer to maximal aerobic capacity as VO_{2peak} in the context of this study.

Table 3. Categorisation and alignment of effort by $RPE_{6\text{-}20}$ score for swim and run protocols.

	Run		Swim		
Category	Median	Range	Median	Range	Difference [95% CI]
Hard	13	10–15	15	12–16	2.0 [1.0, 3.2]
Very Hard	15	12–17	17.5	17–19	2.5 [1.5, 3.7]
Maximal exertion	18	15–20	20	18–20	2.0 [0.6, 2.4]

To align the analyses for all variables and for protocol comparison, data were organised into categories and aligned with participant-reported $RPE_{6\text{-}20}$ from the swim and run tests to create categories of 'Hard', 'Very Hard' and 'Maximal exertion'.

Given the disparate nature of the swim and run testing protocols and environments, data were organised into categories and aligned with participant-reported $RPE_{6\text{-}20}$ from the swim and run tests. The resultant categories of 'Hard', 'Very Hard' and 'Maximal exertion' were created to align the analyses for all variables, and allow for within and between protocol comparison, similar to the methods described previously (Molinari et al. 2020). Table 3 shows the respective $RPE_{6\text{-}20}$ scores for each category.

Statistical analysis

Data were assessed for normality via the Shapiro-Wilk test and found to be normally distributed. Resting and maximal values for swim and run assessments were compared via a paired t-test. For comparison between swim and run protocols, and between Hard, Very Hard and Maximal exertion categories within each protocol, a linear mixed effects analysis was performed. We analysed these data by fitting a mixed model using a compound symmetry covariance matrix with Restricted Maximum Likelihood (REML). In the absence of missing values, this method gives the same p values and multiple comparisons tests as a repeated measures ANOVA. In the presence of missing values, the results can be interpreted like repeated measures ANOVA. We assumed equal variability of differences, so we did not apply the Geisser-Greenhouse correction, and performed Tukey's multiple comparison test, with individual variances computed for each comparison. Simple linear regression was performed to investigate the relationship between swim and run VO_{2peak}. To examine effect size for VO_2 data, we calculated Cohen's d with thresholds of small (0.2), medium (0.5) and large (0.8). Ordinal data for RPE were compared using a Wilcoxon

Table 4. Demographics, anthropometric and cardiometabolic data for participants (2 female, 12 male).

	Mean ± SD	Range
Age (years)	44.3 ± 5.4	34–55
Paramedic experience (years)	19.1 ± 5.1	14–30
ICFP experience (years)	7.1 ± 5.2	1–18
Height (cm)	180.0 ± 6.0	168.0–189.3
Body mass (kg)	80.2 ± 12.5	58.6–104.8
Fat free mass (kg)	61.3 ± 9.0	45.2–79.3
Body Fat (%)	23.6 ± 4.5	17–30
Body Mass Index (kg m^2)	24.7 ± 3.0	21.6–30.2
Waist : Height ratio	0.48 ± 0.05	0.39–0.57
Systolic blood pressure (mmHg)	134 ± 14	111–159
Diastolic blood pressure (mmHg)	81 ± 8	66–93
Resting heart rate (bpm)	65 ± 11	46–80
Run VO_{2peak} (ml.kg^{-1}.min^{-1})	48.5 ± 5.5	40.2–56.7

Male and female values are combined and indicative only and cannot be used for gender-specific reference.

test with the Pratt method for ties. All analyses were conducted using Prism (Version 8.4.3; GraphPad Software, San Diego, California, USA), and statistical significance was determined *a priori* at $p \le 0.05$.

Results

Paramedic physical characteristics

Participants ($n = 14$, 2 female, 12 male) were 44 ± 5 years of age (mean ± SD), with a body mass index within the healthy weight range (24.7 ± 3.0 kg m^2) and waist-to-height ratio 0.48 ± 0.05. Systolic blood pressure (134 ± 14 mmHg) and the range of body mass index values (24.7 ± 3.0, range 21.6–30.2) indicated a modest degree of cardiometabolic disease risk in some participants (Table 4). Note that male and female values are combined, as separation of these data for the two female participants would allow for identification of individual values and risk breaching confidentiality.

Maximal and submaximal oxygen uptake

The mean VO_{2peak} obtained from the swim protocol was, although not statistically significant approximately 6% lower than the run protocol, with small standardised difference (swim 45.5 ± 7.8 ml.kg^{-1}.min^{-1} vs run 48.5 ± 5.5 ml.kg^{-1}.min^{-1}, $p = 0.11$, $d = 0.46$). Simple linear regression was performed to further investigate the relationship between swim and run VO_{2peak}. The scatterplot indicated a positive linear relationship ($r = 0.74$, 95% CI [0.35–0.91], $p = 0.0023$) between the two modes of exercise. A non-linear line was fitted to test for normality using a D'Agostino-Pearson omnibus (K^2) test, and showed these data met the assumptions of homogeneity of variance and linearity, and the residuals were normally distributed. Simple linear regression showed run VO_{2peak} was a moderate predictor of swim VO_{2peak} ($R^2 = 0.55$, $p = 0.0023$) (Figure 2).

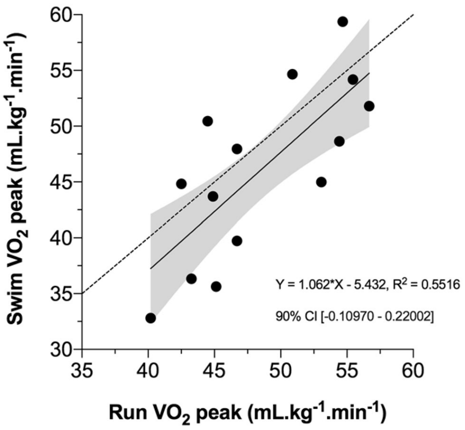

Figure 2. Linear regression for the relationship between participants' Swim VO_{2peak} and Run VO_{2peak} (ml.kg^{-1}.min^{-1}) with 90% confidence intervals (shaded region) and a line of identity (dashed line; where x = y). Alt-text: A regression graph that shows that there is a moderate relationship between the VO_{2peak} measured whilst running with the VO_{2peak} that is measured during swimming.

Submaximal VO_2 was approximately 20% lower in the swim protocol compared to the run protocol at the stages of Hard (swim 27.8 ± 4.9 ml.kg^{-1}.min^{-1} vs run 34.9 ± 5.7 ml.kg^{-1}.min^{-1}, $p = 0.0082$, $d = 1.34$) and Very Hard (swim 33.0 ± 7.8 ml.kg^{-1}.min^{-1} vs run 41.8 ± 8.5 ml.kg^{-1}.min^{-1}, $p = 0.0317$, $d = 1.08$). However, both the swim and run protocols resulted in significant increases in VO_2 from Hard to Very Hard (swim 27.8 ± 4.9 ml.kg^{-1}.min^{-1} to 33.0 ± 7.8 ml.kg^{-1}.min^{-1}, $p = 0.0292$, $d = 0.74$ and run 34.9 ± 5.7 ml.kg^{-1}.min^{-1} to 41.8 ± 8.5 ml.kg^{-1}.min^{-1}, $p = 0.005$, $d = 0.95$) and from Very Hard to Maximal (swim 33.0 ± 7.8 ml.kg^{-1}.min^{-1} to 45.5 ± 7.8 ml.kg^{-1}.min^{-1}, $p < 0.0001$, $d = 1.6$, and run 41.8 ± 8.5 ml.kg^{-1}.min^{-1} to 48.5 ± 5.5 ml.kg^{-1}.min-1, $p = 0.0034$, $d = 0.94$) (Figure 3(a)).

Resting and maximal heart rate

Figure 3(b) details comparison of heart rate for the two protocols. When compared to the run, resting heart rate was higher before the swim. In the Hard and Very Hard stages, heart rate was approximately 14% lower in the swim protocol than in the run protocol. For both the swim and run protocols, heart rate increased progressively from rest to the Hard stage,

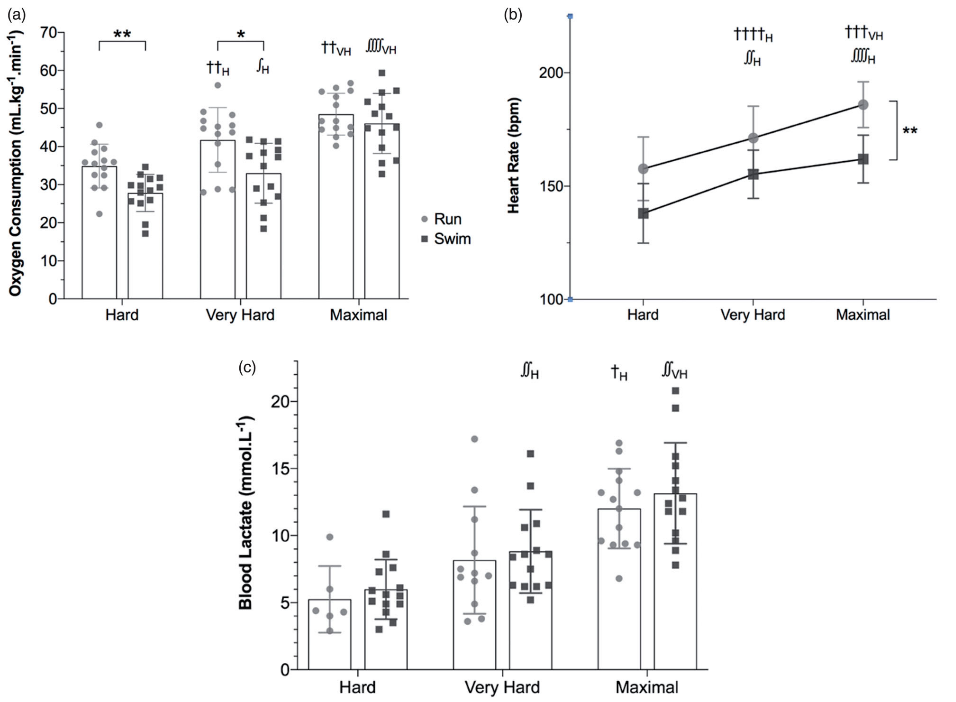

Figure 3. Comparison and progression of each stage in the run and swim VO_{2peak} protocols for a) oxygen consumption ($mL.kg^{-1}.min^{-1}$), b) heart rate (bpm) and c) blood lactate ($mmol.L^{-1}$). In all graphs *denotes a significant difference between swim and run within any given phase (Hard, Very Hard or Maximal) where $*p \leq 0.05$ and $**p \leq 0.01$. †Denotes a significant difference between stages within the run, where $†_H$ denotes a significant difference to the Hard stage and $†_{VH}$ to the Very Hard stage and $† = p \leq 0.05$, $†† = p \leq 0.01$, $††† = p \leq 0.001$, and $†††† = p \leq 0.0001$. Similarly, $\int$ denotes a significant difference between stages within the swim, where $\int_H$ denotes a significant difference to the Hard stage and $\int_{VH}$ to the Very Hard stage and $\int = p \leq 0.05$, $\int\int = p \leq 0.01$, and $\int\int\int\int = p \leq 0.0001$. Alt-text: (a) A bar graph that shows that for running and swimming tests, oxygen consumption increases between the hard, very hard and maximal stages of the tests, (b) a line graph that shows that for running and swimming tests, heart rate increases between the hard, very hard and maximal stages of the tests, (c) a bar graph that shows that for running and swimming tests, blood lactate increases between the hard, very hard and maximal stages of the tests.

and from Hard to the Very Hard stage and Very Hard to Maximal exertion for the run protocol. This pattern was not observed in the swim protocol with only a 7 bpm difference between Very Hard and Maximal exertion, however heart rate at Maximal exertion was 24 bpm greater than at the Hard stage ($p < 0.0001$). For the Maximal exertion category, the maximal heart rate attained was lower in the swim test (162 ± 11 bpm) than the run test (186 ± 10).

Blood lactate and RPE

Figure 3(c) summarises changes in blood lactate, with Table 3 detailing the differences in $RPE_{6\text{-}20}$. Maximal blood lactate was not significantly different between the swim and run tests, but maximal $RPE_{6\text{-}20}$ was higher during the swim protocol compared to the run. There was no difference in blood lactate between the run and swim protocols at rest. During the swim protocol there was a 3.8 $mmol.L^{-1}$ increase in blood lactate from rest to Hard, with a 2.1 $mmol.L^{-1}$ increase observed in the run protocol. There was a further 2.8 $mmol.L^{-1}$ increase in blood lactate from Hard to Very Hard for the swim protocol, and 2.8 $mmol.L^{-1}$ increase from Hard to Very Hard in the run protocol. There were continuing increases in blood lactate from Very Hard to Maximal exertion in the swim protocol, and from Hard to Maximal exertion in the run protocol. There was little difference in blood lactate between the run and swim protocol at the end of the Hard or Very Hard stages (Figure 3(c)). RPE_{6-20} was higher during the swim compared to the run at all stages. In both the run and swim protocols the progressive increase in RPE_{6-20} was closely aligned, with 3 RPE_{6-20} unit (swim) and 2 RPE_{6-20} unit (run) increases from Hard to Very Hard and 1 RPE_{6-20} unit (swim) and 3 RPE_{6-20} unit (run) increases from Very Hard to Maximal exertion.

Discussion

In this study, we developed a novel pool-based VO_{2peak} assessment for high performance helicopter rescue paramedics who are proficient but not elite swimmers and compared this to an established treadmill-based assessment of endurance fitness. To our knowledge, there are no studies that have developed a pool-based maximal aerobic capacity assessment for non-elite occupational swimmers. The swim test generated similar but not directly interchangeable VO_{2peak} and maximal blood lactate values to those arising from a criterion treadmill-based running VO_{2peak} protocol. Compared to the treadmill test, the swim test generated a 6% lower VO_{2peak}, 20% lower submaximal VO_2, lower maximal heart rate, similar blood lactate values, but a higher RPE_{6-20}. We found that in helicopter rescue paramedics, VO_{2peak} generated while running on a treadmill is a moderate predictor of maximal aerobic capacity while swimming. As ICFPs are not high-performance athletes, this difference is unlikely to be clinically or operationally significant. For organisations looking to assess maximal aerobic capacity in non-elite rescue swimmers, a treadmill-based running assessment is sufficient, but swimming competence must still be assessed to ensure the capacity to perform the technical and specific role of the rescue swimmer.

The mean VO_{2peak} values generated in this sample of ICFPs are comparable to results from other studies investigating search and rescue professionals and specialist paramedics (Chapman et al. 2015; Prieto et al. 2013). However, many of these studies in rescue personnel are on men less than 40 years old, whereas our participants' mean age was 44.3 ± 5.4 years, and the sample included two females. It is established that females typically demonstrate lower maximal aerobic capacity than males (Vogel et al. 1986), and there is an inverse relationship between age and maximal aerobic capacity (Fleg et al. 2005). Notably, the two females in our study possessed very good maximal aerobic capacity compared to the sample mean (mean female VO_{2peak} 44.9 $ml.kg^{-1}.min^{-1}$; treadmill). It appears our sample of ICFPs possessed well-developed aerobic capacity appropriate for this occupational cohort. Studies in other occupational groups have proposed a minimum VO_{2peak} of 40-45 $ml.kg^{-1}.min^{-1}$ for specialist rescue roles such as mines rescue personnel and fire fighters (Gledhill and Jamnik 1992; Stewart et al. 2008). The mean VO_{2peak} for ICFPs in our study is comparable with this range, despite participants' relatively higher mean age. However, the concept of a minimum VO_{2peak} for selection to the ICFP role requires further investigation in studies that examine the physiological and performance demands of operational water rescue from a helicopter.

Our incremental protocol demonstrated that when compared to running, swimming VO_2 was approximately 20% lower at the Hard and Very Hard stages, but only 6% lower at Maximal exertion. While highly trained swimmers can achieve similar VO_{2peak} when running and swimming (Fernandes and Vilas-Boas 2012), this has not been demonstrated in non-elite swimmers, specifically those requiring the completion of complex aquatic rescue tasks. Additionally, it should be noted that efficiency is likely to be affected more by swimming than running in this group. Other published protocols in non-elite populations are likely to have required excessive critical power, therefore inducing muscular fatigue and prevention of VO_{2peak} criteria being satisfied (Dalleck, Kravitz, and Robergs 2004; Pelarigo et al. 2018). Compared to elite protocols, our tests utilised shorter distances, short breaks between stages, and fewer repetitions of high intensity effort. This test structure may have facilitated separation of respiratory and muscular fatigue, overcoming some of the limitations of non-elite populations undertaking tests designed for elite athletes.

Exploring explanations for lower VO_2 during the Hard and Very Hard stages of the swim when compared to the run, previous work has demonstrated that post-exercise VO_2 decreases rapidly at the cessation of exercise (Binzen, Swan, and Manore 2001). As VO_2 was sampled at the end of the Hard and Very hard stages, this methodological limitation may explain the differences between run and swim submaximal VO_2 values during these increments. Although we would have ideally captured expired air during active swimming at all stages, the extra weight and drag of the rebreather circuit and helmet would grossly increase resistance and reduce the time-to-fatigue, risking exhaustion in the first two stages. Other investigators have assessed hydrodynamic drag generated by proprietary indirect calorimetry devices used in swimming, which indicated a limited effect on VO_2 (Ribeiro et al. 2015). Paradoxically, in our protocol the increased hydrodynamic drag induced by the rebreather circuit and helmet apparatus may have contributed to the production of VO_2 that correlated with values seen in the Maximal exertion phase of the run test. This response is coupled with real-time expired sampling during the last 50 metres of swimming, whereas submaximal values were sampled at end of exercise.

Regarding supplementary criteria for determination of VO_{2peak}, we observed no significant difference in blood lactate between the swim and run protocols at every aligned stage, and notably, maximal values. A similar metabolic response further supports the usefulness of the run protocol in predicting swim protocol maximal aerobic capacity. The utility of incremental increases in blood lactate concentration to indicate attainment of maximal aerobic capacity has been demonstrated in numerous studies (Howley, Bassett, and Welch 1995; Prettin et al. 2011; Wasserman et al. 1973), and is again seen here in both our protocols. A number of studies indicate shorter swimming increments can elicit swimming VO_{2peak} and peak lactate (Goodwin et al. 2007; Nagle et al. 2019), and blood lactate data further support the structure of our novel swim protocol.

Heart rate is considered a supplementary measure to VO_2 during a maximal aerobic capacity test to confirm VO_{2peak} (Gerrett et al. 2017). Participants demonstrated an incremental increase in heart rate during both protocols, but this increase was more pronounced in running at all stages. Although we saw consistently lower heart rate values during the swim protocol, this was not unexpected. Immersion in approximately 27 °C water in a swimming pool is associated with a significantly reduced heart rate (DiCarlo et al. 1991; Dixon and Faulkner 1971; Hauber, Sharp, and Franke 1997), and this difference is consistent between elite and non-trained swim participants (Dixon and Faulkner 1971). Additionally, change in body position from vertical (running) to horizontal (swimming) is known to result in a reduced heart rate (Chatterjee et al. 1988).

$RPE_{6\text{-}20}$ was substantially higher at all stages of the swimming protocol compared to the run. Previous work has demonstrated RPE to be greater during running compared to tethered swimming (DiCarlo et al. 1991), although we acknowledge tethered swimming is not equal to free-swimming in this study. The higher $RPE_{6\text{-}20}$ was an unexpected result in our cohort, and there is a lack of research regarding this issue. However, the 800 times greater density of water versus air (998.2 vs 1.205 kg.m^{-3} at 20°C and 760 mmHg) means moving against water requires significantly larger energy expenditure (di Prampero and Osgnach 2019). As such, the relative efficiency of swimming is very low, which may be more pronounced in a non-elite swimmer population (di Prampero and Osgnach 2019). Yet paradoxically, this should imply a higher VO_2, not a lower VO_2 at a perceived work rate as seen in our study. In relation to using $RPE_{6\text{-}20}$ as the pacing strategy for the swim protocol, participant reported $RPE_{6\text{-}20}$ were comparable from the pre-determined $RPE_{6\text{-}20}$ of each stage. As the running protocol did not use RPE to guide intensity, there is greater variability reported in the $RPE_{6\text{-}20}$ values during the run. This difference necessitated aligning both the swim and run stages by $RPE_{6\text{-}20}$ for comparative analysis. Future research should investigate the utility of alternative pacing methods.

In the context of setting of minimum standards for helicopter rescue personnel, and when exploring the physical demands of these tasks, our findings support the use of a run maximal aerobic capacity test to determine VO_{2peak}. Because development and implementation of PES and selection processes for specialist roles can be financially and logistically complex (Drain 2017), a run test to predict swimming VO_{2peak} could reduce barriers to organisations implementing scientifically validated PES for water rescue personnel, such as ICFPs. The major strength of our study is that we have demonstrated that comprehensive physiological assessments do not have to be complex. This work translates to practical and real-world utility for specialist occupations, which we hope will increase the application of robust PES across a variety of professions. A limitation of our work is that work intensity for the swim was based on perception of a whole-body exercise compared to a predominantly lower body exercise. Another important limitation is that although the results of this study indicate that a treadmill-based VO_{2peak} assessment may be an acceptable surrogate (but not interchangeable) for a pool-based maximal test in this occupational group, they do not imply swimming proficiency nor competence in the technical aspects of water rescue. During selection to the role and assessment of existing staff, maximal aerobic capacity can be adequately estimated on a treadmill in a physiology laboratory, however a separate assessment would be required to quantify comfort and capability in the aquatic rescue environment. Further validation of these results in a larger sample would be useful, especially given the small number of paramedics who perform this role.

Conclusion

This is the first study to examine the maximal aerobic capacity of helicopter rescue paramedics while swimming. Participants demonstrated well-developed aerobic capacity, especially in the context of an experienced cohort in their mid 40 years of age. Helicopter rescue paramedic maximal aerobic capacity during swimming can be estimated by results from a treadmill-based assessment of V_{2peak}. To assess swimming maximal aerobic capacity in staff performing critical water rescue tasks, our novel pool-based protocol or a treadmill-based test are options for rescue organisations. However, this outcome does not replace the need for assessment of technical rescue swimming proficiency. The findings of this study inform work needed to develop physical employment standards and minimum levels of fitness for search and rescue professionals performing water rescue. Further research should examine the physiological demands of specific tasks relative to maximal effort, and collectively this work may influence recruitment, performance and application of PES in helicopter rescue paramedics and similar specialist occupations.

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Disclosure statement

BM is an operational ICFP with Ambulance Victoria. Ambulance Victoria had no influence on study design, protocol development or reporting of results. No potential conflict of interest was reported by the author(s).

