Institution: University of Portsmouth		
Unit of Assessment: UoA24: Sport and Exercise Sciences, Leisure and Tourism		
Title of case study: Protecting workers in arduous occupations		
Period when the underpinning research was undertaken: 2003 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Martin Barwood	Senior Lecturer	01/09/2007 - 31/07/2013
Jo Corbett	Associate Head (Research)	19/09/2005 - date
Clare Eglin	Principal Lecturer	01/07/1998 - date
Jim House	Reader in Environmental Physiology	01/05/2008 - 22/11/2018
Mitch Lomax	Senior Lecturer	01/10/2007 - date
Gemma Milligan	Senior Lecturer	25/03/2008 - date
Michael Tipton	Professor of Human and Applied Physiology	01/04/1998 - date
Period when the claimed impact occurred: 01 August 2013 - 31 July 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Research from the University of Portsmouth (UoP) has improved the safety and protection of workers undertaking a range of arduous occupations, across terrestrial, aquatic and aerial environments. It has defined the requirements and evaluation process for a GBP250,000,000 next generation, load-carriage and body-armour system, that has improved the protection and fighting capability of the British Army. Where British soldiers have become injured operating in extreme hot or cold conditions, our research has improved their care through impacts on clinical practice and diagnosis accuracy. Our new approaches to defining occupational task demands and physical employment standards (PES) have changed the policies of defence, emergency service and third-sector groups, and informed UK Government flood rescue guidance. This has improved work-place equality, changed training, reduced injuries and increased safety. Our research has also underpinned international aviation-safety legislation, defined the European Standard for aviation-safety equipment, and changed training practices for workers flying offshore; this has protected more than 850,000 passengers in the oil and gas industry each year.

2. Underpinning research

The outputs underpinning this case study represent a body of applied research undertaken by the Individual, Organisational, and Occupational Performance and Extreme Environments Research Groups at UoP. They reflect longstanding relationships with a range of occupational groups, the unique facilities within the Extreme Environments Laboratory (fine environmental control; wind, rain and solar simulation; swimming flume and immersion facility), and our niche expertise in Occupational and Environmental Physiology.

Defence groups often operate in arduous conditions, including extremes of heat and cold. (**R1**) is a representative output from a collaborative research programme with the Defence Science and Technology Laboratory, as part of the UK Ministry of Defence's (MOD) Land Integrated Survivability Programme (**G1**). This study evidenced and quantified the trade-off between protection and physiological burden amongst infantry soldiers using the current body armour and load carriage systems, demonstrating that the extant system caused an inefficient breathing pattern, respiratory muscle fatigue and expiratory flow limitation during marching.

(**R2**), undertaken in conjunction with collaborators at the Institute of Naval Medicine (INM), examined the thermal and biochemical responses to a heat tolerance test of individuals susceptible to malignant hyperthermia, a potentially fatal condition. The research demonstrated that the heat tolerance test did not detect malignant hyperthermia susceptibility with high sensitivity. However, after the heat tolerance test, serum myoglobin was elevated in those with malignant hyperthermia, compared to control participants. These data suggested that serum myoglobin could be used as a novel biomarker to improve the detection of malignant hyperthermia.

Non-Freezing Cold Injury (NFCI) is a debilitating vascular and neurological condition caused by prolonged exposure to cold/wet environments. It is the most common non-combat injury among military personnel in cooler environments, with soldiers of African descent 30 times more likely to develop NFCI than Caucasian soldiers. (**R3**) demonstrated that individuals of African descent experienced a more intense and protracted finger vasoconstriction, and slower rewarming, than Caucasians following a standard thermal challenge. As well as providing a potential explanation for the ethnic differences in NFCI susceptibility, (**R3**) also demonstrated the utility of vascular measurements in assessing cooling and rewarming responses and highlighted that ethnic differences should be considered when defining the 'normal' response to a thermal challenge.