Author contributions

Ben Meadley and Ella Horton: Conceptualisation, Methodology, Investigation, Validation, Data curation, Formal analysis, Writing- Original draft preparation, Writing-Reviewing and Editing, Project Administration, Funding Acquisition. David B. Pyne: Methodology, Formal analysis, Writing- Reviewing and Editing. Luke Perraton: Methodology, Investigation, Writing- Reviewing and Editing, Supervision. Karen Smith: Resources, Writing- Reviewing and Editing, Supervision, Funding acquisition. Kelly-Ann Bowles: Investigation, Writing- Reviewing and Editing, Supervision. Joanne Caldwell-Odgers: Conceptualisation, Methodology, Investigation, Validation, Formal analysis, Writing- Reviewing and Editing, Supervision, Project Administration.

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Data availability statement

Deidentified data is available upon reasonable request from the corresponding author (BM).

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7.3 Summary of Chapter Seven

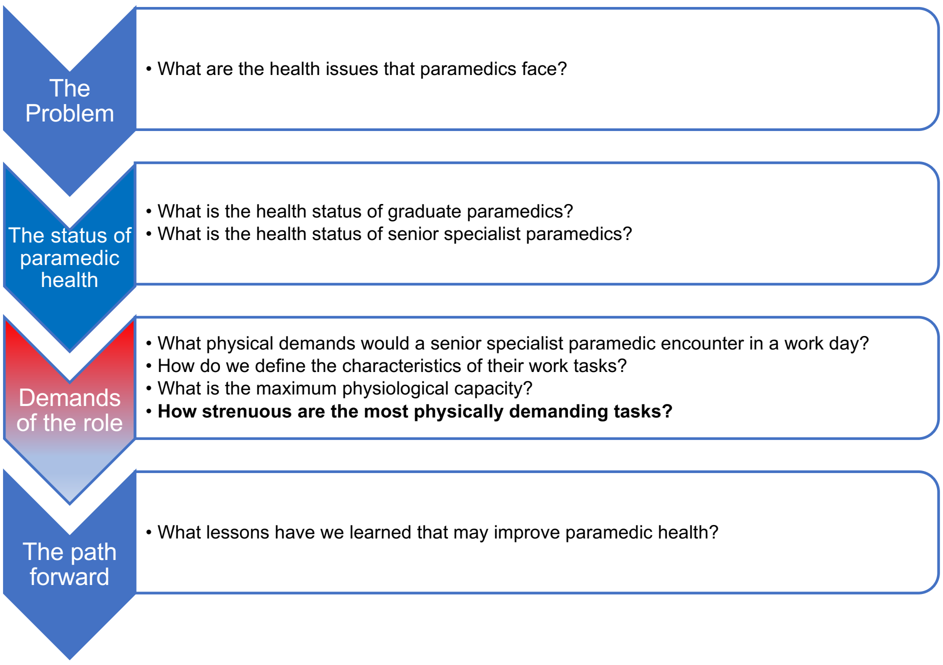
To assess relative physiological demand for ICFP rescue work, maximal aerobic capacity must first be known. In this study ICFPs demonstrated a very high maximal aerobic capacity (VO_{2peak}) in both swimming and running, and there was only a small difference between VO_{2peak} in the swim protocol compared to the run. We found that whilst not interchangeable, run VO_{2peak} was a good predictor of swim VO_{2peak}. For ICFPs performing land and water-based rescues, a treadmill test is sufficient to estimate VO_{2peak} for swimming, but swimming and water rescue proficiency would still need to be assessed separately when selecting staff to the role.

For organisations assessing the physiological capacity of employees undertaking strenuous tasks in land and water, staff would only have to undertake one aerobic capacity test, requiring less resources and logistical burden. This may streamline pre-employment and ongoing testing processes and remove barriers for organisations employing staff who perform these roles. Within the context of this thesis, the study described in this chapter established the maximal aerobic capacity for both swimming and running.

Chapter Eight: The physiological demands of helicopter winch rescue

8.1 Preamble

In Chapter Six, the characteristics of the most physically demanding tasks ICFPs perform (i.e., land and water-based winch rescue) were defined. In the quasi-experimental study described in this chapter, task simulations were created based on the data from Chapter Six. Fourteen ICFPs performed task simulations to assess relative physiological workload for both land and water-based search and rescue tasks. During the task simulations on land and in the water, oxygen consumption, blood lactate, heart rate and perceived exertion were measured, and these values were compared to the data from maximal capacity tests described in Chapter Seven. The aim was to quantify relative physiological workload during tasks performance, compared to maximal capacity.



8.2 Manuscript

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The physiological demands of helicopter winch rescue in water and over land.

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Abstract

Physically demanding water and over land winch rescues are critical tasks for helicopter paramedics. To assess the physiological demands of winch rescue, 14 intensive care flight paramedics (12 male, 2 female, mean (±SD) age 44.3 (±5.4) years, experience 7.1 (±5.2) years) completed land and water-based task simulations. For the land task, VO_2 was 41.7 (±4.5) $mL.kg^{-1}.min^{-1}$, or 86 (±11) % of VO_{2peak}. Task duration was 7.0 (±3.6) min, or 53 (±27) % of maximal acceptable work duration (MAWD) (13.2 (±9.0) min). For the water task, VO_2 was 36.7 (±4.4) $mL.kg^{-1}.min^{-1}$, (81 (±12) % of VO_{2peak}). Water task duration was 10.2 (±1.1) minutes, or 47.6 (±4.8) % of calculated MAWD (21.0 (±15.6) min). These results demonstrate that helicopter rescue paramedics work at very high physiological workloads for moderate durations, and these demands should be considered when developing selection tests and when deploying to rescues, to ensure staff are capable of task performance.

Keywords

Human performance, Aerobic capacity, Physical employment standards, Search and rescue, Paramedic

Practitioner summary

Paramedics performed helicopter winch rescue task simulations in water and over land. Paramedics worked at 81% of VO_{2peak} for 10.2 minutes and 86% of VO_{2peak} for 7 minutes for swim and land tasks respectively. Rescue organisations should consider these demands when selecting and credentialing staff and when deploying to incidents.

Introduction

Paramedics and other expert personnel working in specialist teams such as helicopter emergency medical services (HEMS) perform physically demanding work that may include search and rescue (SAR) tasks in remote wilderness or open water (Meadley *et al.* 2016, Meadley *et al.* 2021a). To assess suitability to work in specialist emergency response teams, organisations mandate minimum physical standards for recruitment (Petersen *et al.* 2011). To ensure selection processes are accurate, valid, fair and equitable, formal physical employment standards (PES) are required to be developed via a scientific, systematic and evidence-based process (Tipton *et al.* 2013). This approach ensures that organisations do not discriminate against capable persons yet identify those unsuitable for the role. Formal PES reduce injury risk in the line of duty and enhance the capability and reliability of service delivery (Legge *et al.* 2013). Further, evidence-based PES are an impediment to legal challenges by unsuccessful candidates (Milligan *et al.* 2016).

A number of procedures to develop scientifically valid PES have been published (Payne and Harvey 2010, Kenny *et al.* 2016, Roberts *et al.* 2016), but the criterion process was described by Tipton et al (2013) which details a six stage methodology to establish defensible physical standards for employment (Tipton *et al.* 2013). PES development requires the determination of critical occupational tasks, identification of interactions between personnel, the environment, equipment, and the physiological demands of the role (Tipton *et al.* 2013). The analysis can include frequent routine duties but crucially, those occasional yet critical tasks (Tipton *et al.* 2013), such as specialised emergency procedures (e.g., technical rescue from imminent life threat) performed by first responder teams.

Indices including blood lactate, heart rate and rate of perceived exertion (RPE) have been used to approximate physiological demand during occupational tasks, including water rescue (Prieto Saborit *et al.* 2010) and wilderness activities (de Waal *et al.* 2021). However, relative demand is most accurately assessed via quantification of oxygen consumption (VO_2) during exercise (Howley *et al.* 1995). A number of portable indirect calorimetry devices have been studied and validated to assess oxygen consumption during occupational activities, including for overland tasks using the Metamax ambulatory gas analysis system (Cortex Biophysic GMbH, Germany) (Milligan *et al.* 2017) and for swimming tasks using the Cosmed AquaTrainer metabolic measurement system (Chicago, Illinois, USA) (Nagle *et al.* 2019). Although these devices are convenient for the research team and participants, they are costly and may not be accessible primarily due to funding limitations. Additionally, there are some indications that this equipment may underestimate VO_2 (Reis 2011, Baldari *et al.* 2013). These and other impediments may prevent organisations developing scientifically valid PES. Therefore, it is imperative that oxygen consumption can still be measured to accurately determine occupational physiological demands.

Well-established, less costly but accurate methods are available to assess VO_2 during task performance. This includes the use of intermittent Douglas bags to capture expired air, allowing for volume, expired oxygen and carbon dioxide to determine VO_2 (Reilly *et al.* 2006a, Reilly *et al.* 2006b). This method has been established as effective and reliable in studies investigating the physiological demands of lifeguards performing surf rescue and helicopter rescue swimmers undertaking open water rescue (Reilly *et al.* 2006a, Meadley *et al.* 2021b) and in firefighters performing land-based tasks (Phillips *et al.* 2015). In addition to quantification of physiological demand, the capture of expired air and calculation of VO_2 enables determination of maximal acceptable work duration (MAWD) for a task (Wu and

Wang 2002). MAWD is a useful metric to assess reasonable task duration prior to the onset of fatigue that may compromise performance and potentially, staff safety. MAWD may be useful to inform resourcing for complex rescue tasks. There is limited data investigating MAWD in this occupational group, specifically for the element of helicopter rescue paramedic work that requires rescue from aquatic environments.

Helicopter rescue paramedics (also known as intensive care flight paramedics, or ICFPs) working for HEMS teams mostly undertake clinical patient care duties, but are intermittently required to perform search and rescue (SAR) tasks as part of their role (Andrew *et al.* 2015). In previous work, our research team has completed the first four stages of PES development for helicopter rescue paramedics performing land and water-based rescue via helicopter winch (Meadley *et al.* 2021a, Meadley *et al.* 2021b). Specifically, through a subject matter expert group, we defined the physically demanding tasks that ICFPs undertake when performing winch rescue (Meadley *et al.* 2021a). The current study focuses on determining the physiological workload during performance of these critical HEMS SAR tasks. As part of the development of PES for this helicopter rescue paramedics, we sought to assess the relative physiological demands and MAWD during overland and water winch rescue using the Douglas bag method and supplementary indices of workload. We expected that in a sample of helicopter rescue paramedics, both overland and water winch rescue would require paramedics to work at moderate relative physiological workload for short-moderate durations. This data can then be used for the development of evidence-based PES for this occupational group.

Materials and methods

Subjects and experimental design

We employed a repeated measures cross-over study of helicopter rescue paramedics working for a helicopter emergency medical service. Paramedics completed two separate land and water-based task simulations to ascertain relative physiological demands during task performance. Ambulance Victoria (AV) is the single provider of HEMS to the people of the state of Victoria (Australia) which covers an area of approximately 237,629 km^2 including remote and difficult-to-access terrain and more than 2,000 km of coastline. AV helicopters are staffed by an ICFP who is deployed from the aircraft to perform land and water-based winch rescue, an air crew officer (who operates the winch among other duties), and a pilot. Ambulance Victoria HEMS operations have been described in detail in previous work (Andrew *et al.* 2015, Meadley *et al.* 2016, Meadley *et al.* 2021a, Meadley *et al.* 2021b).

Eligibility for the study required current employment by AV as an ICFP, with current certification to undertake all duties including winch rescue. Participants were recruited via convenience sampling using corporate email. Once enrolled participants completed a form that described basic demographics and experience in paramedic roles. Written informed consent was obtained from all participants included in the study. The study was approved by the Monash University Human Ethics Research Committee (Project number 19051) and the Ambulance Victoria Research Committee.

Prior to reporting to the testing locations, participants were requested to avoid strenuous exercise in the preceding 24 hours, be free from illness for the preceding 14 days, and have had at least seven days between land and swim task assessments. Testing was conducted between 0700-1200 hours in May-July 2018 (the Australian late autumn and early winter). All participants were required to complete the Exercise and Sports Science Australia Pre-Exercise Screening Tool to identify risks to completion of a strenuous exercise test (Brickwood *et al.* 2013).

Measurements

Anthropometry, body composition and haemodynamics

Each participant had assessment of body mass, resting blood lactate and heart rate and blood pressure prior to each task simulation. Values were measured twice (and the mean value recorded) as follows: after 5 min sitting at rest, blood pressure and heart rate were measured on the left arm using the Welch Allyn Connex 3400 ProBP Automatic Blood Pressure Machine (Welch Allyn Skaneateles Falls, New York, USA). Body mass was measured using calibrated SECA 813 Digital Flat Scales (SECA, Hamburg, Germany). Capillary blood (5 µl) was sampled from a fingertip for analysis of resting blood lactate concentration (Lactate Pro2, Arkray, Tokyo, Japan). Waist circumference was measured using a metric fabric tape measure at the level of the umbilicus before the swim task assessment (Brown *et al.* 2018).

Maximal aerobic capacity (VO_{2peak})

i. Land-based VO_{2peak}

To estimate VO_{2peak} during land-based activity, participants underwent a continuous incremental exercise test to volitional exhaustion on a motorised treadmill in a temperature-controlled laboratory set at 22°C (MyRun, Technogym, Seattle, Washington). VO_{2peak} was estimated by indirect calorimetry (Vmax Encore Metabolic Cart: Carefusion, San Diego, California, USA) as described previously (Costa *et al.* 2009). After familiarisation with the test protocol and the Rating of Perceived Exertion ($RPE_{6\text{-}20}$) scale (Borg 1982), participants completed a three-minute warm up. The protocol commenced at 6 $km.hr^{-1}$ with an incline of 1.5%. Speed increased every three minutes until participants were running at 14 $km.hr^{-1}$, after which incline was increased by 2.5% every three minutes until volitional exhaustion, at which time $\dot{V}O_{2peak}$ was recorded. Within 30 seconds of completion of each 3-minute phase and at test termination, participants indicated $RPE_{6\text{-}20}$ and 5 µl capillary blood was sampled from a fingertip for analysis of blood lactate concentration. Throughout testing, heart rate was monitored continuously via a Polar FT1 watch and H10 heart rate monitor strap (Polar Electro Oy, Kempele, Finland).

ii. Water-based VO_{2peak}

A novel three-stage swimming protocol was developed to estimate Water-based VO_{2peak} and enable standardised data collection. Stage 1 was a freestyle swim of 300 metres at a target $RPE_{6\text{-}20}$ of 15, followed by a two-minute rest. Stage 2 was a freestyle swim of 200 metres at a target $RPE_{6\text{-}20}$ of 18, followed by a two-minute rest. Stage 3 was a 100-metre freestyle swim at a target $RPE_{6\text{-}20}$ of 20, or their maximum effort.

Testing was completed in an outdoor 50-metre swimming pool (water temperature 26.7 (± 0.2) °C, air temperature 14.5 ± (2.0) °C, barometric pressure 767.2 ± (4.5) mmHg). Prior to testing, participants were familiarised with the test protocol and the $RPE_{6\text{-}20}$ scale. Resting blood lactate concentration, heart rate and oxygen consumption were then measured. A swimming-specific heart rate monitor and chest strap were fitted (Garmin Forerunner 735XT watch and HRM

SWIM strap, Garmin, Olathe, Kansas, USA) and continuous heart rate data were recorded. Participants practiced using a rebreather circuit/helmet setup over a short 15-metre swim to ensure they were familiar with the equipment used in Stage 3. The modified diving rebreather circuit (Poseidon Diving Systems AB, Akered, Sweden) was adapted from existing equipment by the research team to allow for in-activity capture of expired air using equipment familiar to the ICFPs. The circuit was secured to the standard issue ICFP water rescue helmet (Classic Full, Pro-tec, Santa Fe Springs, California, USA).

At the end of Stages 1 and 2 participants remained in the water. Expired air was immediately collected on the first breath for 30 seconds using a 120-litre Douglas bag connected to a one-way valve and mouthpiece via corrugated ventilation tubing. The nose clip remained in place throughout data collection. RPE_{6-20} was recorded, and capillary blood lactate was simultaneously measured from an earlobe sample (5 µl). Heart rate was sampled via pulse oximetry (Nonin PalmSat, Nonin, Minneapolis, Minnesota, USA) as a backup in case of failure of the chest heart monitor.

During Stage 3, participants donned the modified diving rebreather circuit and rescue helmet apparatus. A swimming-specific nose clip was used to prevent expiration through the nose and ensure all expired air was collected in the Douglas bag. Expired air was sampled for the last 50-m of the 100-m final stage and sample time was recorded. At the completion of Stage 3 capillary blood lactate, heart rate via pulse oximetry and RPE_{6-20} were immediately recorded. Expired air samples were analysed immediately after collection (ML206 Gas Analyser PowerLab 8/30, ML870, AD Instruments, New South Wales, Australia), with sample volume obtained via a dry volumeter. Both treadmill and swimming protocols fulfilled the requirements of a maximal test for VO_{2max} assessment, namely blood lactate ~8 $mmol.l^{-1}$, respiratory exchange ratio values > 1.0, heart rate > 85% of its maximum values, and an exertion to exhaustion (Howley *et al.* 1995, Fernandes and Vilas-Boas 2012). We acknowledge that we were unable to verify VO_2 plateau during the swim assessment and therefore recorded VO_{2peak} in the run and swim protocols (as opposed to VO_{2max}). Maximal aerobic capacity is therefore referred to as VO_{2peak} in the context of this study. Further details of the swim protocol, testing procedures, equipment and comparison to the standard treadmill protocol are provided in our previous study (Meadley *et al.* 2021b).

Task-simulations

Assessing complex physiological variables with sensitive equipment during live helicopter operations was deemed high-risk and logistically and financially prohibitive. A such, an ICFP subject matter expert focus group was convened to analyse historical land and swim tasks and develop tasks simulations that did not involve actual helicopter flight (Meadley *et al.* 2021a). The resultant task simulations were pilot tested by members of the research team and three ICFPs at the respective land and aquatic locations (described below) to ensure efficient and standardised protocols for participant testing that aligned with actual operational tasks. Following finalisation of the protocols, participants were randomly assigned to complete either the land or swim task simulation first.

i. Land task assessment

The defined task simulation (Meadley *et al.* 2021a) required participants to walk 250m along a steep track whilst carrying land operational rescue equipment at a self-determined pace that enabled sufficient reserve for them to be able to theoretically deliver clinical care at the end of the task. Participants were required to attend a wilderness reserve where there was a 250m rocky gravel track on a steep incline. The track gained 45m in height with a gradient of 18.3%. Participants were briefed on the study protocol and re-familiarised with the Rating of Perceived Exertion (RPE_{6-20}) scale (Borg 1982).

Resting VO_2 was measured prior to donning the ICFP land operational rescue equipment. Participants wore the standardised AV operational land uniform, a two-piece fire-retardant Nomex® flight suit (Sisley Clothing, Maryland, New South Wales, Australia), with the jacket fabric weight 200 grams per square meter (GSM) and pants fabric weight 200 GSM and a cotton undershirt, and sturdy hiking boots (total weight 3.9 kg). The specialised AV land operational rescue equipment consists of a full-body winch harness, winch hook connector, medical backpack, supplementary equipment bag containing rope (a "tag-line") and personal protective equipment for the patient (goggles and helmet), collapsible winch stretcher (Medevac IIA, Lifesaving Systems, Florida USA), radios, a lifejacket containing signalling equipment and flight helmet. The total weight of all carried equipment was 43.4 kg. The individual weights of this equipment are detailed in previous work (Meadley *et al.* 2021a).

The land winch rescue simulation and physiological sampling were performed as follows (Figure 1): All equipment for carriage was laid on the ground and timing commenced. The equipment was modified by the participant for ease of carriage per the standardised AV operating procedure that was known to and practiced by all participants at 6-week intervals (per AV training requirements). Specifically, the total load is split between torso (harness, winch connector, medical backpack, stretcher, lifejacket, radios) and the left and right hands (flight helmet, supplementary equipment bag). Once loaded, the rescue gear was carried 250m up the 18.3% incline of the gravel track at a self-determined pace. Specifically, participants were instructed to undertake the task at a pace where it was assumed the 'patient' that required rescuing was in life threat. A member of the research team walked with the participant carrying two pre-prepared apparatus comprising a 120 litre Douglas bag connected to a one-way valve and mouthpiece via corrugated ventilation tubing with a three way tap between the tubing and the bag. Upon reaching the sampling points, the participants kept moving and the researcher walked with them, whilst switching the three-way tap to sample expired air. There was no interruption in velocity. Sampling expired air occurred over 25m from 125m–150m and again over 25m from 225m–250m and the time taken to cover the 25m (and hence expired air collection time) was recorded and the tap closed. A nose clip was fitted for each 25m segment and removed once sampling was ceased. $RPE_{6\text{-}20}$ was recorded at the end of each expired air sample. Heart rate was monitored throughout the simulation using a physical activity monitor (Garmin Forerunner 735XT watch and HRM SWIM strap, Garmin, Olathe, Kansas, USA). Finally, capillary lactate and $RPE_{6\text{-}20}$ were sampled at 250m when the simulation was terminated. Expired air samples were analysed on site immediately after collection (ML206 Gas Analyser PowerLab 8/30, ML870, AD Instruments, New South Wales, Australia), including a desiccant filter box. The gas analyser was calibrated immediately before each testing session with 16.0% O_2 and 3.98% CO_2. Participant sample %O2 and %CO2 were recorded. Sample volume was obtained by two researchers rolling the Douglas bag tightly and compressing the bag until it was empty, and the air was evacuated through a dry volumeter (Model 750, Landis and Gyr, Sydney, Australia). The dry volumeter was calibrated at the commencement of the studies as per Monash University laboratory quality assurance processes for all laboratory equipment.

ii. Swim task assessment

The defined task simulation (Meadley *et al.* 2021a) required participants to use any stroke to swim 50m in open water whilst wearing AV operational rescue equipment, use the AV operational winch rescue sling (known as a strop, Safety Equipment Technical Services, Monbulk, Victoria, Australia) to rescue a manikin from a life raft, and then swim-tow the manikin back 25m from the raft (a total swim distance of 75m per bout). Participants were instructed to undertake the task at a pace where it was assumed the two 'patients' requiring rescue were in life threat. The task was then to be repeated once more. Participants were required to attend a local ocean baths complex where there was a 50m enclosure of ocean water. A platform was located at the 25m point, and an inflatable 6-person life raft (Winslow Life Raft Company, Lake Suzy, Florida, USA) was secured to a jetty pillar at the 50m mark. Participants were briefed on the study protocol and re-familiarised with the $RPE_{6\text{-}20}$ scale.