(**R4**, **R5**, **R6** and **R7**) are examples of our research defining job demands and designing, validating and implementing PES for a range of occupational groups. These evidence-based, objective standards were established using a framework developed by **Tipton** and **Milligan** (*Eur J Appl Physiol*. 2013; 113(10): 2435-2346) and ensure that employees can meet the physical demands of the job, irrespective of sex, race, age, or disability. (**R4**) details the development and implementation of a new PES for the RAF Regiment, the ground fighting force of the RAF, to ensure that Regiment members possess the necessary physical attributes for the role (**G2**). (**R5**) and (**R6**) detail research undertaken in collaboration with the RNLI, to develop and implement a task-related fitness test for beach lifeguards and lifeboat crew (**G3**). Flooding is now a significant annual threat to life and property; (**R7**), undertaken in collaboration with Surf Life Saving GB, examined the impacts of ambient air and water temperature, and work rate, on simulated flood rescue. The research demonstrated that, when wearing current flood rescue personal protective equipment (PPE), emergency responders could become incapacitated by peripheral cooling in cold conditions and by heat-related exhaustion in warmer conditions.

Finally, many workers are exposed to aerial environments, such as those who fly offshore within the oil and gas industry. If a helicopter ditches offshore, underwater escape may be required. However, breath-hold time is typically less than the time for egress. Emergency underwater breathing systems (EUBS) are devices increasing underwater survival time. (**R8**) extended Tipton's previous research developing the original EUBS for use in the oil and gas sector and was undertaken in collaboration with Coleshaw, a consultant for the UK Civil Aviation Authority, as part of the joint-industry Helicopter Safety Research Management Committee programme (**G4**). The research developed and tested a novel method for assessing the performance of different EUBS in a scenario representing the underwater escape from a helicopter in cold water and made recommendations for standardised procedures to assess EUBS efficacy in situations relevant for helicopter egress.

3. References to the research

3.1 Research outputs

R1. Armstrong, N. C. D., Ward, A., **Lomax, M.**, **Tipton, M. J.**, & **House, J. R.** (2019). Wearing body armour and backpack loads increase the likelihood of expiratory flow limitation and respiratory muscle fatigue during marching. *Ergonomics, 62*(9), 1181-1192. https://doi.org/10.1080/00140139.2019.1629638

R2. House, C. M., **Tipton, M. J.**, Hopkins, P. M., & Roiz de Sa, D. (2019). Thermoregulation and markers of muscle breakdown in malignant hyperthermia susceptible volunteers during an acute heat tolerance test. *Journal of Science and Medicine in Sport, 22*(5), 586-590. https://doi.org/10.1016/j.jsams.2018.11.012

R3. Maley, M. J., **Eglin, C. M.**, **House, J. R.**, & **Tipton, M. J**. (2014). The effect of ethnicity on the vascular responses to cold exposure of the extremities. *European Journal of Applied Physiology*, *114*(11), 369-2379. https://doi.org/10.1007/s00421-014-2962-2

R4. Treweek, A. J., **Tipton, M. J.**, & **Milligan, G. S.** (2019). Development of a physical employment standard for a branch of the UK military. *Ergonomics*, *62*(12), 1572-1584. https://doi.org/10.1080/00140139.2019.1663271

R5. Reilly, T., Iggleden C., Gennser M., **Tipton, M.** (2006). Occupational fitness standards for beach lifeguards. Phase 2: the development of an easily administered fitness test. *Occupational Medicine, 56*(1)12-17. https://doi.org/10.1093/occmed/kqi168

R6. Reilly, T., & **Tipton, M.** (2005). Task-based standards for lifeboat crew: Avoiding ageism. *International Congress Series, 1280*, 219-223. https://doi.org/10.1016/j.ics.2005.02.078

R7. **Tipton, M. J.**, Abelairas-Gómez, C., Mayhew, A., & **Milligan, G. S.** (2020). The thermal demands of flood rescue and impacts on task performance. *Ergonomics, 63*(1), 109-118. https://doi.org/10.1080/00140139.2019.1683617

R8. **Barwood, M. J., Corbett, J.,** Coleshaw, S., Long, G., & **Tipton, M. J.** (2010). Performance of emergency underwater breathing systems in cool (25°C) and cold (12°C) water. *Aviation, Space, and Environmental Medicine, 81*(11), 1002-1007. https://doi.org/10.3357/ASEM.2831.2010

3.2 Evidence of the quality of the research

All outputs are original research studies employing appropriate design, techniques, analysis, and interpretation and are published in peer-reviewed journals relevant to the discipline. R2 and R4 are returned in REF2 with Output IDs 25158154 and 15799513, respectively.