Baseline VO_2 was measured prior to donning the AV operational water rescue equipment. Participants wore the operational water rescue uniform, including an immersion/dry suit (OWFS, Ursuit, Turku, Finland), a full-body winch harness, winch hook connector, rescue strop for patient recovery, a lifejacket containing signalling equipment, snorkel, mask (full-face to prevent exhalation through nose during expired air sampling), fins and a water rescue helmet. To simulate towing a winch cable as per the AV procedure (i.e., AV ICFPs do not disconnect from the helicopter winch cable during water rescues), a 75m time-expired section of winch cable and a winch hook was connected to the participant for the entire task simulation. During live rescues, the helicopter air crew officer would 'feed out' cable, allowing the paramedics to swim freely and drag the cable through the water, but whilst remaining connected. Throughout the entire task simulation, to replicate a live rescue situation, a researcher (wearing gloves) held the winch cable in two hands and allowed the cable to feed out freely as the participants swam and dragged the cable through the water. Resistance was not applied. The total weight of all equipment was 16.1 kg. The individual weights of this equipment are detailed in previous work (Meadley *et al.* 2021a)(Meadley *et al.* 2021a).

The water winch rescue simulation and physiological sampling were performed as follows (Figure 2): Whilst clothed in the water-specific rescue gear detailed above, participants connected the mock winch cable and hook to their winch hook connector. Participants entered the water and swam slowly to the starting position. The test commenced and participants swam, using any stroke, 50 metres to a life raft that contained a 50kg water rescue training manikin (LifeTec, Warriewood, NSW, Australia) that was pre-positioned so that the legs and body were in the raft and the arms and head were slumped over the rim of the raft. Participants extracted the dummy from the raft and secured it in a rescue strop. The manikin was then swim-towed from the raft 25 m to the platform. During this swim, expired air was sampled via Douglas bag by two researchers who swam next to the participant during the last 12.5m (Figure 2), and the time was recorded. Once at the platform, RPE_{6-20} and capillary lactate were assessed. Participants then completed a slow swim back to the starting position and the process was repeated. Expired air samples were analysed on site immediately after collection (ML206 Gas Analyser PowerLab 8/30, ML870, AD Instruments, New South Wales, Australia), including a desiccant filter box. The gas analyser was calibrated immediately before each testing session with 16.0% O_2 and 3.98% CO_2. Participant sample %O2 and %CO2 were recorded. Sample volume was obtained by two researchers rolling the Douglas bag tightly and compressing the bag until it was empty, and the air was evacuated through a dry volumeter (Model 750, Landis and Gyr, Sydney, Australia). The dry volumeter was calibrated at the commencement of the studies as per Monash University laboratory quality assurance processes for all laboratory equipment.

Calculation of Maximal Acceptable Work Duration (MAWD)

As per the method described by Wu and Wang (Wu and Wang 2002) we were able to calculate MAWD for these tasks from the relative VO_2 (task simulation mean VO_2 as a percentage of VO_{2peak}) via the formula MAWD=95.336 x $e^{-7.28 \times \%VO2peak}$, with R^2=0.83 indicating a strong relationship between MAWD and physical workload (i.e., as physical workload increases, MAWD decreases).

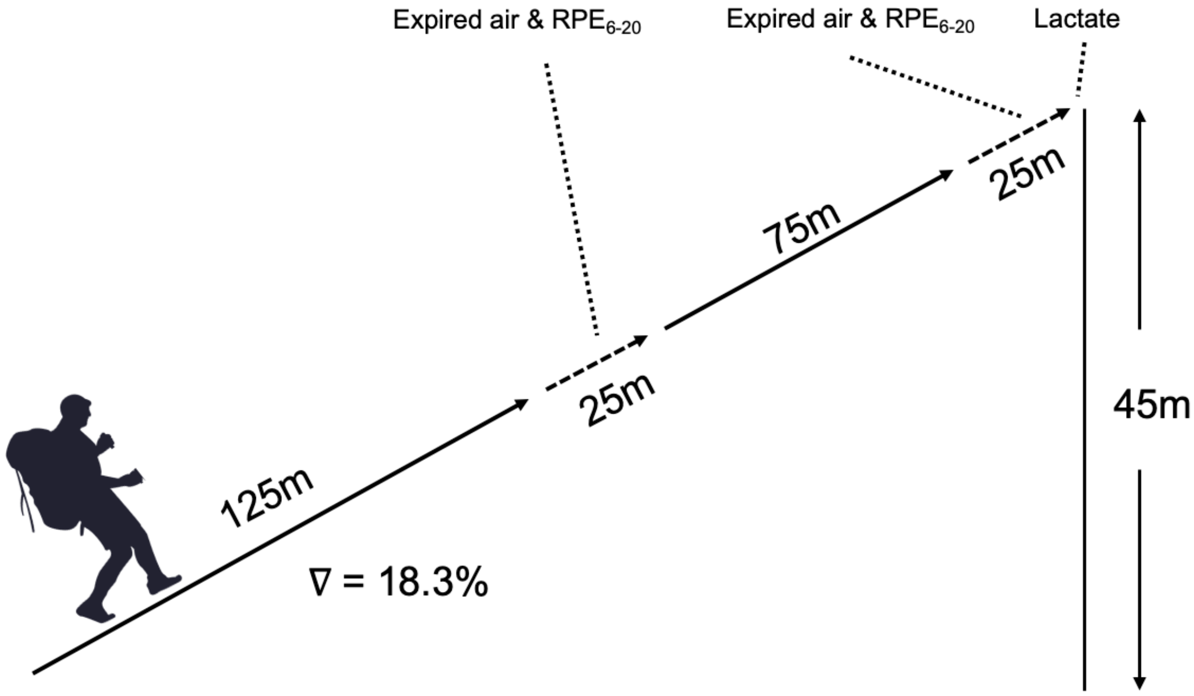
Figure 1 caption:

Land task assessment

Participants carried 43.4kg of rescue equipment over 250m of rocky terrain, gaining 45m altitude at a gradient of 18.3%. RPE_{6-20} was recorded, and expired air sampled during continuous exercise at 125-150m and 225-250m. Capillary lactate was sampled at 250m where the simulation terminated.

Figure 1 Alt-text:

A diagram of the land task assessment that shows a person walking 250m up a hill rising 45m in altitude, at a gradient of 18.3% whilst carrying a pack. The diagram also shows that expired air and RPE_{6-20} were measured at 125-150m and 225-250m, and that blood lactate was measured once at the end of the test. The diagram is accompanied by a photograph of a person walking up a hill, carrying some equipment, whilst expired air is sampled by a research assistant.



Expired air & RPE6-20
Expired air & RPE6-20
Lactate
125m
25m
75m
25m
45m
∇ = 18.3%

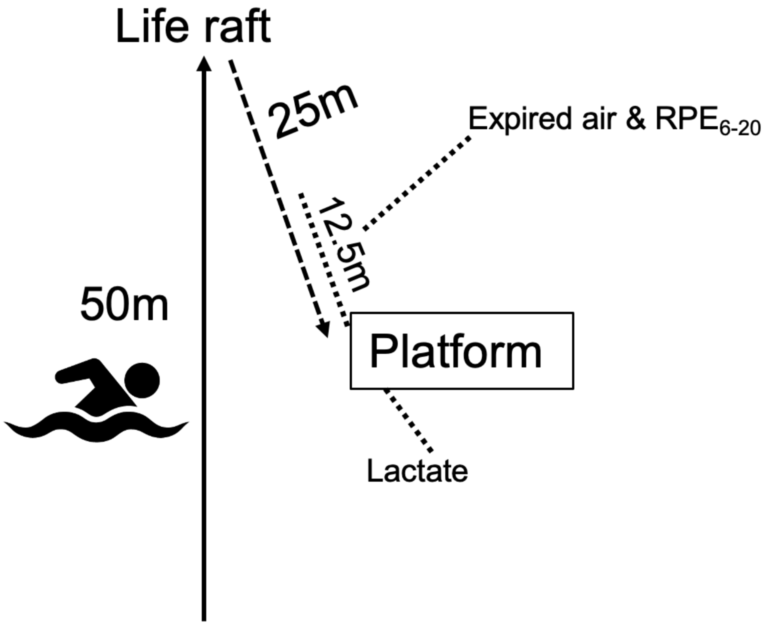
Figure 2 caption:

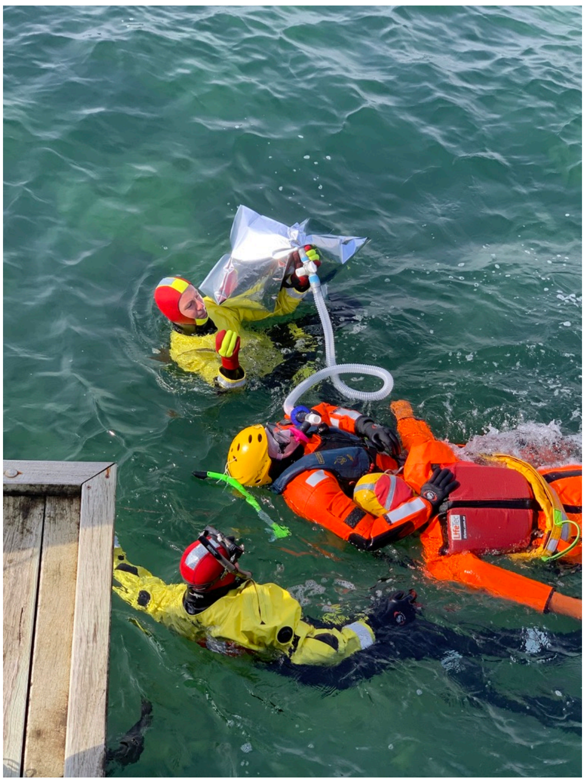
Swim task assessment

Participants swam 50m to recover a 50kg manikin from a life raft and towed it to a platform. RPE_{6-20} was recorded, and expired air was sampled during continuous exercise over the last 12.5m of the swim/tow. Capillary lactate was sampled at the platform after the swim/tow (75m). The entire process was repeated once, and then the simulation terminated.

Figure 2 Alt-text:

A diagram of the swim task assessment that shows a person swimming 50m to a life raft. The diagram also shows that expired air and RPE_{6-20} were measured during the last 12.5m of a 25m swim back to a platform, and that blood lactate was measured once at the end of the test. The diagram is accompanied by a photograph of a person swimming in the ocean, dragging a manikin, whilst expired air is sampled by research assistants.


Life raft
25m
Expired air & RPE6-20
12.5m
50m
Platform
Lactate



Statistical analysis

Data were assessed for normality via the Shapiro-Wilk test and found to be normally distributed. Data are reported as mean (±SD). Unpaired t-tests were used to compare demographics of the study participants and the whole ICFP population, and paired t-tests were used to assess differences between the physiological sampling points. To examine effect size for VO_2 data, we calculated Cohen's d with thresholds of small (0.2), medium (0.5) and large (0.8). All analyses were conducted using Prism (Version 8.4.3; GraphPad Software, San Diego, California, USA), and statistical significance was determined *a priori* at $p < 0.05$. Relative workloads reported in this study reference participants' VO_{2peak} measured in the respective maximal aerobic capacity test (i.e., land task simulation relative VO_2 was calculated as a percentage of treadmill VO_{2peak} and swim task simulation relative VO_2 was calculated as a percentage of pool-based VO_{2peak}).

Results

Participant characteristics

When participants (n=14, 12 male, 2 female) were compared to the entire ICFP group employed by AV, there was no difference between mean (SD) age (participants 44.3 (±5.4) vs group 47.4 (±6.5) years, p = 0.11), overall paramedic experience (19.1 (±5.1) vs 22.0 (±6.8) years, p = 0.14) or experience as an ICFP (7.1 (±5.2) vs 10.1 (±6.2) years, p = 0.10). ICFPs demonstrated low cardiometabolic disease risk with body mass index 24.7 (±3.0) $kg.m^{-2}$, waist: height ratio 0.48 (±0.05), resting heart rate 65 (±11) bpm, and arterial blood pressure 134 (±14) mmHg systolic/81 (±8) mmHg diastolic. Note that female and male values are combined, as separation of these data by sex would allow for identification of individual values and risk breaching confidentiality.

Maximal physiological data:

VO_{2peak} for the treadmill test was 48.5 (±5.5) mL.kg^{-1}.min^{-1}, maximum heart rate 186 (±10) bpm, maximum blood lactate 12.0 (±3.0) mmol.L^{-1}, and maximum $RPE_{6\text{-}20}$ 18 (±2). VO_{2peak} for the swim test was 45.5 (±7.8) mL.kg^{-1}.min^{-1}, maximum heart rate 162 (±11) bpm, maximum blood lactate 13.2 (±3.8) mmol.L^{-1}, and maximum $RPE_{6\text{-}20}$ 20 (±1).

Physiological demands and MAWD: Land task

Ambient air temperature was 11.8 (±2.0) ºC, barometric pressure 1012.3 (±2.4) hPa and relative humidity 70.7 (±13.3)% on the days of data collection. Table 1 details expired air collection, oxygen consumption, task duration, and MAWD for the land task. From the commencement of the land task, relative VO_2 increased to 84 (±12) % of VO_{2peak} by the phase 1 sampling point (125m-150m). This had increased by a further 4% when the task was completed (41.0 (±5.8) to 42.4 (±4.4) mL.kg^{-1}.min^{-1}, $p = 0.48$, $d=0.27$). Overall task VO_2 was 41.7 (±4.5) mL.kg^{-1}.min^{-1}, which equated to 86 (±11) % of VO_{2peak} (Figure 3). Land task duration was 7.0 (±3.6) min, which represented 53 (±27) % of calculated MAWD (13.2 (±9.0) min). Peak blood lactate was 11.1 (±3.9) mmol.L-1 or 99 (±33) % of maximum (Figure 4a). Peak heart rate was 173 (±11) bpm or 93 (±6) % of maximum (Figure 4b), and peak $RPE_{6\text{-}20}$ was 17 (±2) or 94 (±8) % of maximum (Figure 4c).

Physiological demands and MAWD: Swim task

Ambient air temperature was 12.3 (±1.9) ºC, sea temperature 18.4 (±0.4) ºC, barometric pressure 1020.9 (±5.8) hPa and relative humidity 69.3 (±12.2) % on the days of data collection. On all testing days, sea state was estimated at a degree of 2 (swell height 0.1-0.5m) according to the Douglas Sea Scale (Owens 1984). Table 1 details expired air collection, oxygen consumption, task duration, and MAWD for the swim task. From the commencement of the swim task, relative VO_2 had risen to 78 (±9) % of VO_{2peak} by the phase 1 sampling point (75m, at the platform in Figure 2). This had increased by a further 5% by task completion (35.6 (±4.2) to 37.9 (±5.3) $mL.kg^{-1}.min^{-1}$, $p = 0.21$, $d=0.48$). Overall task VO_2 was 36.7 (±4.4) $mL.kg^{-1}.min^{-1}$, which equated to 81 (±12) % of VO_{2peak} (Figure 3). Swim task duration was 10.2 (±1.1) min, which represented 47.6 (±4.8) % of calculated MAWD (21.0 (±15.6) min). Peak blood lactate was 8.1 (±2.4) $mmol.L^{-1}$ or 61 (±18) % of maximum (Figure 4a). Peak heart rate was 167 (±15) bpm or 103 (±9) % of maximum (Figure 4b), and peak RPE_{6-20} was 16 (±2) or 80 (±10) % of maximum (Figure 4c).

Table 1. Oxygen consumption data for maximal aerobic capacity and the land and swim tasks in Intensive Care Flight Paramedics (n=14). Data are presented as mean (±SD).

		Land Task	Swim Task
Maximal aerobic capacity			
VO_{2peak}	$L.min^{-1}$	3.9 (±0.7)	3.6 (±0.7)
	$mL.kg^{-1}.min^{-1}$	48.5 (±5.5)	45.5 (±7.8)
Resting VO_2	$L.min^{-1}$	0.5 (±0.2)	0.6 (±0.2)
	$mL.kg^{-1}.min^{-1}$	6.1 (±1.8)	7.1 (±1.5)
Phase 1			
Expired air volume	L	38.7 (±6.6)	31.1 (±8.5)
Sample time	sec	28.4 (±4.7)	24.5 (±5.2)
VO_2	$L.min^{-1}$	3.3 (±0.6)	2.9 (±0.5)
	$mL.kg^{-1}.min^{-1}$	41.0 (±5.8)	35.6 (±4.2)
VO_{2peak}	%	84 (±12)	78 (±9)
Phase 2			
Expired air volume	L	36.7 (±7.9)	35.1 (±4.9)
Sample time	sec	25.1 (±4.3)	26.7 (±4.4)
VO_2	$L.min^{-1}$	3.4 (±0.6)	3.1 (±0.5)
	$mL.kg^{-1}.min^{-1}$	42.4 (±4.4)	37.9 (±5.3)
VO_{2peak}	%	87 (±9)	83 (±12)
Difference b/w phase 1-2	p^*	0.48	0.21
	$d^\#$	0.27	0.48
Mean task VO_2	$L.min^{-1}$	3.4 (±0.6)	3.0 (±0.5)
	$mL.kg^{-1}.min^{-1}$	41.7 (±4.5)	36.7 (±4.4)
Relative workload	% VO_{2peak}	86 (±11)	81 (±12)
Task time	min	7.0 (±3.6)	10.2 (±1.1)
MAWD†	min	13.2 (±9.0)	21.0 (±15.6)

*** Paired t-test for difference between Phases 1 and 2 (i.e., points of expired air sampling).**

 # Cohen's d for effect size with thresholds of small (0.2), medium (0.5) and large (0.8)

† Maximum acceptable work duration

Figure 3 caption: Oxygen consumption (mL.kg^{-1}.min^{-1}) in Intensive Care Flight Paramedics (n=14) during the land and swim winch task simulations. Data are presented as mean (±SD).

Figure 3 Alt-text:

A bar graph that shows oxygen consumption for the swim task and the land tasks assessments

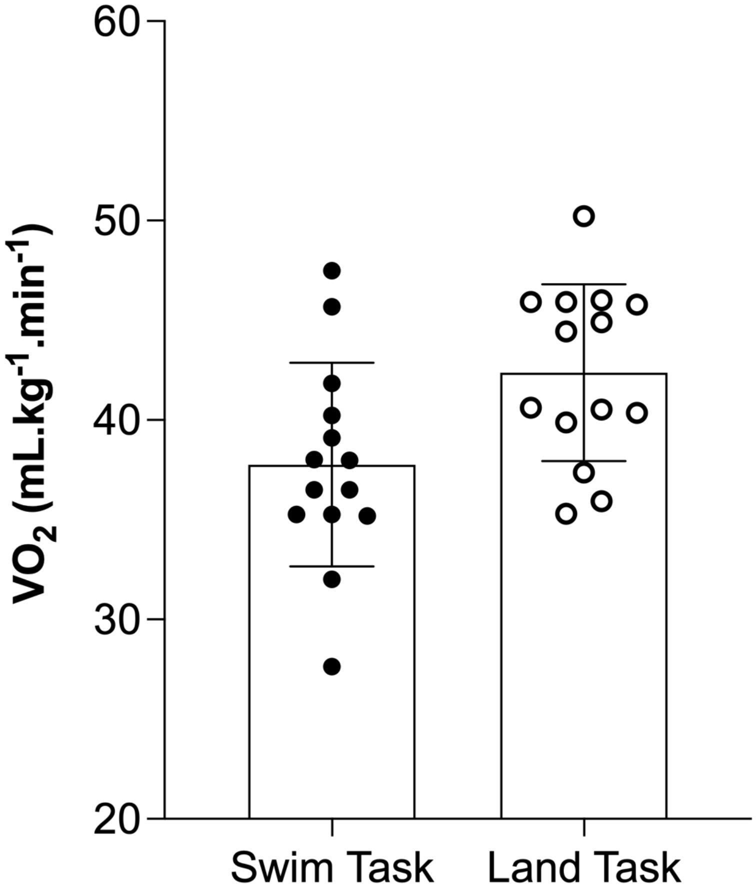


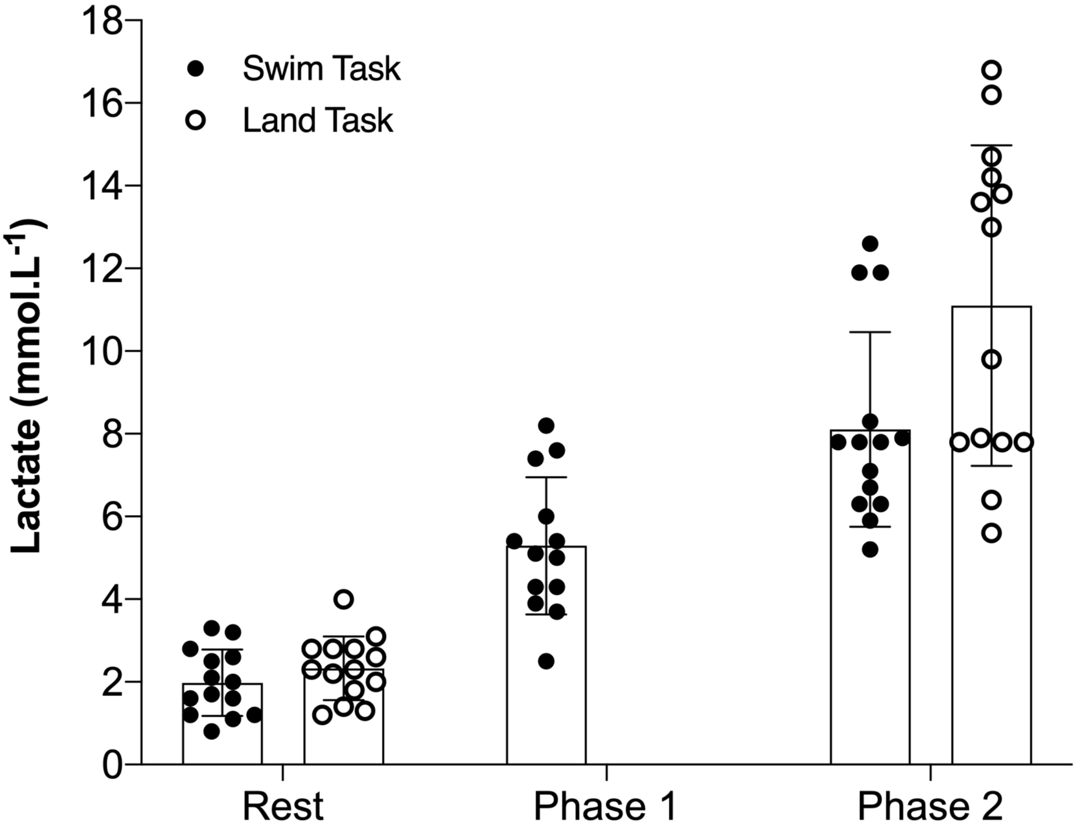
Figure 4 caption: Blood lactate (mmol.L^{-1}), heart rate (bpm) and RPE_{6-20} in Intensive Care Flight Paramedics (n=14) during the Swim task and Land task simulations. Data are presented as mean (±SD).

a) **Blood lactate**
b) **Heart rate**
c) **RPE_{6-20}**

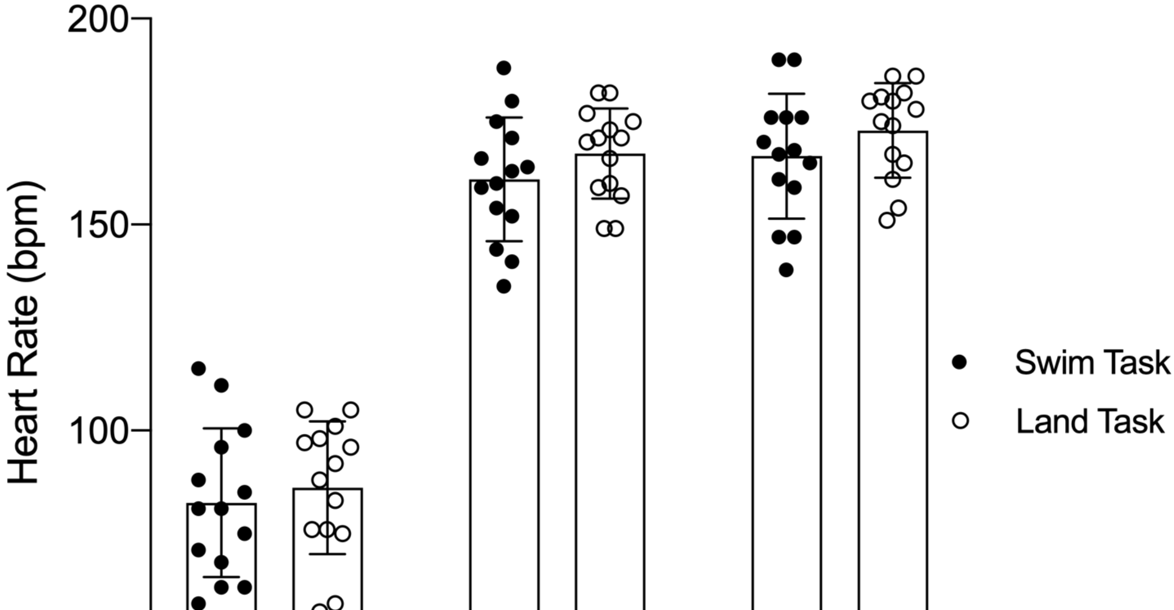
Figure 4 Alt-text:

a) **A bar graph that shows that for the swim task, blood lactate increased between rest, and then end of the test (Phase 2), and for the land task, blood lactate increased from rest, to Phase 1 and then the end of the test (Phase 2).**
b) **A bar graph that shows that for the swim and land tasks, heart rate increased between rest, Phase 1 and then the end of the test (Phase 2).**
c) **A bar graph that shows that for the swim and land tasks RPE_{6-20} increased between Phase 1 and then the end of the test (Phase 2)**

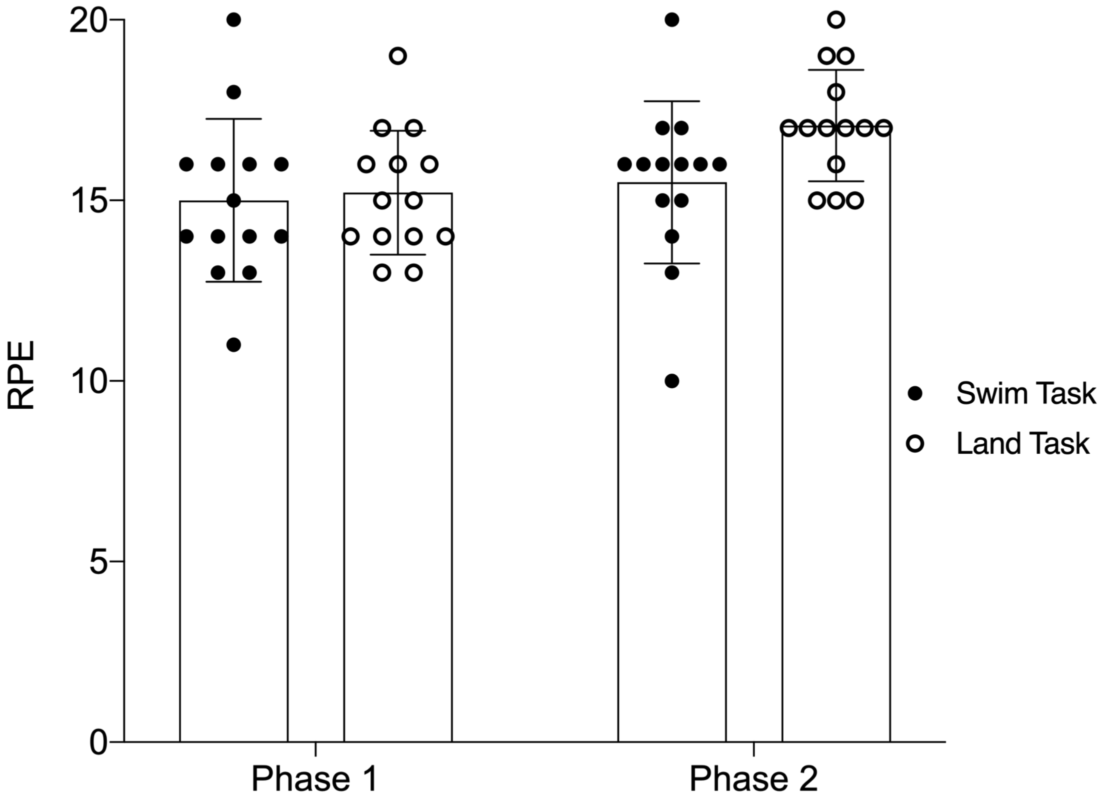
a)


Swim Task
Land Task
Lactate (mmol.L-1)
0
2
4
6
8
10
12
14
16
18
Rest
Phase 1
Phase 2

b)


Heart Rate (bpm)
50
100
150
200
Rest
Phase 1
Phase 2
Swim Task
Land Task

c)



Discussion

In this study, we required ICFPs to undertake task simulations to assess relative physiological workload during complex land and water-based search and rescue tasks. To our knowledge there are no studies that have investigated the physiological demands of this profession. More so, there is no evidence of research that has examined the relative workload and MAWD for personnel performing the helicopter rescue swimmer role. We found that for land winch rescue tasks, this sample of helicopter rescue paramedics worked at approximately 86% of their maximal aerobic capacity for more than half the calculated MAWD in order to rescue one person. For water winch rescue tasks, helicopter rescue paramedics worked at approximately 81% of their maximal aerobic capacity for slightly less than half the calculated MAWD in order to rescue two people.

When comparing relative physiological demands of ICFPs performing the land task simulation, Sol et al. investigated wildland firefighters who performed load carriage tasks similar to our simulation. Load weight was less (24-28kg vs 43.2kg) and average gradient less (approximately 6% vs 18.3%) but walk time was longer (13-40 vs approximately 7.2 min). The resultant relative workload was 46-47% of estimated VO_{2max} (Sol *et al.* 2018) was substantially less than the 86% seen in the ICFPs in our study. In a search and rescue task simulation performed by Australian Army first responders lasting approximately 20 min, soldiers worked at 74.1% of VO_{2peak} and 80% of maximum heart rate (Tofari *et al.* 2013). Although this task was of a longer duration, maximum heart rate was substantially lower than seen in ICFPs performing the land task simulation (80% versus 93%). Further, in a recent study developing PES for paramedics most akin to AV ICFPs, members of the Hazardous Area Response Teams (HART) in the United Kingdom demonstrated high maximal aerobic capacity and high relative physiological workloads for land-based tasks in particular. In that study, task simulations invoked similar physiological strain to that seen in the ICFP tasks, but HART duties were more varied, and the HART cohort was approximately 5 years younger (Siddall *et al.* 2021). This comparison highlights that specific assessment of task physiological demands should be tailored to the job and the employee demographic.

Some authors have proposed models and methods to predict maximum work duration and physiological demands in load carriage tasks, and these have provided general guidance for a number of professions (Drain *et al.* 2016, Taylor *et al.* 2016). Although there is variability in the specific elements of task performance in studies assessing the dynamics of load carriage (Bilzon *et al.* 2001, Robinson *et al.* 2018), our task simulations have demonstrated that ICFPs are required to work by comparison at very high relative workloads for moderate periods of time. Specifically, Taylor et al. identified that firefighters can be required to be loaded with 20 kg of gear at the commencement of their work tasks, representing up to 40% of their bodyweight (Taylor *et al.* 2015), which provides reasonable guidance for workload in that occupation. By comparison, the ICFPs in this study carried 43.4 kg of load from the commencement of the land task, which represented 54% of their mean (±SD) 80.2 (±12.5) kg body weight, albeit for a shorter timeframe than may be seen in fire fighters (e.g., fire fighter rescue simulation = 25.6 min versus ICFP land task 7 min) (Taylor *et al.* 2015).

Further, Drain et al. investigated models for the physiological capacity of load carriage. In this review, the authors propose development of a predictive tool for military personnel and fire fighters undertaking physically demanding load carriage tasks (Drain *et al.* 2016). When discussing this, the reference task utilises an exemplar of an 81.2 kg individual with a VO_{2max} of 3.83 $L.min^{-1}$, which is directly comparable to the data from the ICFP participants land task data (80.2 kg, VO_{2peak} 3.9 $L.min^{-1}$). However, the described work task differs considerably, with a lesser load to be carried (20 kg versus 43.4 kg for ICFPs), flat ground versus the steep gradient reported in ICFP rescue work, differing relative oxygen consumption (35% VO_{2max} versus 86% of VO_{2peak} in ICFPs) and longer MAWD (8.2 hours versus 13.2 min in ICFPs) (Drain *et al.* 2016). Predictive models may allow for broad projection of anticipated demands. However, our findings highlight the necessity and value of performing studies for niche professions where little or no previous work has been done, as predictive models may not be applicable to select specialist groups.

For water based occupational tasks, similar intensities have been demonstrated in other studies investigating rescue swimming, although there is an absence of specific comparable data in helicopter rescue paramedics. A study of beach lifeguards indicated that surf rescues invoked very high physiological workload (approximately 85-85% of VO_{2max}), a relative heart rate comparable to the ICFP cohort (approximately 90% versus ICFP 103% of maximum) and similar peak blood lactate (9.7 (±1.1) mmol/L versus ICFP 8.1 (±2.4) mmol/L. However, participants were half the age of ICFPs (22.2 versus 44.3 years) and task duration was substantially shorter (2.7 versus 10.2 min) (Prieto Saborit *et al.* 2010). Another study of beach lifeguards, participants performed a manikin tow (similar to our study) albeit in a swim flume. Self-paced task duration and mean blood lactate were similar to the ICFP task swim simulation but mean relative VO_2 was 19% less (Reilly *et al.* 2006a). Finally, another study in beach lifeguards required young (29.1 (±4.6) years) lifeguards to perform a rescue simulation including a run, swim and swim-tow (swim distance 300m). Again, high physiological demand was shown (mean peak heart rate 195 bpm; mean peak blood lactate 13.5 mmol/L), but task duration was shorter than for ICFPs in this study (6.0 versus 10.2 minutes) (Salvador *et al.* 2014). It is important to acknowledge that familiarity with a task and job experience has been shown to improve efficiency in performance, and work by Milligan et al suggests minimum fitness levels should be based on inexperienced staff (Milligan *et al.* 2017). Given the high experience level of the participants in our study, this key point should be factored into the design and implementation of PES for ICFPs.

Studies quantifying physiological demands in swimmers performing rescues focus on lifeguarding (Reilly *et al.* 2006b, Prieto Saborit *et al.* 2010, Salvador *et al.* 2014), yet have not integrated assessment of acceptable work duration in an occupation where critical, highly demanding tasks may have to be performed more than once. Whilst comparison of MAWD in other water-based studies is not possible, our findings may inform resource deployment to water rescue cases where there are multiple patients. Specifically, based on our findings, the requirement to rescue more than four patients in the water may exceed MAWD (task time to rescue two patients 10.2 (±1.1) minutes versus MAWD = 21.0 (±15.6) min). Thus, task repetition and exceeding MAWD may result in fatigue and the inability to complete a critical task, which has obvious consequences in life-saving occupations.

Cumulative physiological strain with multiple rescues has been seen in a study of fire fighters rescuing six patients during a task simulation. VO_2, heart rate and blood lactate increased as more patients were rescued, more so after rescuing the fourth and fifth patients, and peak relative VO_2 was similar that seen in the ICFPs (mean (SD) 44 (±5) $mL.kg^{-1}.min^{-1}$, 83 (±7) % of VO_{2max}). Further, Wu et al. studied recovery after two bouts of cycling at 60% and 70% of maximal capacity, albeit lower than those intensities seen in ICFPs. The findings indicated that complete recovery time (CRT) was 23.4 minutes when working at 70% of maximum capacity for ~14 minutes (Wu *et al.* 2005). In an extension of this work, Ye and Pan utilised a combination of a questionnaire and the 70% of maximum cycling test to develop model for prediction of CRT after high intensity work, with similar duration noted (~28.6 minutes (Ye and Pan 2015). The results of these studies indicate that as high intensity work is completed and/or repeated, sufficient recovery should be allowed to minimise cumulative physiological strain, which could impair performance. Of note, this is unlikely to be possible in helicopter winch rescue where there may be imminent life threat, thus multiple rescues carry the real risk of cumulative fatigue. Although our study is the first to report MAWD for a rescue swimming task, further work is required to assess whether or not the method described by Wu and Wang (Wu and Wang 2002) is the most accurate to determine an acceptable upper limit for the duration of water winch rescue by ICFPs. Similarly, additional work is needed to assess cumulative fatigue in the ICFP rescue environment, thus providing guidelines regarding the deployment of multiple helicopter resources to rescues where recovery time may be insufficient, and the upper limit of acceptable work duration exceeded.

Acceptable physiological demand and MAWD has however, been explored in other occupations. A study by Bugajska et al. assessed a range of industrial workers across the age spectrum, and defined excessive physical workload as sustained tasks at greater than 30% of VO_{2max} (Bugajska *et al.* 2011). Further, a review by Jorgensen suggests limits for physical work over 8 hours of 50% of VO_{2max} in trained subjects. In contrast, ICFPs in the current study were required to work at 80-85% of VO_{2peak} but the tasks are of much shorter duration than reported in these studies, and the rescue tasks may need to be repeated. Therefore, recommendations for limitations on task duration and/or frequency for ICFPs based on these studies is challenging given the differences in task duration. However, when comparing ICFP physically demanding tasks to similar professions performing rescue tasks, much of the previous work has been undertaken in fire fighters and military personnel based on land. Bos et al. investigated work tasks of Dutch firefighters and noted that whilst the frequency of performing physically demanding tasks was in practice low, simulations of critical yet intermittently performed physically demanding rescue tasks exceeded the 90th percentile value of the actual duration of tasks (Wu and Wang 2002, Bos *et al.* 2004). Further, in a study of participants with similar health profiles to ICFPs who performed simulated load carriage tasks (22kg weighted vest), Peoples et al. demonstrated that where exercise intensity exceeded 80% of peak aerobic power, the upper acceptable work limit was mean (SD) 6.30 (±0.79) min (Peoples *et al.* 2016). The strenuous nature of ICFP work is further highlighted when comparing both of these studies to the ICFP land task, which invoked ~86% of VO_{2peak}, and an actual task time of 13.2 (±9.0) min and MAWD of 21.0 (±15.6) min). Of note, both Taylor et al. and Peoples et al. suggest that historical models for determination of MAWD are not applicable to emergency services personnel such as ICFPs, and thus provide formulae to predict upper and lower acceptable durations (Peoples *et al.* 2016, Taylor *et al.* 2016). These formulae may be more applicable to the ICFP tasks, and their application to ICFP rescue tasks present opportunities for future research.

In contrast to other emergency services workers of a similar demographic such as firefighters and police (Gendron *et al.* 2019, Smith *et al.* 2020), the ICFPs in this study demonstrate good overall health, are physically active and aerobically fit (Meadley *et al.* 2021c). However, the health status does not imply ongoing capability to satisfactorily perform the physically demanding tasks described in our study. Physical employment tests that must be passed to gain initial employment are infrequently repeated for incumbent employees (Sothmann *et al.* 2004), including the ICFPs in the current study. As such, there are opportunities to ensure ICFPs can meet the physiological requirement of their role, thus enhance service delivery as well as patient and ICFP safety. Sluiter and Frings-Dresen acknowledged the importance of repeated assessment of an employee's ability to perform high demand jobs as they progress through careers, which may also allow for intervention strategies to ensure ongoing capacity (Sluiter and Frings-Dresen 2007). A systematic review of fitness tests and occupational tasks for military personnel acknowledges that ongoing assessment and surveillance of employee capacity is challenging for employers, but acknowledged the importance of the correlation between ongoing tests and common job tasks (Hauschild *et al.* 2017). Whilst employers may face cultural and industrial barriers to ongoing assessment of physical capacity, they also have a responsibility to ensure their employee are safe and proficient. High fatality rates are seen in other rescue professional such as firefighters, where advancing age, poor cardiometabolic health and declining physical capacity can lead to fatal outcomes during operational work (Smith 2011, Storer *et al.* 2014, Smith *et al.* 2020). Given the physiological workloads described for ICFP rescue tasks in the current study, initial and ongoing physical capacity assessments that simulate the high relative workload and task durations revealed in the current study should be considered as essential for the safety of the community and the workforce.

In summary, the combination of high physiological workload, relative short MAWD and older age of ICFPs performing helicopter winch rescue presents a range of challenges. Staff require adequate physical preparation, training and rest to be able to sustain the workloads described. Further, although uncommon, ICFPs may be tasked to a number of cases over an individual shift or have to rescue multiple patients beyond the bounds of the task simulations used in this study, and cumulative fatigue may impact ability to perform tasks at the required intensity. Incident response planning should consider multiple helicopter responses where it is anticipated that MAWD and/or physiological demand may be exceeded, or if inadequate recovery time is available. Finally, personnel performing tasks that require high physiological demands should be continually assessed for their capability to undertake these duties, and this is particularly pertinent for the paramedics involved in this study.

A limitation of our work is the relatively small sample size. Further validation of these results in a larger sample would be beneficial given the small number of personnel who perform the helicopter rescue swimmer role. The rescue manikin may not be representative of average mass, however, is designed by the manufacturer to replicate human buoyancy and drag. For two participants, during the swim task simulation, VO_{2peak} was exceeded by approximately 10-15%. This may indicate that true maximal aerobic capacity was not achieved for those participants during maximal testing and thus may affect data for relative physiological workload.

Conclusion

This is the first study to examine the physiological demands of helicopter rescue paramedics performing land and water winch rescue. ICFPs performing land and water-based rescue via winch from a helicopter are required to perform complex life-saving rescue tasks at greater than 80% of their maximal aerobic capacity for moderate durations. Calculations of MAWD indicate that an ICFP could rescue two persons on land and four persons in the water before exceeding recommended maximal work time. The results of this study provide a foundation for task-to-test analyses for this occupation. During the development and implementation of PES, organisations employing personnel that are required to perform helicopter winch rescue should ensure assessments replicate this high physiological workload. Additionally, when deploying helicopter resources to critical rescue incidents, the physiological demands of the tasks and MAWD should be factored in to resource allocation.

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Competing interests

BM is an operational ICFP with Ambulance Victoria. Ambulance Victoria had no influence on study design, protocol development or reporting of results. All other authors have no competing interests to declare.

Author contributions

Ben Meadley and Ella Horton: Conceptualization, Methodology, Investigation, Validation, Data curation, Formal analysis, Writing- Original draft preparation**,** Writing- Reviewing and Editing, Project Administration, Funding Acquisition. **Luke Perraton**: Methodology, Investigation, Writing- Reviewing and Editing, Supervision. **Karen Smith**: Resources, Writing- Reviewing and Editing, Supervision, Funding acquisition. **Kelly-Ann Bowles**: Investigation, Writing- Reviewing and Editing, Supervision. **Joanne Caldwell:** Conceptualization, Methodology, Investigation, Validation, Formal analysis**,** Writing- Reviewing and Editing, Supervision, Project Administration.

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Data availability

Deidentified data is available upon reasonable request from the corresponding author (BM).

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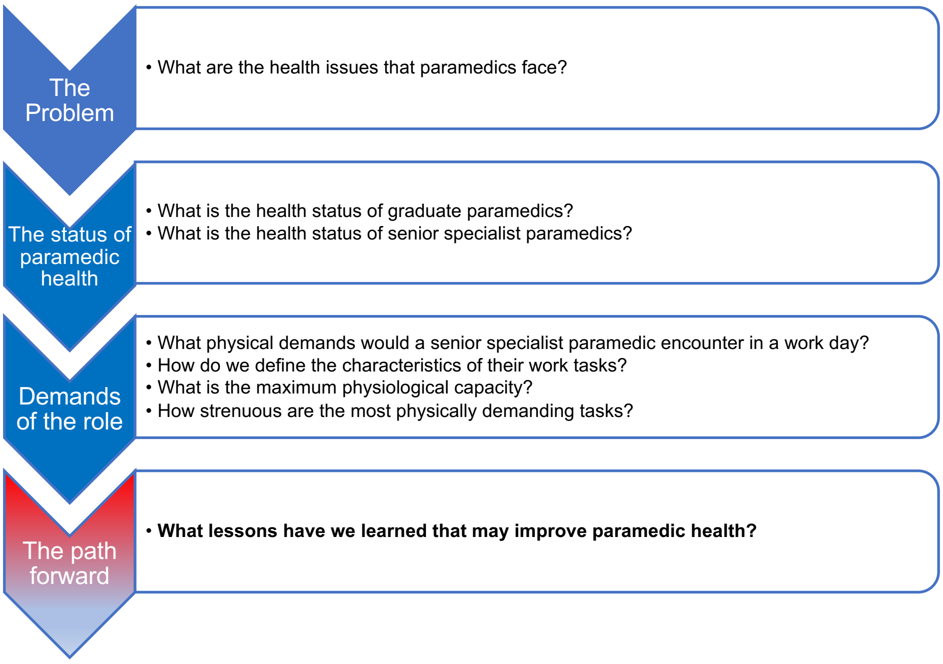
8.3 Summary of Chapter Eight

This study found that for land winch rescue tasks, ICFPs worked at approximately 86% of their maximal aerobic capacity for more than half of the calculated maximal acceptable work duration (MAWD) in order to rescue one person. For water winch rescue tasks, ICFPs worked at approximately 81% of their maximal aerobic capacity for slightly less than half of the calculated MAWD in order to rescue two people. The data from Chapter Four demonstrated that ICFPs are fit, healthy and undertake very high levels of physical activity, and the data from Chapter Seven indicated ICFP maximal aerobic capacity is high. Nonetheless ICFPs are not high-performance endurance or aerobic power athletes, yet these intermittent, essential, and lifesaving winch rescue tasks invoke very high physiological demand. The implications for the profession are significant. Initial and ongoing physical assessments should replicate these demands as part of a formalised physical employment standard. Furthermore, when deploying ICFPs to physically demanding cases, there should be due consideration for the physiological strain that may be encountered, which in turn may influence resource allocation (e.g., sending additional helicopters to a rescue of multiple patients). Many of these findings may be applied to other areas of paramedicine and other like professions.

In the context of the thesis, this study has found that ICFPs undertake strenuous occupational tasks, which may contribute to the excellent health status in this group of long-term shift workers. The mechanisms for this are possibly due to performance of the tasks themselves, or the fact that the ICFPs must be in a state of readiness to undertake the tasks at any time, or a combination of these. Additionally, a degree of survivor bias may be present, in that only those who satisfy the selection requirements for the role were assessed in the research.

Further work is required to investigate the link between the physically demanding nature of ICFP work and their overall health status, and importantly, whether components of the positive ICFP health profile identified in Chapters Four, Seven and Eight may be used to improve paramedic health across the population. This research has demonstrated that whilst cardiometabolic and physiological health may be compromised in some paramedics, high levels of physical activity and a physically demanding job may limit the manifestation of poor health.

Chapter Nine: Discussion and conclusions



9.1 Summary of key findings

In this final chapter, the major findings of the studies described in this thesis are discussed, including the strengths and limitations of the research projects. Based on these findings, recommendations for strategies and further research to improve paramedic cardiometabolic and physiological health and wellbeing are made.

The primary aims of this thesis were to examine the relationship between working as a paramedic and cardiometabolic, dietary and physical health, and to gain an understanding of the specific physical performance demands of specialist paramedics and how they may contribute to overall health.

1. **Paramedics face several risks to their cardiometabolic and physiological health.**

In Chapters One (Introduction) and Two (Editorial), the knowledge gaps regarding paramedic cardiometabolic and physiological health were identified. Compromised health in paramedics and other shift workers has been demonstrated across several core health areas including mental health, sleep, diet, and physical activity (7, 11, 90). Addressing concerns regarding paramedic health and wellbeing is essential to ensure a healthy workforce that is ready and capable of providing the highest standard of care to the community.

The incidence of poor mental health of paramedics is well reported (51, 91). However, the mind does not exist independently to the rest of the body. Several large studies highlight the importance of systemic wellbeing, and its dependence on a multitude of factors including diet, physical activity and the presence or absence of cardiometabolic disease (57, 92-94). Whilst some studies have demonstrated poor systemic health in paramedics (8, 24, 46, 95), there remains a gap in the literature regarding cardiometabolic and physiological health status in paramedics. Additionally, questions remain regarding what point of a career may poor health manifest, and factors that may influence health status (i.e., physically demanding work tasks).

In summary, Chapters One and Two established that:

- Working as a paramedic may compromise health, but the associations between diet, physical activity and the physical demands of paramedic work and overall health are poorly understood.
- It is not known when poor health first manifests during a paramedic's career.
- There is a need for research that considers the multifactorial nature of paramedic cardiometabolic and physiological health.
- There is a need for high quality studies performed by multidisciplinary research teams to identify the numerous factors that contribute to paramedic cardiometabolic and physiological health.

These knowledge gaps identified in Chapter One and Chapter Two (20) were the basis for the development of the aims, objectives and methods for the studies described in this thesis. This was achieved via five studies utilising longitudinal, qualitative consensus, cross-sectional and quasi-experimental methodologies. The first two studies examined cardiometabolic and dietary health, as well as physical activity, firstly in a sample of first year graduate paramedics and then in a sample of specialist helicopter rescue paramedics. Based on the findings of these studies, the final three studies further explored the physically demanding nature of the helicopter rescue paramedics' most strenuous work tasks.

The subsequent research projects that form this thesis generated three major findings related to paramedic cardiometabolic and physiological health.

2. **Diet, cardiometabolic health and physical activity in graduate paramedics did not change substantially during the first year of practice.**

The study in Chapter Three revealed no major changes in diet, cardiometabolic health and physical activity during the first year of graduate paramedic practice, indicating than any significant changes may occur later in the career. However, the study did highlight some concerns regarding some baseline anthropometric values. For example, 48% of male GAPs had a BMI > 25.0 $kg.m^{-2}$ at baseline. Whilst this may raise some concerns, median BMI was well below that seen in North American paramedics (46, 96), and in other studies of Australian paramedics and the wider population (49, 97, 98).

Another finding from Chapter Three was a small difference between males and females regarding BMI change over the 12 months. Male paramedics had 0.7% decline in BMI compared to 1.7% increase in females. Conversely, other studies of young adults with similar demographics showed an opposite trend (99, 100). Long term follows up studies of GAPs would be useful to elucidate a greater risk of weight gain for male or female paramedics, and at which point in the career this may manifest. Such data may assist in the development of tailored programs for those with a greater risk to their health.

Aligned with the BMI data, baseline median waist to height ratio for the group described in Chapter Three was under the threshold of 0.5 (≥ 0.5 indicates risk for cardiometabolic disease) (53, 101). As with BMI, it did not change meaningfully over 12 months. However, there was again a reasonable proportion of the participants that showed some degree of suboptimal health, with 18% of GAPs having a waist to height ratio of > 0.5 at baseline. Unfortunately, few studies report waist to height ratio in paramedics or other health care workers, and it is therefore difficult to provide comparisons. Nonetheless, the BMI and waist to height ratio data were somewhat informative for the overall health status (and for detection of changes) in GAPs. These simple, cheap, and helpful assessments may be useful for further longitudinal studies in paramedics (including this cohort of GAPs in follow up studies) but may also serve as reliable metrics for ongoing occupational health monitoring in paramedicine.

One of the more costly and detailed investigations in the Chapter Three study were the biomarker analyses. Baseline and 12-month data for GAPs revealed normal values and little change over the study period. The exception was the ~14% increase in glucose and insulin derived HOMA IR, where ~9% increase in insulin specifically led to a small rise. Whilst this has also been reported in other health care workers completing shift work (48), the HOMA IR was still less than the upper threshold for cardiometabolic health risk (102). Although insulin was the primary determinant of the HOMA IR rise in this cohort, insulin assay is expensive, invasive, and no point of care device is yet commercially available. As the supplementary findings in Chapter Three indicate, in combination with other simple measures such as BMI, waist to height ratio and blood pressure, glucose assessment using a point of care glucometer is a practical and reliable method for research and monitoring of cardiometabolic health risk in paramedics.

Regarding AV GAP cardiovascular fitness, the maximal aerobic capacity assessments showed average to moderate results comparable to normative data (103), and results seen in junior paramedics in Finland who had similar baseline VO_{2max} values and a limited change over 12 months (104). Good cardiovascular fitness has been shown to be important in limiting the incidence of metabolic syndrome in firefighters (105) and in improving cardiometabolic health and pancreatic function (106). Thus, higher cardiovascular fitness may be important in the prevention of cardiometabolic disease in paramedics. Future research should consider programs that aim to improve and monitor cardiovascular fitness. Although expensive and resource intensive laboratory-based assessments were used in the studies described in Chapters Three and Four, simpler tests of maximal aerobic capacity, such as the 6-minute walk tests, are accessible and reliable (107, 108) and may be suitable and cheaper alternatives for future research and occupational health monitoring in paramedics.

For physical activity, the GAPs described in Chapter Three did not meet minimum recommendations for steps per day (109), but they did for minutes of MVPA per week (60). Other health professionals such as nurses have shown higher levels (110), therefore further work is required to ascertain if there are specific issues related to paramedicine that affect levels of physical activity. Shift patterns appear to have limited effect on physical activity, but unsurprisingly the day off after a nightshift had an impact on the amount of physical activity completed. Although previous work has indicated shift workers are as physically active as the wider population (111), further work is needed to explore more thoroughly whether shift patterns affect paramedic physical activity, and what other factors (e.g., personality traits, involvement in organised sport) may play a role. More specifically, there are limited studies quantifying the physical demands of generalist paramedic work (18), and the application of PES methodology (as discussed in Chapters Six, Seven and Eight) to large paramedic cohorts may assist in determining what role occupational physical activity has on long-term cardiometabolic health in paramedics. Finally, dietary analysis via the FFQ assessment did not reveal major concerns, with most results within recommended values (112), as seen in other emergency services workers such as firefighters (31). The exception was that consumption of highly processed or take-away food was almost double that recommended (40). This finding presents an opportunity for further work to understand how consumption of these food types can be reduced, but also speaks to previous work regarding the barriers to healthy eating in paramedics (90). The FFQ was however easily administered, and with high its information yield, its use in longer term studies of paramedic diet is feasible.

The overall GAP cardiometabolic and physiological health profiles showed reasonable baseline health whilst identifying some areas for improvement. No significant changes occurred in their first year. Further work is required and may include studies of interventions to reduce fast food and processed food consumption, promote physical activity (including improving aerobic capacity), and longer-term studies that are designed to detect when poor cardiometabolic and physiological health manifests (including long-term follow up of the GAP cohort described in Chapter Three). Additionally, the findings of this work detail a suite of assessment tools that can be applied in future research and occupational health programs involving paramedics.

3. **Senior specialist paramedics with extended careers in paramedicine demonstrate excellent cardiometabolic and physiological health.**

Given their extended exposure to a career in paramedicine, it was anticipated that the ICFP group studied in Chapter Four would show some signs of poor cardiometabolic and physiological health. At least, given an average of approximately 20 years in the profession, they may have shown a worse profile than the GAPs studied in Chapter Three. Surprisingly, this was not the case.

Abnormal fasting lipid profile is well-established as a risk factor for cardiovascular disease (113), but for the ICFPs, these values were within normal range. Only one of the 15 participants indicated risk for insulin resistance via assessment of HOMA IR (102), opposing results from other health care workers completing shift work (48). Additionally, assessment of heart rate and blood pressure revealed mostly normal results (114). The median BMI of 25.1 $kg.m^{-2}$ was just above the threshold of 25.0 $kg.m^{-2}$ for overweight, yet below results reported in studies of paramedics in Australia (23) and North America (46, 96), and larger studies of other paramedics and the wider population (46, 49, 96-98). Additionally, the majority of ICFPs were below the ≥ 0.50 threshold for waist to height ratio, indicating a lower risk of cardiometabolic disease (53).

ICFP maximal aerobic capacity was higher than that seen in normative data for similar age groups (103) and in the GAPs in Chapter Three. Compared to a study of other Australian paramedics, ICFPs were on average ~7 years older, yet had a ~2 $mL.kg^{-1}.min^{-1}$ higher VO_{2max} (115). Compared to the GAPs in Chapter Three, ICFPs were a median 20.5 years older yet median VO_{2max} was ~6 $mL.kg^{-1}.min^{-1}$ higher. Given studies in firefighters have shown a negative association between age, career length and cardiorespiratory fitness and other markers of cardiometabolic health (116), high aerobic capacity (which was confirmed by the results for the swimming aerobic capacity assessments in Chapter Seven) is likely to play a key role in the excellent cardiometabolic health profile seen in ICFPs.

Physical activity levels in the ICFPs were notably higher than those seen in the GAPs. ICFPs exceeded minimum recommendations for steps per day by approximately 16% (109), and complete three times the recommenced minutes of MVPA per week (117). Although absolute amounts of activity were affected by the type of shift worked, this had little effect on exceeding minimum recommended levels. Compared to the GAPs, ICFPs undertook approximately 39% more steps per day, and more than double the minutes of MVPA per week. In addition to high aerobic capacity, the high levels of physical activity seen in the ICFPs may contribute to the healthy BMI and overall positive cardiometabolic and physiological health profile (59).

ICFP dietary assessment revealed a ~31% higher energy intake than average adult daily energy intake in Australia, however proportions for each macronutrient were within recommended values (112), like results seen in physically active Australian firefighters (31). It should be noted that this work was unable to establish if increased energy intake is associated the physical demands of the ICFP role, which presents an opportunity for future work. Although in general ICFP dietary profile indicated even distribution of macronutrient consumption, highly processed/take-away food consumption was double the recommended levels, very similar to that seen in the GAPs studied in Chapter Three. This commonality may once again be reflective of the barriers to eating well when working as a paramedic. The presence of this finding in two distinct cohorts highlights the need for further work regarding the assessment of the quality of paramedics' diet, and the development of improvement strategies.

The study in Chapter Four indicates that it is possible to undertake shift work for several years and remain healthy, and that the overall cardiometabolic and physical activity profile of ICFPs is better than what has been reported in other paramedics and shift workers. Reasons may include high aerobic capacity and physical activity levels, low BMI, and the very physically demanding nature of the role as discussed in Chapters Six, Seven and Eight. Future work should investigate other factors that that influence health-related behaviours in this group such as personality type, the physical selection tests for entry into the role, or other reasons. Additionally, the cardiometabolic and physiological health data from this study may be useful to guide the development of intervention strategies to improve health for all paramedics.

4. **Senior specialist paramedics with excellent cardiometabolic and physiological health are required to perform very physically demanding tasks.**

With an understanding of the cardiometabolic and physiological health status of the ICFP group established in Chapter Four, the case report in Chapter Five gave the first insight into the physically demanding nature of the helicopter rescue role, giving an indication to what bearing these demands may have on overall health. In this study, the ICFP possessed aerobic capacity comparable to that seen in other studies investigating search and rescue professionals and specialist paramedics (115, 118). In fact, some authors have proposed a minimum VO_{2max} of 40-45 $mL.kg^{-1}.min^{-1}$ for similar specialist rescue roles (119, 120). However, recommendations regarding minimum VO_{2max} for selection to the ICFP role are beyond the scope of this thesis, and further investigations should be undertaken to determine the feasibility of including maximal aerobic capacity assessments in role selection assessments.

Nonetheless, the requirement to sustain 81% of maximum heart rate (approximately equivalent to a relative VO_2 of 44.8 $mL.kg^{-1}.min^{-1}$) for 10 minutes at near maximal exertion was a significant finding. Importantly for this profession, these demands are in the context of the ICFP being required to deliver cognitively demanding clinical care once reaching the patient, in contrast to studies of physical demands in other populations such as construction workers (121, 122).

The physiological demands demonstrated in this case report were the impetus for applying the PES methodology to investigate the ICFP group specifically, and other areas within paramedicine (and other occupations) could benefit from publication of case reports to provide foundation data for the physical demanding nature of the tasks they perform. To facilitate data collection during routine work, widespread use of wearable technology to capture physiological information during paramedic work is feasible and reliable (123, 124), and the studies in Chapter Three and Four support this assertion.

Although the studies in Chapters Six and Seven are not specifically linked to the cardiometabolic and physiological health status of ICFPs or other paramedics, they nonetheless represent essential components of the PES methodology, and provide important implications for the profession. The study in Chapter Six demonstrated the utility of convening a focus group of SMEs to describe the characteristics and complexities of physically demanding roles. Our findings complement similar work by Hughes et al. who investigated critical job tasks and physical performance tests in corrections officers (125), and Arvey et al. who used SMEs for analysis of physical task requirements for police officers (126). The methods described in Chapter Six, specifically the use of SMEs to analyse historical data, are readily applicable to other areas of paramedicine. Reaffirming the previous statement regarding widespread use of wearable technology to measure gross physical demands at work, data derived from such monitoring could facilitate prospective capture of the physical demands of work, allowing more thorough analysis of historical cases by SMEs.

In Chapter Seven, as part of the PES process, we established maximal aerobic capacity in ICFPs whilst swimming and running. The mean VO_{2peak} values in ICFPs were high but not especially different to results from other studies investigating search and rescue professionals and specialist paramedics (115, 118). However, the novel swimming VO_{2peak} protocol we developed has important ramifications for rescue paramedics, other rescue swimmers, and the wider HEMS SAR profession who perform aquatic rescues. Other protocols in non-elite populations are likely to have induced muscular fatigue and prevented of VO_{2peak} criteria being met (127, 128). As our protocol utilised short distances, breaks between phases, and less repetition of high intensity effort, the test appears to have overcome some of the limitations of assessing maximal aerobic capacity in non-elite populations in the water. Additionally, and importantly, there was only a 6% difference in maximal capacity in the pool protocol compared to the treadmill assessment of VO_{2peak}, implying that a treadmill test is sufficient to assess VO_{2peak} in ICFPs. These findings may be transferrable to other paramedics performing similar tasks that aren't necessarily associated with HEMS teams, but replication and validation via dedicated studies is required.

Finally, in the study in Chapter Eight, ICFPs undertook land and water-based task simulations to assess relative physiological workload for tasks defined by the SMEs in Chapter 6. In water winch rescue simulations, the ICFP worked at 81% of their maximal aerobic capacity, and in the land task, 86% of maximum. By comparison, a study of wildland firefighters performing overland load carriage tasks demonstrated relative workload of 46-47% of estimated VO_{2max} (129), substantially less than the ICFPs. In search and rescue simulation performed by Australian Army first responders, participants worked at 74.1% of VO_{2peak} and 80% of maximum heart rate (130). Additionally, in a recent study developing PES for specialist rescue paramedics in the United Kingdom, task simulations invoked similar physiological demands to that seen in the ICFP tasks (19). Comparing water-based tasks specifically, a study of lifeguards demonstrated that surf rescues had high physiological workload (approximately 85-85% of VO_{2max}) and similar blood lactate to the ICFPs (9.7 ±1.1 mmol/L versus ICFP 8.1 ±2.4 mmol/L) (131). In another study of beach lifeguards performing tasks simulations, blood lactate was similar to the ICFP task swim simulation, but oxygen consumption was 19% less (132). A third study in beach lifeguards performing a rescue simulation including a run, swim, and swim-tow showed comparably high mean peak heart rate (195 beats per minute) and high mean peak blood lactate (13.5 mmol/L) (133).

Before further exploring the physical demands of ICFPs, and the implications for cardiometabolic and physiological health in paramedics, there are additional findings from the work in Chapter Eight. These are important for their relevance to the HEMS and SAR professions, and other paramedics performing physically demanding job tasks. Firstly, the VO_2 data in Chapter Eight was used to calculate maximal acceptable work duration (MAWD) for the critical winch rescue tasks. This is a useful metric to estimate the onset of fatigue, which may compromise performance and staff safety. The MAWD data indicated that rescuing more than two people on land and more than four people in water may exceed MAWD. As such, deployment of multiple HEMS resources to complex rescue tasks should be considered where it is anticipated that MAWD and/or physiological demand may be exceeded.

Another important factor when considering the physical demands of the work ICFPs perform is the older age of the craft group. The clinical experience requirements for selection to the role mean that ICFPs are generally in their thirties when they first apply. There are no age limits for application and ongoing employment for ICFPs, and they tend to remain in the role for many years. Work by Bugajska et al. assessed a range of industrial workers across the age spectrum and defined excessive physical workload as sustained tasks at greater than 30% of VO_{2max}, and that capability to perform such work should be frequently assessed in those over 40 years (134). More specifically, Prieto et al demonstrated an inverse relationship between rescue effectiveness and age when investigating mine rescuers, firefighters, and lifeguards (118). Further, Walker et al examined body composition, aerobic capacity, power, and strength in ageing Australian firefighters, and found declines in performance that mirrored those seen in the general population (135). In comparison, ICFPs in this study were 44.3 ±5.4 years (and the mean age of the wider group at the time of the study was higher still at 47.4 ±6.5 years), and they were required to work at 80-85% of VO_{2peak} for sustained periods. Although ICFPs are metabolically healthy, physically active, and aerobically fit (136), given their mean age, there are opportunities to ensure patient and practitioner safety through initial and ongoing physical capacity assessments for ICFPs that simulate the high relative workload and task duration.

When comparing ICFP physically demanding tasks to those performed by the wider paramedic population, most studies have focused on manual handling tasks (18, 137, 138). However, cardiopulmonary resuscitation (CPR) has been defined as one the most physically demanding tasks for those providing emergency health care and is a requirement for all paramedics. A study in French emergency responders indicated approximately 42-46% of VO_{2max} was required for extended periods of CPR (139), with similar results (approximately 47%) seen in another study of healthy volunteers performing CPR at varying rates. Superficially, the most physically demanding tasks of generalist paramedic practice are a little over half the relative workload of the rescue tasks performed by ICFPs, which could account in some part for the differences in cardiometabolic health seen in Chapters Three and Four. However, formal assessment of generalist paramedic work demands, ideally via the PES methodology, is required to further investigate the physically demanding nature of their work and any association with overall health status.

In Chapter Four, shift working ICFPs demonstrated an excellent cardiometabolic health profile despite an extended paramedic career. In Chapters Five through to Eight, the strenuous nature of their work is revealed. It would be reasonable to then assert that such strenuous work may in some way account for good cardiometabolic and physiological health. However, as previously mentioned, several studies suggest occupational physical activity does not confer the same health benefits as leisure time physical activity. In the CORDIS study, a prospective cohort study of industrial workers, moderate to hard occupational activity was associated with higher all-cause mortality when compared to light occupational activity (140). In a study of 182 Belgian workers from a range of professions that included the performance of physical demanding load lifting tasks, occupational physical activity was associated with higher mean systolic blood pressure (141). Further, in the Copenhagen Male Study, in men with low baseline fitness, a requirement to perform physically demanding occupational tasks was associated with an increase in all-cause mortality (142). Whilst these data are concerning, studies that report the physical activity paradox are generally not reported in those undertaking specialist roles.

The patterns are different in some occupations where the employees have higher baseline cardiorespiratory fitness. In a study of wildland firefighters where the physical demands of work are similar to ICFPs, the training and operational work requirements resulted in improvements in lipid profile, blood glucose, and haemoglobin A1C (another marker of insulin resistance) (143). In a study comparing sedentary clerks, police officers and firefighters, the most physically active firefighters demonstrated a more favourable cardiometabolic health profile. (144). Additionally, in a study of US urban firefighters, there was an inverse relationship between increases in cardiorespiratory fitness and the incidence of markers of cardiometabolic disease (145). In the context of these studies, and the findings of this thesis, several important factors appear to contribute to the excellent cardiometabolic and physiological health profile of ICFPs. Firstly, baseline fitness is of a high standard, with mean maximal aerobic capacity above populations norms and higher than generalist paramedics. Secondly, key cardiometabolic risk factors are unremarkable, including a mostly good diet, normal BMI, lipid profile and insulin resistance scores. Thirdly, physical activity levels well exceed international recommendations. Finally, the physical demands of the rescue work

ICFPs undertake are very high, although that work is undertaken intermittently. Whilst the performance of those task themselves are unlikely confer significant health benefits, the requirement of the role is that ICFPs must be able to complete them at any time, without notice. This implied requirement is likely a major contributor to ICFPs ensuring that they are healthy enough to undertake their critical role. Whilst sufficient data is presented in this thesis to at least suggest this to be a factor, deeper, qualitative exploration of ICFP traits and health related behaviours is required to confirm the hypothesis.

The major findings of the studies in the thesis are summarised in Table 9.1.

Table 9.1: Summary of major findings

Major findings
In graduate paramedics (GAPs) with no prior exposure to shift work: • Dietary patterns, HRQoL, cardiometabolic health, aerobic capacity and physical activity levels did not change meaningfully in the first year of practice. • Baseline BMI, physical activity levels and some dietary behaviours were suboptimal. • Health could be better optimised prior to commencing their career.
In helicopter rescue paramedics (ICFPs) with extended careers in paramedicine: • Markers of metabolic health (BMI, blood pressure, glucose, insulin, and lipids) and dietary intake were within normal reference ranges despite ~20 years of shift work in paramedicine. • Amounts of essential physical activity (steps per day and minutes per day of MVPA) were well above recommended levels. • Compared to other paramedics and shift working populations ICFPs appeared to be metabolically healthier, had higher HRQoL and aerobic capacity.
Further exploration of the ICFP role revealed: • ICFPs perform physically demanding tasks above and beyond those undertaken by the wider paramedic population. • Paramedic SME focus groups can analyse historical data to describe the characteristics of physically demanding work • The most physically demanding tasks are land and water winch rescue. • For land winch rescue tasks, ICFPs worked at approximately 86% of their maximal aerobic capacity for more than half the calculated MAWD to rescue one person. • For water winch rescue tasks, helicopter rescue paramedics worked at approximately 81% of their maximal aerobic capacity for slightly less than half the calculated MAWD to rescue two people. • These very high physiological demands for work tasks may in part explain the excellent cardiometabolic and physiological health profile of ICFPs

9.2 Strengths and limitations of research

This section provides an overview of the strengths and limitations of the studies described in this thesis. Further details are provided in each individual chapter. The complexities of field research in paramedicine are numerous, and include a geographically disparate workforce, shift work, frequent movement of employees between various work locations, fatigue from high workloads and variable roster patterns to name a few. These complexities led to several challenges when undertaking research in this population.

Regarding study design and flow of the studies in this thesis, several limitations are noted. Firstly, the comparison of the GAP cohort with the ICFPs may seem disparate. The original research design aimed to include paramedics from the wider, established general duties workforce. Additionally, the research team hoped to include paramedics across all professional groups (i.e., GAP, established general duties paramedics and specialist paramedics) from other ambulance services in Australia, to make this a truly national study. This would have enhanced the flow and linearity of the studies within this thesis. Nevertheless, four major factors affected this. Specifically, these were: funding, significant barriers to undertaking field research in other Australian ambulance services which were revealed when initial enquiries were made, the sheer volume of work that would be involved within the allowable timeframe, and finally, the COVID19 pandemic. As such, the research team was required to choose, and the GAP and ICFP cohorts were the populations identified as the most underrepresented in the wider literature.

Although the sample sizes in the studies would be considered small, participants described in this thesis represented nearly 29% of GAPs and 31% of ICFPs employed by AV during the study period. Participation in the studies was primarily limited by the use of convenience sampling as the recruitment method, which was the only ethical and feasible method of recruitment in this population. There is a risk of selection bias in that highly motivated GAPs and ICFPs may have been more inclined to participate in the study, however participants had a wide range of age, experience, and participants volunteered from all areas of the service.

Another limitation was that reference data from similar occupational populations of GAPs and ICFPs were not available. However, we were able to compare results with published reference ranges from the wider general population. Additionally, statistical analysis methods were constrained by the sample sizes. Larger sample sizes would have allowed for more advanced statistical analyses and models, and this should be taken into consideration when undertaking future work investigating paramedic cardiometabolic and physiological health.

For the study into graduate paramedics described in Chapter Three, we recruited equal numbers of women and men, which aids generalisability of the results to both sexes. However, for the studies investigating cardiometabolic health and physiological demands in ICFPs, only two women worked in the role at the time, with both volunteering as participants for the studies. Nonetheless, any inferences to female ICFP cardiometabolic health and physiological demands are limited. Further work is needed to validate the findings from this work in a larger sample of GAPs and ICFPs, specifically female ICFPs.

A major strength of the research is that there was a small loss to follow-up in the GAP participants, and no loss of participants from the ICFP group. This is especially important in the context of the COVID-19 pandemic which was declared in the latter part of data collection for both groups. Although there are numerous barriers to undertaking field research in paramedicine, the GAP and ICFP participants were committed and enthusiastic.

The COVID-19 pandemic significantly affected data collection, study design, and thesis flow and structure. For ICFPs that wore physical activity monitors in the study described in Chapter Four, we intended to repeat the maximal aerobic capacity assessments at the end of the 12 months. The original aim was to match and compare GAP and ICFP maximal aerobic capacity and physical activity data, and to explore reasons for any differences. Additionally, deeper analyses of body composition using specialised laboratory equipment was unable to be completed, which would have provided supplementary data to the BMI and body mass information in both groups. These assessments were not able to be completed due to the closure of the physiology laboratory in the latter part of the project. Lastly, the writing of this thesis was undertaken whilst working predominantly full-time as a paramedic during the pandemic. This included numerous state-wide lockdowns whilst assisting children through remote learning, which presented a range of unanticipated and novel challenges.

The major strength of this thesis is that the studies herein have demonstrated that comprehensive dietary, cardiometabolic and physiological health assessments in paramedics do not have to be complicated. Adequate planning and preparation can assist in overcoming the unique challenges research into this profession present. Acknowledging the strengths and limitations of the studies outlined in this thesis will allow future work to translate into practical and real-world strategies to improve paramedic health and wellbeing.

9.3 Recommendations to improve the cardiometabolic and physiological health of paramedics

The studies described in this thesis enable several recommendations to be made to improve the health and wellbeing of paramedics. These recommendations should be interpreted in the context of the availability of resources required to implement them within a given system, and are summarised as follows:

9.3.1 Recommendations to organisations employing paramedics

i. The profession should better prepare undergraduate paramedic students and graduate ambulance paramedics for the rigors of a career in paramedicine.

- The findings from Chapter Three indicate that there are opportunities for paramedics to start their career in a better state of health. Ambulance services, universities and professional associations should collaborate to ensure that prospective paramedics are informed of the possible effects on health of a career in paramedicine and should provide strategies to be fit for duty even before they commence.

ii. Employers should incorporate long-term health and wellbeing programs from the first year of practice as a paramedic.

- Even though workplace health programs are not a novel concept, these are not common in paramedicine. There is an opportunity to instigate tailored health programs for paramedics, that align with ongoing research to identify and combat the health challenges that face paramedics.

iii. Organisations should implement continuous monitoring programs for diet, cardiometabolic and physiological health.

- The studies in Chapters Three and Four showed that longitudinal monitoring of health parameters is feasible. Additionally, the SME focus group studies in Chapter Six identified the utility of the historical data analysis to provide insights into the physical demanding nature of paramedic work. Ongoing collection of in-field, real-time physiological and health data with modern technologies and simple point of care assays (e.g., smart watches and glucometers) can yield large datasets that will allow for continuous monitoring of employee health, driving intervention strategies and supporting research.

iv. Organisations should explore the use of health and physical activity promotion programs within paramedicine.

- As stated, workplace health promotion and intervention programs are not new. However, the ICFP data from Chapters Four and Eight suggest that some health behaviours may protect paramedics against health decline as the career progresses. Increasing steps per day, MVPA and decreasing BMI in particular are simple strategies that could be easily implemented and evaluated for their impact on cardiometabolic and physiological health in paramedics.

9.3.2 Recommendations to paramedics

i. During the undergraduate education, paramedic students should optimise cardiometabolic and physiological health in preparation for their career

- The suboptimal health status of some of the GAPs described in Chapter Three suggests that individual paramedics should aim to embed positive health behaviours in preparation for the rigors of shift work and paramedicine. This may include paying particular attention to diet, BMI, and levels of physical activity

ii. Paramedics should self-monitor cardiometabolic and physiological health status throughout the career

- Modern technology allows for easy monitoring of health and physiological parameters. Smart phones and watches, for example, allow for continuous monitoring of steps per day, MVPA, heart rate and even electrocardiogram. If indications of deteriorating or poor health are detected, health care professional advice should be sought early. This may enable modification of work practices and application of interventions to improve health.

9.3.3 Recommendations for further research

i. Longitudinal monitoring of cardiometabolic health and physical activity

- It was apparent from the results of the study in Chapter Three that 12 months was an insufficient period to detect significant changes in cardiometabolic and physiological health. This cohort specifically should be followed up later (e.g., five and 10 years) to investigate whether cardiometabolic and physiological health have deteriorated. In addition, similar longitudinal studies using the same measures should be undertaken in other jurisdictions and with large sample sizes.

ii. Health improvement intervention studies

- Although health intervention studies are not new, there is a lack of data regarding the efficacy of such programs in the complex profession of paramedicine. Whilst a variety of interventions have been studied across several occupations, their effectiveness is debatable. For paramedicine, innovation is required. New strategies might include assessing the utility of undertaking physical activity whilst at work, undertaking physical activity whilst commuting to work, or the effectiveness of nutrition education and food preparation for a mobile workplace.

iii. Conduct an analysis of the physical demands of generalist paramedic practice

- The physical demands of generalist paramedic practice in Australia have not been studied using the PES methodology. This is also applicable to other specialist areas of paramedicine including wilderness response, special operations, alpine response, and aquatic response paramedics. The PES methodology described in this thesis should be applied to all areas of paramedicine. This will ensure the physical demands of all paramedics are accurately assessed, that selection tests are valid, and associations between works demand and health status can be measured.

A summary of these recommendations is provided in Table 9.2.

Table 9.2 Summary of recommendations for further research

Recommendations
• Perform long-term follow up studies (e.g., at 5, and 10 years) in the paramedics described in Chapter Three. • Assess long term cardiometabolic and physiological health through multi-centre, longitudinal studies over extended periods (e.g., 3-5 years) with larger sample sizes
• Develop and evaluate dietary, physical activity and lifestyle intervention programs designed to improve cardiometabolic and physiological health in paramedics
• Perform studies that quantify the physical demands for generalist paramedics • Perform studies that quantify the physical demands for the other specialist paramedic sub-groups • Use the physical employment standards methodology to develop robust, scientifically validated PES for all paramedics

9.4 Conclusions

This thesis investigated the cardiometabolic and physiological health of Australian paramedics. In graduate paramedics with no prior exposure to shift work, dietary patterns, HRQoL, cardiometabolic health, aerobic capacity and physical activity levels did not change substantially in the first year of practice. However, baseline BMI, physical activity levels and some dietary behaviours were suboptimal. Extended longitudinal studies of paramedics from the beginning of employment may identify at which point in a paramedic's career negative health effects may manifest.

Conversely, despite prolonged exposure to shift work, and contrary to data reported from the wider paramedic workforce, ICFPs demonstrate good dietary health, good cardiometabolic health, excellent HRQoL and aerobic capacity, and levels physical activity well above international recommendations. ICFPs are likely to be healthier than the wider paramedic and shift working populations due to their lower body weight, better diet, high amounts of physical activity and a very physically demanding job. Specifically, ICFPs performing land and water-based rescue via winch from a helicopter are required to perform complex life-saving rescue tasks at 80-85% of their maximal aerobic capacity for moderate durations. These extreme physical demands may bear some relationship to the excellent health profile. To combat the effects of an extended career in paramedicine, due consideration should be given to ICFP health behaviours and the influence of a physically demanding role on overall health.

Tertiary institutions educating paramedics, employers of paramedics, and paramedics themselves should consider these findings, and implement strategies to optimise cardiometabolic and physiological health in this essential profession. Such strategies should be applied from the beginning of undergraduate education, at paramedicine career commencement and beyond, to better enable paramedics to combat the negative health effects that may result from their work.

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Appendices

Appendix A	Pre-course selection requirements – Ambulance Victoria MICA Flight Paramedic
Appendix B	Monash University Human Research Ethics Committee Approvals
Appendix C	Ambulance Research Committee Approvals
Appendix D	Exercise and Sports Science Australia Pre-Exercise Screening Tool
Appendix E	Example Participant Information Statement & Example Consent Form
Appendix F	Example data collection forms
Appendix G	RAND Short-form 36 Item Questionnaire (SF-36) for Health-Related Quality of Life
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Appendix A - Pre-course selection requirements – Ambulance Victoria MICA Flight Paramedic

Ambulance Victoria

Pre-Course Selection Requirements

MICA & ALS Flight Paramedic

Please note:

It is the applicant's responsibility to demonstrate their competency in each area assessed during the AAV selection process and to ensure their attendance at each assessment.

All enquiries regarding the recruitment and selection process should be directed to the Recruitment Department on: 9840 3653.

July 2021

members score the responses against the selection criteria. The outcome of the interview is based upon the panel's agreed score.

Applicants may be presented with a hypothetical patient case history and be asked how they would manage this situation. The major focus of the interview will be to assess the applicant's suitability, based on the selection criteria outlined in the relevant position description.

At the end of the interview applicants are given the opportunity to ask questions and offer any other information which may not have been covered which supports their application.

Rationale:
The interview gives the panel an opportunity to meet with applicants and determine whether or not they have the appropriate skills and attributes to perform the MFP or FP position. It also gives the applicant an opportunity to discuss, and ask questions, relating to the position.

5. Referee Checks & Endorsements

Referees & endorsements provided by applicants must be able to comment on recent work performance from a supervisory perspective. References and endorsements are an important part of the selection process and may impact on the final selection decision. As such, additional information may be requested where required.

6. Swimming Assessment

MFP & FP applicants are required to demonstrate their proficiency in swimming by participating in a 15 metre underwater swim (whilst clothed in overalls and footwear - boots), followed by a 400 metre swim (must be completed without stopping, in less than 17 minutes & 30 seconds) followed immediately by 10 minutes treading water.

Rationale:
MICA and ALS Flight Paramedics travel on both rotary and fixed wing aircraft to transport patients across expanses of water some distance from land. In the event of an aircraft having to ditch into water, it is expected that the crew members are capable of exiting the aircraft underwater, swimming to safety and remaining afloat for a period of time.

In addition, the five Air Ambulance Victoria helicopters are accredited as Search and Rescue (SAR) resources by the Australian Maritime Safety Authority (AMSA). As such, MICA Flight Paramedics are required to be highly competent swimmers, able to rescue sick, injured or incapacitated persons in open and closed water. Thus, the MICA Flight Paramedic must be a competent and strong swimmer in challenging environments.

Purpose

To ensure that crews are able to exit an aircraft and swim to a position of safety in the event of a forced descent into water, and to assess applicant's competency as a rescue swimmer.

The test must be completed in ambulance issue overalls and boots.

Standard

Underwater

1. Swim 15 metres underwater at the deep end of a pool without surfacing for a breath, dressed in overalls and boots.

Rationale: Persons may be required, in the case of a forced descent into water, to swim clear of an aircraft wreckage. Aircraft sink rapidly and escape would entail an under-water evacuation.

2. Applicants will be required to tread water for two minutes immediately after the under-water swim.

***Rationale**:* Applicants are permitted to discard their boots at this point, as they would impede their efforts to swim clear of the aircraft wreckage. Removal of other clothing at this point would be unlikely however, due to the proximity to the crash site and the difficulty of removing ambulance issue flight suits when wet.

Swim

Immediately after treading water for two minutes, applicants will be required to swim 400 metres in less than 17 minutes & 30 seconds, without stopping for any period of time to tread water, stand or walk.

***Rationale**:* A flammable fuel/oil slick might form rapidly in the vicinity of the crash site, requiring that crew members swim clear of the crash site as quickly as possible to avoid eye/skin/respiratory inflammation and any flotsam from the wreckage.

Treading Water

Immediately following the completion of the 400 metre swim applicants must tread water for 10 minutes.

***Rationale**:* Having swum clear of the immediate area of the crash site, crew members would be required to wait for some time before being rescued.

Applicants must satisfactorily complete all aspects of this testing to progress to the next stage of assessment.

Swimming Assessment - Distance / Times / Comments

Applicant:	**Date and Time:**

Underwater

Distance: 15 metres **Completed:** Y / N

Comments: ______________________________

Treading Water

*** Please note: This time is used for applicants to remove their boots before commencing the 400 metre swim**

Time: 2 mins **Completed:** Y / N

Comments: ______________________________

Swimming

Distance: 400 metres **Completed:** Y / N
Time: _________min
Comments: ______________________________

Treading Water

Time: 10 mins **Completed:** Y / N

Comments: ______________________________

Name of Adjudicator ______________________________

Signature of Adjudicator ______________________________

7. Task-Specific Physical Capacity Assessment

MFP applicants are required to demonstrate their ability to work under physical duress in a simulated winch-in-to-patient situation. The applicant will be required to complete a fifteen hundred (1500) metre walk, 750 metres uphill, 750 metres downhill, in less than 20 minutes, whilst wearing and carrying Air Ambulance issued equipment.

Please note: this test is a hike test only so running up or down the hill will not be permitted.

Rationale:
MICA Flight Paramedics are often presented with significant physical challenges in inhospitable environments. This may include situations where a MFP may be winched into a location that is some distance from the patient. This assessment is designed to assess the applicant's ability to perfom physical tasks that are specific to the role of the MFP in a simulated environment.

The applicant is required to wear the Ambulance Victoria-issue overalls and boots (no shoes – ankle-high boots only) and the following equipment weighing a total of 34.45kgs.

***Applicants eligible to participate in this assessment will be provided opportunity to familiarise themselves with this equipment at Air Ambulance Essendon in their own time.**

EQUIPMENT	WEIGHT
Flight Helmet	1.50
Winch Harness	2.40
'Y' Piece	1.00
Overland Winch Vest	1.60
MMR Portable Radio	0.60
AAV DTW Pack **Contents as below*	10.75
406 DT-I Titanium Stretcher *No extension Strap	12.15
PPE/ Tagline Kit **Contents as below*	4.45
Total Weight	**34.45**

***AAV DTW Pack**	***Weight***
*Kagali Backpack *No extension Strap*	*2.40*
2 x Blankets (Bulk)	*2.45*
Normal Saline Bags 5 x 1000ml, 1 x 500ml	*5.90*
Total Weight	***10.75***

***PPE/ Tagline Kit**	***Weight***
Yellow Kit Bag	*1.25*
Tagline Kit	*3.20*
Total Weight	***4.45***

Timed gear carry

Applicant:

Time: 20 mins **Completed:** Y / N

Comments: ______________________________

____

____

Name of Adjudicator ______________________________

Signature of Adjudicator ______________________________

Appendix B - Monash University Human Research Ethics Committee Approvals

MONASH University

Monash University Human Research Ethics Committee

Approval Certificate

This is to certify that the project below was considered by the Monash University Human Research Ethics Committee. The Committee was satisfied that the proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and has granted approval.

Project ID:	15285
Project Title:	Cardiometabolic health of Graduate Ambulance Paramedics
Chief Investigator:	Dr Kelly Bowles
Approval Date:	26/07/2018
Expiry Date:	26/07/2023

Terms of approval - failure to comply with the terms below is in breach of your approval and the *Australian Code for the Responsible Conduct of Research*.

1. The Chief Investigator is responsible for ensuring that permission letters are obtained, if relevant, before any data collection can occur at the specified organisation.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash letterhead and the Monash University complaints clause must include your project number.
6. Amendments to approved projects including changes to personnel must not commence without written approval from MHUREC.
7. Annual Report - continued approval of this project is dependent on the submission of an Annual Report.
8. Final Report - should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected completion date.
9. Monitoring - project may be subject to an audit or any other form of monitoring by MUHREC at any time.
10. Retention and storage of data - The Chief Investigator is responsible for the storage and retention of the original data pertaining to the project for a minimum period of five years.

Kind Regards,

Professor Nip Thomson

Chair, MUHREC

CC: Assoc Professor Maxine Bonham, Dr Joanne Caldwell Odgers, Dr Luke Perraton, Dr Alexander Wolkow, Dr Karen Smith, Mr Benjamin Meadley

List of approved documents:

Document Type	File Name	Date	Version
Consent Form	CONSENT FORM_SHAPES_1_C	19/07/2018	1
Supporting Documentation	transport of specimens	19/07/2018	1
Supporting Documentation	Placement of an In-Dwelling Safety Cannula in a Vein	19/07/2018	1
Supporting Documentation	Blood sampling	19/07/2018	1
Supporting Documentation	Blood sampling procedure	19/07/2018	1
Supporting Documentation	Freezing of specimens	19/07/2018	1
Supporting Documentation	Food Diary	19/07/2018	1
Supporting Documentation	Detailed Project Proposal_Cardiometabolic	19/07/2018	1
Explanatory Statement	EXPLANATORY STATEMENT_Shapes_1_C	19/07/2018	1

Page 1 of 1

Monash University Human Research Ethics Committee

Approval Certificate

This is to certify that the project below was considered by the Monash University Human Research Ethics Committee. The Committee was satisfied that the proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and has granted approval.

Project ID:	17784
Project Title:	Physical Activity and Sleep Monitoring in Ambulance Paramedics
Chief Investigator:	Dr Kelly Bowles
Approval Date:	29/11/2018
Expiry Date:	29/11/2023

Terms of approval - failure to comply with the terms below is in breach of your approval and the *Australian Code for the Responsible Conduct of Research*.

1. The Chief Investigator is responsible for ensuring that permission letters are obtained, if relevant, before any data collection can occur at the specified organisation.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash letterhead and the Monash University complaints clause must include your project number.
6. Amendments to approved projects including changes to personnel must not commence without written approval from MUHREC.
7. Annual Report - continued approval of this project is dependent on the submission of an Annual Report.
8. Final Report - should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected completion date.
9. Monitoring - project may be subject to an audit or any other form of monitoring by MUHREC at any time.
10. Retention and storage of data - The Chief Investigator is responsible for the storage and retention of the original data pertaining to the project for a minimum period of five years.

Kind Regards,

Professor Nip Thomson

Chair, MUHREC

CC: Dr Kelly Bowles, Dr Karen Smith, Dr Joanne Caldwell Odgers, Assoc Professor Maxine Bonham, Dr Luke Perraton, Mr Benjamin Meadley

List of approved documents:

Document Type	File Name	Date	Version
Explanatory Statement	EXPLANATORY STATEMENT_PASMAP	04/11/2018	1
Consent Form	CONSENT FORM_PASMAP	04/11/2018	1
Supporting Documentation	Email_invitation_PASMAP	04/11/2018	1
Supporting Documentation	AV Research Application Form _PASMAP_26_10_2018	04/11/2018	1
Supporting Documentation	Detailed Project Proposal_PASMAP	04/11/2018	1
Supporting Documentation	Email_invitation_PASMAP	06/11/2018	1

Monash University Human Research Ethics Committee

Approval Certificate

This is to certify that the project below was considered by the Monash University Human Research Ethics Committee. The Committee was satisfied that the proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and has granted approval.

Project Number:	12323
Project Title:	Physiological characteristics of paramedics undertaking winch rescue in an Australian Helicopter Emergency Medical Service (HEMS) - Phase One: Subject Matter Expert Focus Group
Chief Investigator:	Dr Kelly Bowles
Approval Date:	06/02/2018
Expiry Date:	06/02/2023

Terms of approval - failure to comply with the terms below is in breach of your approval and the *Australian Code for the Responsible Conduct of Research*.

1. The Chief Investigator is responsible for ensuring that permission letters are obtained, if relevant, before any data collection can occur at the specified organisation.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash letterhead and the Monash University complaints clause must include your project number.
6. Amendments to approved projects including changes to personnel must not commence without written approval from MHUREC.
7. Annual Report - continued approval of this project is dependent on the submission of an Annual Report.
8. Final Report - should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected completion date.
9. Monitoring - project may be subject to an audit or any other form of monitoring by MUHREC at any time.
10. Retention and storage of data - The Chief Investigator is responsible for the storage and retention of the original data pertaining to the project for a minimum period of five years.

Thank you for your assistance.

Professor Nip Thomson

Chair, MUHREC

CC: Dr Luke Perraton, Dr Joanne Caldwell Odgers, Dr Kelly Bowles, Assoc Professor Maxine Bonham, Dr Karen Smith, Mr Benjamin Meadley

List of approved documents:

Document Type	File Name	Date	Version
List of data variables	HEMS Winch Debrief for MFP use - edited 200417	29/01/2018	1
Consent Form	AV_privacy_policy	29/01/2018	1.0
List of data variables	SME_FOCUS_participant_data_form	29/01/2018	1.0
Supporting Documentation	AV Code of Conduct	29/01/2018	1.0
Supporting Documentation	AV_Research_App_HEMS_Paramedics_Water_focus_group_final	29/01/2018	1.0
Explanatory Statement	Information_Sheet_HEMS_focus group	31/01/2018	1.0
Consent Form	consent-form-final_focus_group	31/01/2018	1.0
Focus Group questions	Subject Matter Expert Focus Protocol	31/01/2018	1.0

Monash University Human Research Ethics Committee

Approval Certificate

This is to certify that the project below was considered by the Monash University Human Research Ethics Committee. The Committee was satisfied that the proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and has granted approval.

Project Number:	14222
Project Title:	Physiological characteristics of paramedics undertaking winch rescue in an Australian Helicopter Emergency Medical Service (HEMS) - Phase Two: Task Simulations & Subject Matter Expert Focus Group
Chief Investigator:	Dr Kelly Bowles
Approval Date:	13/06/2018
Expiry Date:	13/06/2023

Terms of approval - failure to comply with the terms below is in breach of your approval and the *Australian Code for the Responsible Conduct of Research*.

1. The Chief Investigator is responsible for ensuring that permission letters are obtained, if relevant, before any data collection can occur at the specified organisation.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash letterhead and the Monash University complaints clause must include your project number.
6. Amendments to approved projects including changes to personnel must not commence without written approval from MHUREC.
7. Annual Report - continued approval of this project is dependent on the submission of an Annual Report.
8. Final Report - should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected completion date.
9. Monitoring - project may be subject to an audit or any other form of monitoring by MUHREC at any time.
10. Retention and storage of data - The Chief Investigator is responsible for the storage and retention of the original data pertaining to the project for a minimum period of five years.

Thank you for your assistance.

Professor Nip Thomson

Chair, MUHREC

CC: Dr Joanne Caldwell Odgers, Dr Karen Smith, Dr Luke Perraton, Assoc Professor Maxine Bonham, Mr Benjamin Meadley

List of approved documents:

Document Type	File Name	Date	Version
Consent Form	consent-form-final_bookmarking_focus_group	24/05/2018	1
Consent Form	consent-form-final_task_sim_video_land	24/05/2018	1
Consent Form	consent-form-final_task_sim_video_water	24/05/2018	1
Supporting Documentation	AV_Research_App_HEMS_Paramedics_Bookmarking_final_23_5_18	24/05/2018	1
Supporting Documentation	AV Code of Conduct	24/05/2018	1
Supporting Documentation	Email x 2 - Invitation to Participate	12/06/2018	1.0
Explanatory Statement	Information_Sheet_HEMS_boomarking_focus_group	12/06/2018	2.0
Explanatory Statement	Information_Sheet_HEMS_task_sims_overland	12/06/2018	2.0
Explanatory Statement	Information_Sheet_HEMS_task_sims_water	12/06/2018	2.0

Monash University Human Research Ethics Committee

Approval Certificate

This is to certify that the project below was considered by the Monash University Human Research Ethics Committee. The Committee was satisfied that the proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and has granted approval.

Project ID:	16340
Project Title:	Physiological characteristics of paramedics undertaking winch rescue in an Australian Helicopter Emergency Medical Service (HEMS) - Phase Three: Baseline Physiological and Metabolic Assessments
Chief Investigator:	Dr Kelly Bowles
Approval Date:	17/08/2018
Expiry Date:	17/08/2023

Terms of approval - failure to comply with the terms below is in breach of your approval and the *Australian Code for the Responsible Conduct of Research*.

1. The Chief Investigator is responsible for ensuring that permission letters are obtained, if relevant, before any data collection can occur at the specified organisation.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash letterhead and the Monash University complaints clause must include your project number.
6. Amendments to approved projects including changes to personnel must not commence without written approval from MHUREC.
7. Annual Report - continued approval of this project is dependent on the submission of an Annual Report.
8. Final Report - should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected completion date.
9. Monitoring - project may be subject to an audit or any other form of monitoring by MUHREC at any time.
10. Retention and storage of data - The Chief Investigator is responsible for the storage and retention of the original data pertaining to the project for a minimum period of five years.

Kind Regards,

Professor Nip Thomson

Chair, MUHREC

CC: Dr Joanne Caldwell Odgers, Dr Kelly Bowles, Dr Luke Perraton, Assoc Professor Maxine Bonham, Dr Karen Smith, Mr Benjamin Meadley

List of approved documents:

Document Type	File Name	Date	Version
Explanatory Statement	Information_Sheet_HEMS_survey_metabolic	28/07/2018	1
Consent Form	consent-form-final_HEMS_baseline_Water	28/07/2018	1
Consent Form	consent-form-final_HEMS_baseline_treadmill	28/07/2018	1
Consent Form	consent-form-final_HEMS_baseline_metabolic	28/07/2018	1
Consent Form	consent-form_HEMS_survey	28/07/2018	1
Questionnaires / Surveys	Perceptions_of_cardiometabolic_health_in_HEMS_paramedics	28/07/2018	1
Supporting Documentation	transport of specimens	28/07/2018	1
Supporting Documentation	SECA_mBCA	28/07/2018	1
Supporting Documentation	collection of specimens	28/07/2018	1
Supporting Documentation	insert_cannula	28/07/2018	1
Supporting Documentation	Placement of an In-Dwelling Safety Cannula in a Vein	28/07/2018	1

Monash University Human Research Ethics Committee

Approval Certificate

This is to certify that the project below was considered by the Monash University Human Research Ethics Committee. The Committee was satisfied that the proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and has granted approval.

Project ID:	19051
Project Title:	Physiological characteristics of paramedics undertaking winch rescue in an Australian Helicopter Emergency Medical Service (HEMS) - Phase Four Physiological Testing of Task Performance
Chief Investigator:	Dr Kelly Bowles
Approval Date:	02/04/2019
Expiry Date:	02/04/2024

Terms of approval - failure to comply with the terms below is in breach of your approval and the *Australian Code for the Responsible Conduct of Research*.

1. The Chief Investigator is responsible for ensuring that permission letters are obtained, if relevant, before any data collection can occur at the specified organisation.
2. Approval is only valid whilst you hold a position at Monash University.
3. It is responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by MUHREC.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash letterhead and the Monash University complaints clause must include your project number.
6. Amendments to approved projects including changes to personnel must not commence without written approval from MUHREC.
7. Annual Report - continued approval of this project is dependent on the submission of an Annual Report.
8. Final Report - should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected completion date.
9. Monitoring - project may be subject to an audit or any other form of monitoring by MUHREC at any time.
10. Retention and storage of data - The Chief Investigator is responsible for the storage and retention of the original data pertaining to the project for a minimum period of five years.

Kind Regards,

Professor Nip Thomson

Chair, MUHREC

CC: Dr Joanne Caldwell Odgers, Assoc Professor Maxine Bonham, Dr Luke Perraton, Dr Karen Smith, Ms Megan Jepson, Ella Horton, Mr Benjamin Meadley

List of approved documents:

Document Type	File Name	Date	Version
Supporting Documentation	HEMS_Email_Invite_Task Performance	06/03/2019	1
Consent Form	HEMS_Task_Consent_water	06/03/2019	1
Consent Form	HEMS_Task_Consent_land	06/03/2019	1
Supporting Documentation	research_proposal_HEMS_task_performance	06/03/2019	1
Explanatory Statement	HEMS_Task_Information_participants_land V2	29/03/2019	V2
Explanatory Statement	HEMS_Task_Information_Participants_Water V2	29/03/2019	V2

Appendix C - Ambulance Research Committee Approvals

AmbulanceVictoria

375 Manningham Road
Doncaster VIC 3108
PO Box 2000 Doncaster VIC 3108
T 03 9840 3500
ABN 50 373 327 705 004

1 AUGUST 2018

Ben Meadley and Alexander Wolkow

Building 1, 270 Ferntree Gully Rd

NOTTING HILL VIC 3168

Dear Ben Meadley & Alexander Wolkow

Re: Research Proposal: "Sleep and Health in Ambulance Paramedic Employees and Students (SHAPES)" dated 18/07/2018

I am pleased to inform you that Ambulance Victoria (AV) has approved participation in the above study, subject to:

- Receipt of HREC approval
- Return of Confidentiality Deed

The researchers will need to sign a confidentiality agreement (attached) and return via email to the AV Research Governance Manager prior to obtaining any AV data.

Note, that any changes to the original application will require submission of a protocol amendment to the AV Research Committee for consideration. Please ensure that AV is informed of any protocol changes as soon as possible.

As a component of the ongoing communication processes, AV requires annual progress reports and a final report on completion of the study. You will be emailed the progress report approximately four weeks prior to the due date. Progress reports are required to be submitted by email.

We look forward to working with you on this important project.

Yours sincerely

[redacted]

Steve Bernard
Medical Director
Ambulance Victoria

Document: FOR/FCS/065 v5.0 Approved: 6th April 2016
TRIM Ref: FOR/FCS/065

ambulance.vic.gov.au

AmbulanceVictoria

375 Manningham Road
Doncaster VIC 3108
PO Box 2000 Doncaster VIC 3108
T 03 9840 3500
ABN 50 373 327 705 004

2 NOVEMEBER 2018

Benjamin Meadley

[redacted]

Dear Benjamin Meadley

Re: Research Proposal: "Physical Activity and Sleep Monitoring in Ambulance Paramedics" dated 26/10/2018

I am pleased to inform you that Ambulance Victoria (AV) has approved participation in the above study, subject to:

- Receipt of HREC approval
- Return of Confidentiality Deed

The researchers will need to sign a confidentiality agreement (attached) and return via email to the AV Research Governance Manager prior to obtaining any AV data.

Note, that any changes to the original application will require submission of a protocol amendment to the AV Research Committee for consideration. Please ensure that AV is informed of any protocol changes as soon as possible.

As a component of the ongoing communication processes, AV requires annual progress reports and a final report on completion of the study. You will be emailed the progress report approximately four weeks prior to the due date. Progress reports are required to be submitted by email.

We look forward to working with you on this important project.

Yours sincerely

[redacted]

Prof STEVE BERNARD
Medical Director
Ambulance Victoria

375 Manningham Road
Doncaster VIC 3108
PO Box 2000 Doncaster VIC 3108
T 03 9840 3500
ABN 50 373 327 705 004

31 MAY 2018

File Ref: FOL/18/2802

Ben Meadley

[redacted]

Dear Ben Meadley,

Re: Research Proposal: "Physiological requirements of paramedics undertaking winch rescue in an Australian Helicopter Emergency Medical Service (HEMS)" dated 23/05/2018

I am pleased to inform you that Ambulance Victoria (AV) has approved participation in the above study, subject to:

- Receipt of HREC approval
- Return of Confidentiality Deed

The researchers will need to sign a confidentiality agreement (attached) and return via email to the AV Research Governance Manager prior to obtaining any AV data.

Note, that any changes to the original application will require submission of a protocol amendment to the AV Research Committee for consideration. Please ensure that AV is informed of any protocol changes as soon as possible.

As a component of the ongoing communication processes, AV requires annual progress reports and a final report on completion of the study. You will be emailed the progress report approximately four weeks prior to the due date. Progress reports are required to be submitted by email.

We look forward to working with you on this important project.

Yours sincerely

[redacted]

DR KAREN SMITH
Manager Research and Evaluation
Ambulance Victoria

Appendix D - Exercise and Sports Science Australia Adult Pre-Exercise Screening Tool

ADULT PRE-EXERCISE SCREENING TOOL

Name: ______________________________

Date of Birth: ____________________ Male ☐ Female ☐ Date: ____________________

STAGE 1 (COMPULSORY)

AIM: to identify those individuals with a known disease, or signs or symptoms of disease, who may be at a higher risk of an adverse event during physical activity/exercise. This stage is self administered and self evaluated.

Please circle response

1.	Has your doctor ever told you that you have a heart condition or have you ever suffered a stroke?	Yes	No
2.	Do you ever experience unexplained pains in your chest at rest or during physical activity/exercise?	Yes	No
3.	Do you ever feel faint or have spells of dizziness during physical activity/exercise that causes you to lose balance?	Yes	No
4.	Have you had an asthma attack requiring immediate medical attention at any time over the last 12 months?	Yes	No
5.	If you have diabetes (type I or type II) have you had trouble controlling your blood glucose in the last 3 months?	Yes	No
6.	Do you have any diagnosed muscle, bone or joint problems that you have been told could be made worse by participating in physical activity/exercise?	Yes	No
7.	Do you have any other medical condition(s) that may make it dangerous for you to participate in physical activity/exercise?	Yes	No

IF YOU ANSWERED 'YES' to any of the 7 questions, please seek guidance from your GP or appropriate allied health professional prior to undertaking physical activity/exercise

IF YOU ANSWERED 'NO' to all of the 7 questions, and you have no other concerns about your health, you may proceed to undertake light-moderate intensity physical activity/exercise

I believe that to the best of my knowledge, all of the information I have supplied within this tool is correct.

Signature ______________________ Date ______________

ESSA EXERCISE & SPORTS SCIENCE AUSTRALIA — Fitness Australia THE HEALTH & FITNESS INDUSTRY ASSOCIATION — SPORTS MEDICINE AUSTRALIA

EXERCISE INTENSITY GUIDELINES

INTENSITY CATEGORY	HEART RATE MEASURES	PERCEIVED EXERTION MEASURES	DESCRIPTIVE MEASURES
SEDENTARY	< 40% HRmax	Very, very light RPE# < 1	• Activities that usually involve sitting or lying and that have little additional movement and a low energy requirement
LIGHT	40 to <55% HRmax	Very light to light RPE# 1-2	• An aerobic activity that does not cause a noticeable change in breathing rate • An intensity that can be sustained for at least 60 minutes
MODERATE	55 to <70% HRmax	Moderate to somewhat hard RPE# 3-4	• An aerobic activity that is able to be conducted whilst maintaining a conversation uninterrupted • An intensity that may last between 30 and 60 minutes
VIGOROUS	70 to <90% HRmax	Hard RPE# 5-6	• An aerobic activity in which a conversation generally cannot be maintained uninterrupted • An intensity that may last up to about 30 minutes
HIGH	≥ 90% HRmax	Very hard RPE# ≥ 7	• An intensity that generally cannot be sustained for longer than about 10 minutes

= Borg's Rating of Perceived Exertion (RPE) scale, category scale 0-10

ADULT PRE-EXERCISE SCREENING TOOL

STAGE 2 (OPTIONAL)

Name: ______________________________

Date of Birth: ____________________ Date: ____________________

AIM: To identify those individuals with risk factors or other conditions to assist with appropriate exercise prescription. This stage is to be administered by a qualified exercise professional.

		RISK FACTORS
1. Age ______ Gender ______	≥ 45yrs Males or ≥ 55yrs Females +1 risk factor	
2. Family history of heart disease (eg: stroke, heart attack) Relative / Age / Relative / Age ☐ Father ___ ☐ Mother ___ ☐ Brother ___ ☐ Sister ___ ☐ Son ___ ☐ Daughter ___	If male < 55yrs = +1 risk factor If female < 65yrs = +1 risk factor Maximum of 1 risk factor for this question	
3. Do you smoke cigarettes on a daily or weekly basis or have you quit smoking in the last 6 months? Yes No If currently smoking, how many per day or week? ______	If yes, (smoke regularly or given up within the past 6 months) = +1 risk factor	
4. Describe your current physical activity/exercise levels: Sedentary ☐ Light ☐ Moderate ☐ Vigorous ☐ Frequency (sessions per week) ___ ___ ___ Duration (minutes per week) ___ ___ ___	If physical activity level < 150 min/ week = +1 risk factor If physical activity level ≥ 150 min/ week = -1 risk factor (vigorous physical activity/ exercise weighted x 2)	
5. Please state your height (cm) ______ weight (kg) ______	BMI = ______________ BMI ≥ 30 kg/m^2 = +1 risk factor	
6. Have you been told that you have high blood pressure? Yes No	If yes, = +1 risk factor	
7. Have you been told that you have high cholesterol? Yes No	If yes, = +1 risk factor	
8. Have you been told that you have high blood sugar? Yes No	If yes, = +1 risk factor	

Note: Refer over page for risk stratification.

STAGE 2 Total Risk Factors = ______

9. Have you spent time in hospital (including day admission) for any medical condition/illness/injury during the last 12 months? Yes No	If yes, provide details
10. Are you currently taking a prescribed medication(s) for any medical conditions(s)? Yes No	If yes, what is the medical condition(s)?
11. Are you pregnant or have you given birth within the last 12 months? Yes No	If yes, provide details. I am ______ months pregnant or postnatal (circle).
12. Do you have any muscle, bone or joint pain or soreness that is made worse by particular types of activity? Yes No	If yes, provide details

STAGE 3 (OPTIONAL)

AIM: To obtain pre-exercise baseline measurements of other recognised cardiovascular and metabolic risk factors. This stage is to be administered by a qualified exercise professional. (Measures 1, 2 & 3 – minimum qualification, Certificate III in Fitness; Measures 4 and 5 minimum level, Exercise Physiologist*).

	RESULTS		RISK FACTORS
1. BMI (kg/m²)		BMI ≥ 30 kg/m² = +1 risk factor	
2. Waist girth (cm)		Waist > 94 cm for men and > 80 cm for women = +1 risk factor	
3. Resting BP (mmHg)		SBP ≥140 mmHg or DBP ≥90 mmHg = +1 risk factor	
4. Fasting lipid profile*		Total cholesterol ≥ 5.20 mmol/L = +1 risk factor	
Total cholesterol		HDL cholesterol >1.55 mmol/L = -1 risk factor	
HDL		HDL cholesterol < 1.00 mmol/L = +1 risk factor	
Triglycerides		Triglycerides ≥ 1.70 mmol/L = +1 risk factor	
LDL		LDL cholesterol ≥ 3.40 mmol/L = +1 risk factor	
5 Fasting blood glucose*		Fasting glucose ≥ 5.50 mmol = +1 risk factor	
		STAGE 3 Total Risk Factors =	

RISK STRATIFICATION

Total stage 2
or
Total stage 3
Plus stage 2 (Q1 - Q4)

≥ 2 RISK FACTORS – MODERATE RISK CLIENTS
Individuals at moderate risk may participate in aerobic physical activity/exercise at a light or moderate intensity (Refer to the exercise intensity table on page 2)

< 2 RISK FACTORS – LOW RISK CLIENTS
Individuals at low risk may participate in aerobic physical activity/exercise up to a vigorous or high intensity (Refer to the exercise intensity table on page 2)

Note: If stage 3 is completed, identified risk factors from stage 2 (Q1-4) and stage 3 should be combined to indicate risk. If there are extreme or multiple risk factors, the exercise professional should use professional judgement to decide whether further medical advice is required.

Appendix E - Example Participant Information Statement and Example Consent Form

MONASH University

Please print a copy of this information for future reference.

Participant Information Statement

Project title:

Physiological characteristics of paramedics undertaking search and rescue in an Australian Helicopter Emergency Medical Service (HEMS) – Phase Four. Physiological Testing of Task Performance

Principal Researcher and PhD student:

Mr. Ben Meadley
T: 0418 395 209

Primary Supervisor:

Dr. Kelly-Ann Bowles
T: 03 9904 4176

Co Supervisors:

Dr Joanne Caldwell-Odgers (Specialist Investigator)
T: 03 9905 4688

Prof. Karen Smith
T: 03 9896 6083

A/Prof. Maxine Bonham
T: 03 9902 4272

Dr. Luke Perraton
T: 03 9904 4289

The aims of this study are:

- Collect physiological data whilst MICA Flight Paramedics complete the defined tasks as determined in earlier research.
- Compare this physiological data to baseline data collected in your baseline assessments

This **anonymous and voluntary** study is part of a PhD research project being undertaken by Mr. Ben Meadley.

Who is eligible to participate in the study?

Qualified Intensive Care (MICA) Flight Paramedics who have completed baseline testing

What are we asking you to do?

As a frontline MICA Flight Paramedic performing winch access and search and rescue in the HEMS environment, we are inviting you to participate in two tasks. The tests, locations and anticipated time commitments are detailed below:

Investigation	Location	Time Commitment
Land winch task performance	Churchill National Park	1 hour

You will be required to arrange your own transport to the study sites (located at Churchill National Park) which is likely to incur a cost to you.

The specific investigations and actions you will be required to undertake are:

Day of testing: (Approximately 1 hou)

Attend Churchill National Park and perform the following task:

Don the MICA Flight Paramedic overland rescue personal protective equipment, and with the specified role equipment, reconfigure for carriage, and then walk, at least 250 metres over uneven, steep terrain, whilst navigating any obstacles. Once reaching the patient, recover, provide basic clinical care, then secure the patient in the winch stretcher. Relocate the patient to a safe position and recover to the aircraft

- Your heart rate and GPS position will be monitored during the simulation.
- Your capillary lactate will be sampled at the start, end of walk, end of simulation and 3 minutes post completion. This is a small blood sample from your earlobe.
- Your expired air will be sampled at the during the task.
- You will be shown a chart to rate your level of exertion at the start, midpoint, end of walk and end of the simulation.
- You will be filmed to ensure consistency of task performance. Footage will be deleted once confirmation of task performance is verified between participants

How will this benefit me?

We cannot guarantee that you will receive any individual benefits from this research. However, you will be providing expert input regarding your experience in HEMS search and research. This information will be used to develop a series of tests to quantify the physiological demands of your role. This study is being conducted to increase the health, safety and welfare of you and your patients.

How will this information be used?

The data will be used to identify the actual physical requirements of HEMS Search and rescue/winch rescue. From this, a series of tests will be developed to quantify the physiological demands of your role.

A larger study will commence after analysis of this data is complete. You may have the opportunity to participate in the larger study if you volunteer. It is anticipated that the results of the study will be reported at a conference and/or in a scientific peer-reviewed journal.

How will my privacy and confidentiality be maintained?

Confidentiality will be maintained **at all times,** as all data will be anonymous. We will not analyse or report data at a level that would enable you to be identified. Video and/or audio files will be stored on secure Monash University servers. Only the researchers will have access to the raw data.

After the research is completed and published all electronic data collected from the study will be deposited onto an online Monash University data repository called LabArchives, in accordance with NHMRC guidelines.

Availability of the results of the study

A report summarising the results from the study will be made available to you after the study has been completed. It is also anticipated that the results of the survey will be reported at a conference and/or in scientific peer-reviewed journals.

Can I withdraw my consent from the study?

Participation is completely voluntary and you are free to decline to participate. You are also free to withdraw from the study at any time once the study has commenced. As we have no personal identifying information within the data, it may not be possible to remove your data once the study is completed. Your informed consent will be requested once you volunteer for the study; you will be asked to complete informed consent forms. Should you have any queries about this survey please feel free to contact one of the researchers.

Funding

This study is partially funded by a grant from the Australian & New Zealand College of Paramedicine

Complaints?

Should you have any concerns or complaints about the conduct of the project, you are welcome to contact the Executive Officer, Monash University Human Research Ethics (MUHREC):

Executive Officer Monash University Human Research Ethics Committee (MUHREC)

Room 111, Building 3e, Research Office, Monash University, VIC 3800
Tel: +61 3 9905 2052
Email: muhrec@monash.edu
Fax: +61 3 9905 3831

MONASH University

CONSENT FORM

General consent form for blood sampling at Monash University.

Lead Physiologist: **Dr Joanne Caldwell-Odgers**
Primary investigator: **Mr Ben Meadley**

I have volunteered to take part in blood sampling at Monash University. I participate at my own free will and take full responsibility for my participation. I confirm I have read and/or have been informed and understood all the relevant test procedures. The nature, demands, and risks have been explained to me. I have had the opportunity to consider the information, ask questions regarding the testing procedures, and have had these answered satisfactorily by the test operator. I also confirm that all the relevant health and safety aspects of the test have been explained to me. I hereby consent to participate in the testing and acknowledge that I am free to withdraw from the test procedure at any time without giving a reason.

I consent to taking part in the following test procedures:	Yes	No
1. Assessment and recording of: a. Height b. Weight c. Waist: Height ratio d. Body composition analysis (SECA mBCA) e. Resting Blood Pressure f. Resting Heart Rate g. Resting 12-lead ECG (electrocardiogram)	☐	☐
2. Insertion of an intravenous needle or cannula for the withdrawal and storage of blood	☐	☐
3. Analysis of blood for the following: a. Fasting Blood Glucose b. Fasting Insulin c. C-Reactive Protein d. Lipid profile	☐	☐
I consent for the data collected during my participation in the testing at Monash University be used for teaching, education, and/or research purposes.	☐	☐

Name of Participant ____

Participant Signature ______________________________ Date ______________

Appendix F - Example data collection forms

MONASH University

Graduate Paramedic

PARTICIPANT DATA COLLECTION FORM

NAME: ____

AGE: ____

PHONE: ____

EMAIL (personal): ____

ASSIGNED REGION & Branch: ____

PREVIOUS FULL-TIME CAREER: ____

ALLERGIES: ____

MEDICATIONS: ____

MEDICAL CONDITIONS: ____

Graduate Paramedic
Baseline metabolic and physiological testing
Data Record – 12 month

Participant ID: ____________________

Initials: ____________________

Day: ____________________

Date: ____________________

Time: ____________________

Temp: ____________________

Humidity: ____________________

Measurement	**Result**
Age	years
DOB	
Sex	
Weight	kg
Height	metres
Resting HR	bpm
Waist circ	m
Blood Pressure	mmHg
BMI	kg/m2
REE	Kcal/d
TEE	Kcal/d
FFM	kg
FM	kg
%BF	%
Run VO_2max	$ml.kg^{-1}.min^{-1}$
Run VO_2max	$l.min^{-1}$
Max HR	
Max lactate	
Max RPE	

Blood taken @:____________________

Notes/issues: ____________________

Feed @: ____________________

Time feed-run: ____________________

Appendix G - RAND Short-form 36 Item Questionnaire (SF-36) for Health-Related Quality of Life

HEALTH

RAND > RAND Health > Surveys > RAND Medical Outcomes Study > 36-Item Short Form Survey (SF-36) >

36-Item Short Form Survey Instrument (SF-36)

RAND 36-Item Health Survey 1.0 Questionnaire Items

Choose one option for each questionnaire item.

1. In general, would you say your health is:

- 1 - Excellent
- 2 - Very good
- 3 - Good
- 4 - Fair
- 5 - Poor

2. **Compared to one year ago**, how would you rate your health in general **now**?

- 1 - Much better now than one year ago
- 2 - Somewhat better now than one year ago
- 3 - About the same
- 4 - Somewhat worse now than one year ago
- 5 - Much worse now than one year ago

The following items are about activities you might do during a typical day. Does **your health now limit you** in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
3. **Vigorous activities**, such as running, lifting heavy objects, participating in strenuous sports	1	2	3
4. **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
5. Lifting or carrying groceries	1	2	3
6. Climbing **several** flights of stairs	1	2	3
7. Climbing **one** flight of stairs	1	2	3
8. Bending, kneeling, or stooping	1	2	3
9. Walking **more than a mile**	1	2	3
10. Walking **several blocks**	1	2	3
11. Walking **one block**	1	2	3
12. Bathing or dressing yourself	1	2	3

During the **past 4 weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of your physical health**?

	Yes	No
13. Cut down the **amount of time** you spent on work or other activities	1	2
14. **Accomplished less** than you would like	1	2
15. Were limited in the **kind** of work or other activities	1	2
16. Had **difficulty** performing the work or other activities (for example, it took extra effort)	1	2

During the **past 4 weeks**, have you had any of the following problems with your work or other regular daily activities **as a result of any emotional problems** (such as feeling depressed or anxious)?

	Yes	No
17. Cut down the **amount of time** you spent on work or other activities	1	2
18. **Accomplished less** than you would like	1	2
19. Didn't do work or other activities as **carefully** as usual	1	2

---

20. During the **past 4 weeks**, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

- 1 - Not at all
- 2 - Slightly
- 3 - Moderately
- 4 - Quite a bit
- 5 - Extremely

---

21. How much **bodily** pain have you had during the **past 4 weeks**?

- 1 - None
- 2 - Very mild
- 3 - Mild
- 4 - Moderate
- 5 - Severe
- 6 - Very severe

---

22. During the **past 4 weeks**, how much did **pain** interfere with your normal work (including both work outside the home and housework)?

- 1 - Not at all
- 2 - A little bit
- 3 - Moderately
- 4 - Quite a bit
- 5 - Extremely

These questions are about how you feel and how things have been with you **during the past 4 weeks**. For each question, please give the one answer that comes closest to the way you have been feeling.

How much of the time during the **past 4 weeks**...

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
23. Did you feel full of pep?	1	2	3	4	5	6
24. Have you been a very nervous person?	1	2	3	4	5	6
25. Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
26. Have you felt calm and peaceful?	1	2	3	4	5	6
27. Did you have a lot of energy?	1	2	3	4	5	6
28. Have you felt downhearted and blue?	1	2	3	4	5	6
29. Did you feel worn out?	1	2	3	4	5	6
30. Have you been a happy person?	1	2	3	4	5	6
31. Did you feel tired?	1	2	3	4	5	6

32. During the **past 4 weeks**, how much of the time has **your physical health or emotional problems** interfered with your social activities (like visiting with friends, relatives, etc.)?

- 1 - All of the time
- 2 - Most of the time
- 3 - Some of the time
- 4 - A little of the time
- 5 - None of the time

How TRUE or FALSE is **each** of the following statements for you.

	Definitely true	Mostly true	Don't know	Mostly false	Definitely false
33. I seem to get sick a little easier than other people	1	2	3	4	5
34. I am as healthy as anybody I know	1	2	3	4	5
35. I expect my health to get worse	1	2	3	4	5
36. My health is excellent	1	2	3	4	5

Appendix H - Sample Australian Eating Survey Report

The Australian Eating Survey™

Your Dietary Analysis Report

[redacted]

Understanding how your food intake measures up to current Australian recommendations is an important step towards improving your eating habits. This report contains the results of your Australian Eating Survey™ that was completed on **27 February 2019**

The report compares your usual dietary intake to Australian dietary recommendations, which are based on the best available scientific evidence for nutrition and health. For more information on how your Australian Eating Survey™ report is generated, please refer to website (http://www.australianeatingsurvey.com.au)

Your report contains two sections. The first section has two parts:

a. Your overall energy intake and the contribution of specific food groups to your average daily energy intake. It details how much of your daily energy intake (kilojoules) usually comes from healthy food groups (core foods) compared to the amount coming from less healthy foods, also called discretionary choices.
b. Your Australian Recommended Food Score (ARFS). This is a measure of how much variety within each of the healthy food groups you usually have over a week. Your ARFS is a summary score of the overall healthiness and nutritional quality of your usual eating patterns.

This section helps to identify the food groups where your intake is close to recommendations. It also shows you which areas you can try to make improvements in, either by cutting back on the amount you eat, or increasing the number of serves, or increasing the variety.

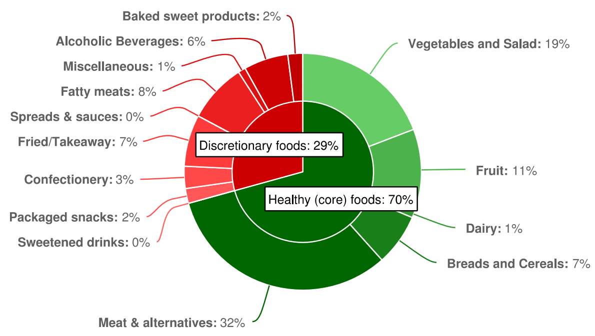
The second section gives detailed information about your nutrient intake based on the detailed analysis from your Australian Eating Survey™ responses. This includes how your macronutrient (protein, fat and carbohydrate) and micronutrient intakes (vitamins and minerals) compare with national recommended intake targets. This section also provides information on key food sources of these nutrients to help you improve your eating habits.

Important Notice*:
The information contained in this report is designed for general purposes only. It will not take into account any pre-existing medical conditions or other individual circumstances (such as use of vitamin and/or mineral supplements or any food sensitivities or allergies). As a result, it may not be a complete representation of your individual circumstances and should not replace the advice of your medical practitioner or an Accredited Practising Dietitian.

Your Daily Energy Intake is: **5797** **kJ/day**

What proportion of your food intake comes from healthy (core) foods?

Foods in your diet contributing to your energy intake



Due to rounding, the percentages from healthy (core) foods and discretionary foods may not add up to 100%.

This graph shows the contribution of the "healthy" and "discretionary" foods you eat as a proportion of your overall energy intake (kilojoules).

Ideal ratios:
Healthy (core) foods - aim for 85-90%
Discretionary foods - aim for a maximum of 10-15%

Healthy foods, also called "core" foods, are needed by your body every day to provide essential nutrients.

In this graph these foods have been split into five groups:

1. Vegetables
2. Fruit
3. Breads and cereals (breakfast cereals, breads, rice, noodles, pasta)
4. Milk, yogurt and cheese (including non-dairy sources)
5. Meat, chicken and fish, and meat alternatives (vegetarian choices), such as eggs, nuts, and seeds, legumes, beans.

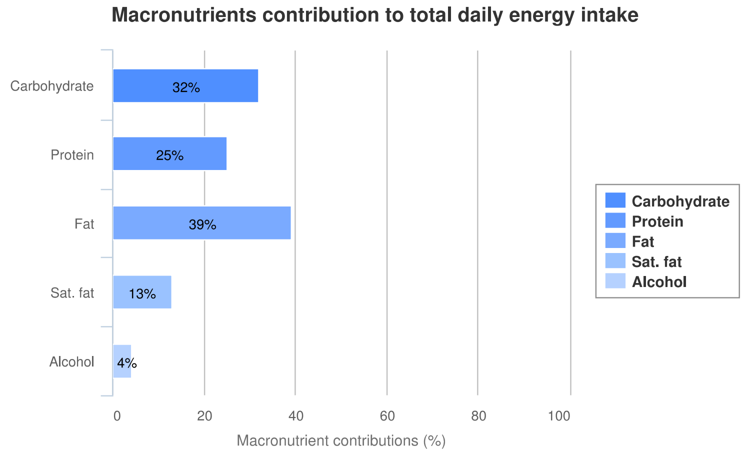
Most Australians need to eat larger portions and have more variety of vegetables and salad, smaller portions of meat and potato, and less discretionary food choices.

Discretionary foods are energy-dense, nutrient-poor foods and drinks. The recommendation is to consume them only occasionally and in small amounts. These are foods that may be enjoyable, but your body does not need them.

Most Australians need to eat less discretionary foods.

almonds. Food sources of polyunsaturated fat include oily fish (e.g. salmon, tuna, sardines), margarines and oils made from safflower, sunflower, corn or soy, and nuts such as walnuts and brazil nuts, and seeds.

How does your macronutrient intake compare to recommendations?*



Ideal intake ranges of macronutrients (as % of energy intake)*:

- Carbohydrate: 45-65%
- Protein: 15-25%
- Fat: 20-35%; Saturated fat plus Trans Fat: <10%
- Alcohol: less than 5%

This graph shows your intake of macronutrients as proportions of your total energy intake*. A food intake that has carbohydrate, protein and fat intakes within the ideal ranges helps you to meet your requirements for general health. An increase in one macronutrient often leads to a decrease in others. If your nutrient intake is high in carbohydrate it tends to be lower in fat (and vice versa). Intakes higher in protein tend to be lower in carbohydrate and/or fat.

If you choose to consume ***alcohol***, moderation is the key. Adult recommendations are for no more than two standard drinks per day. Children, adolescents (aged less than 18 years) and women who are pregnant, planning pregnancy or breastfeeding should not drink alcohol.

Micronutrients and Fibre

Micronutrients are the vitamins and minerals that your body requires. Although the exact micronutrient requirements will vary from person to person, recommendations are made based on age, gender and life stage (i.e. pregnancy or breastfeeding). These recommendations can be used to determine whether your current food intake contains sufficient amounts of these key micronutrients.

The Australian Recommended Food Score focuses on the variety of healthy core foods you usually eat. It takes a sub-set of foods from the Australian Eating Survey™ and calculates an overall diet quality score. Your ARFS score is made up from the scores from each food group category. Higher scores indicate healthier eating patterns and a dietary intake that is of higher nutritional quality.

Category *(maximum score)*	**Your score**
Vegetables *(21 points)*	**19**
Fruit *(12 points)*	**8**
Meat, chicken and fish *(7 points)*	**3**
Vegetarian** choices (eggs, legumes, nuts) *(6 points or 12 points**)* **If you are vegetarian you can double the points for this category.	**3**
Grains *(13 points)*	**2**
Dairy *(11 points)*	**2**
Condiments *(2 points)*	**0**
Water *(1 points)*	**1**
Overall *(73 points)*	**38**

Overall ARFS (out of 73)	**Rating**
<33	Needs work
33-38	Getting there
39-46	Excellent
47+	Outstanding

Your Nutrient Intake

This section summarises your nutrient intake analysis that has been calculated from the Australian Eating Survey™*. Your results have been compared to the Nutrient Reference Values for health developed by the National Health and Medical Research Council.

Macronutrients

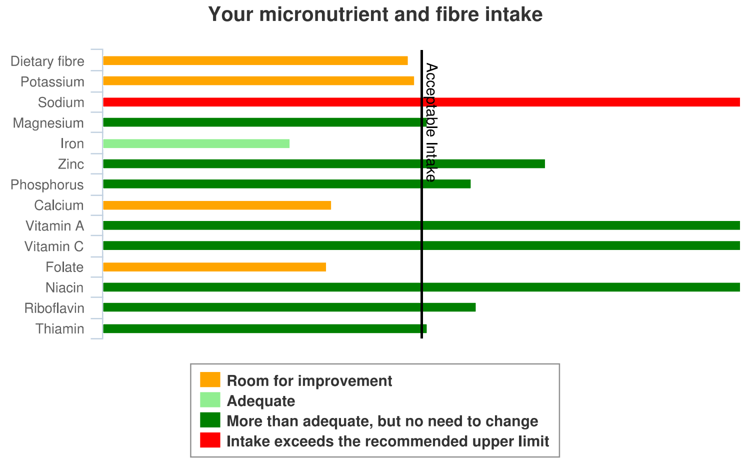
Protein, carbohydrate and fat are all macronutrients and contribute to your kilojoule intake (energy intake). While alcohol is not a nutrient required by the body, it does contain kilojoules and so it contributes to your energy intake.

Carbohydrate: Dietary sources of ***complex carbohydrates*** include grains and cereals (e.g. pasta, rice), breakfast cereals, breads, fruits, potato, corn and sweet potato, beans and lentils, dairy foods. Processed and refined carbohydrates are found in discretionary foods such as savoury snack foods (e.g. potato crisps, biscuits), some drinks (e.g. soft drink, fruit juice), confectionary and desserts.

Protein: Rich sources of ***protein*** include lean meats, chicken, fish, eggs, legumes (e.g. lentils, beans, soy), nuts, dairy products.

Fat: There are four types of ***fat***: saturated, trans, monounsaturated and polyunsaturated. Major sources of saturated and trans fats include fatty cuts of meat, full fat dairy foods, butter, cream, most commercially baked products (e.g. biscuits and pastries), most deep-fried fast foods, coconut and palm oil. Food sources of monounsaturated fats include margarine spreads (canola or olive oil-based), olive, canola and peanut oils, avocado, and nuts such as peanuts, hazelnuts, cashews and

How does your micronutrient and fibre intake measure up to recommendations?



The graph above shows your micronutrient and fibre intake* compared to the ideal intake range (i.e. Recommended Dietary Intake or Adequate Intake) for each nutrient.

For each nutrient on the graph above:

- An orange bar indicates that your usual intake for that nutrient is low and trying to eat more foods higher in this nutrient will help you reach the recommended intake.
- A light green bar indicates that your usual intake for that nutrient is in the target range but you could eat more foods that are high in this nutrient.
- A dark green bar indicates that your usual intake for that nutrient is adequate and there is no need to change.
- A red bar indicates that your usual intake for that nutrient is above the recommended limit and you should aim to cut back on foods high in this nutrient to avoid health problems. Not all nutrients have an upper limit.

Your intake of each micronutrient is shown in the table below.

Your micronutrient and fibre intake based on your usual eating patterns*:

Thiamin	**1.1** mg/day
Riboflavin	**1.3** mg/day
Niacin	**35.9** mg/day
Folate	**281.2** µg/day
Vitamin C	**204.1** mg/day
Vitamin A	**1618.5** µg/day
Calcium	**721.2** mg/day
Phosphorus	**1158.9** mg/day
Zinc	**11.1** mg/day

Iron	**10.6** mg/day
Magnesium	**325.9** mg/day
Sodium	**2032.4** mg/day
Potassium	**2744.3** mg/day
Fibre	**24.0** g/day

Please note: Your micronutrient analysis above does not include any vitamin and/or mineral supplements that you may currently take.

Do I need to take a vitamin and/or mineral supplement?

This will depend on your situation. The nutrient analysis provided above does not account for any vitamin and/or mineral supplements that you may be taking currently nor any pre-existing medical condition or allergies. The Australian Eating Survey™ is a validated tool for measuring dietary intake, but it asks you only about foods that are most commonly eaten in Australia.

If your analysis revealed your usual food intake is inadequate in one or more micronutrients, then try to increase your intake of foods that are good sources of those nutrients. If you need more help you could discuss the results from your Australian Eating Survey™ with your doctor or an Accredited Practising Dietitian before taking a supplement. Simple changes to the foods that you usually eat will improve your nutrient intakes. Sometimes a supplement is required and your dietitian or doctor can provide you with the appropriate advice.

How do I improve my intake of vitamins, minerals and fibre?

As a guide, you may need to consume more of the foods that are good sources of the micronutrients and fibre that have been flagged in orange and light green in your
those nutrient sources that appear in red. The table below contain
nutrients, including the key food sources.

I would like further advice on how to improve my diet, what should I do?

An Accredited Practising Dietitian is best placed to provide you with individualised dietary advice based on your Australian Eating Survey™ results. Click here to find a dietitian. (https://daa.asn.au/find-an-apd/)