3.3 Related grants

G1. **House J. R.** *Investigating the impact of the physical characteristics of PPE on physiological burden in future operating environments*. Funded by Defence Science and Technology Laboratory, 01/01/14 → 31/12/19 (GBP56,599)

G2. **Tipton, M. J.** & **Milligan, G. S.** *The development of a physical employment standard for the Royal Air Force and the influence of extreme environments on selection criteria.* Funded by the Royal Air Force, 05/09/16 → 04/03/20 (GBP49,777)

G3. **Tipton, M. J.** *Medical & Fitness standards for lifeboat crew*. Funded by the Royal National Lifeboat Institution, 2003 (GBP110,000)

G4. **Tipton, M. J.,** & **Barwood, M. J.** *Establishing a standard for helicopter emergency underwater breathing systems*. Funded by the Civil Aviation Authority, 01/08/08 → 31/12/08 (GBP10,000).

4. Details of the impact

Following criticisms of the size and weight of body armour used during British military operations in Afghanistan (2008 to 2012), the UK MOD established 'Virtus', a GBP250,000,000 Defence Equipment and Support procurement programme that aimed to bring a next generation of integrated infantry load-carriage and body-armour system into service. **Our research informed and impacted the design, specification and evaluation processes underpinning this programme**. (**R1**) provided the evidence underpinning the requirement for the new system to minimise breathing restriction, as well as the subsequent test and evaluation plan for this requirement. This directly resulted in the introduction of spirometry tests into the procurement process, to quantitatively assess the respiratory impairment imposed by any new body-armour (**S1**). This body of research also demonstrated the negative impact of poorly-fitting body-armour on soldier performance. Findings were presented to the Army, and Defence Equipment and Support in July 2016 and underpinned the policy that 'Virtus' should fit the entire user population, resulting in the decision to increase the number of available sizes of body-armour plate from one to five (**S1**). The impacts from this research contributed to the introduction into service in 2016 of a new, lighter, slimmer and more comfortable body armour and load-carriage system**. This system received a 96% positive rating from troops, compared to 62% for its predecessor, has improved the wearer's ability to perform a range of tasks, and has increased the fighting capability and protection of UK soldiers** (**S2**). Between 2016 and 2019, 52,000 sets of the new 'Virtus' body armour system were delivered (**S2**), with a further 42,000 sets due to be delivered by 2021.

[Text removed for publication]. In recognition of our NFCI research expertise, **Tipton** was invited to join the MOD Surgeon General's NFCI Research Steering Group, and **Eglin** and **Tipton** were invited to join the MOD's NFCI Independent Senior Advisory Committee. According to Dr Hollis (Clinical Lead for NFCI in Defence Medical Services; British Armed Forces), (**R2**) and our body of related research, disseminated through this group, has had '*untold value to military patients and the Armed Forces medical community in offering their knowledge to the development of our services… **documented progress and improvement in patient care has resulted***' (**S4**). The impacts of improved diagnostic accuracy and patient care are significant. Between 1 April 2011 and 31 March 2018, approximately 250 (including 4 higher tariff [more severe]) claims for NFCI were awarded per year under the UK's Armed Forces Compensation scheme. These awards totalled GBP11,527,400 with the majority to personnel of Black, Asian and Minority Ethnic descent. Since 2018, this has reduced to an average of 50 (0 higher tariff claims) claims per year (https://www.gov.uk/government/collections/armed-forces-compensation-scheme-statistics-index).

At the other end of the temperature spectrum, heat illness resulted in 137 hospital admissions of British soldiers between 2007 and 2015, and 3 deaths in 2013. Approximately 140 soldiers per year are referred to the INM's Heat Illness Clinic, to determine their fitness to return to duty following an episode of heat illness. (**R3**), identifying a novel biomarker (myoglobin) for the detection of malignant hyperthermia, directly **changed the Standard Operating Procedures of the Heat Illness Clinic** with the assessment of myoglobin now included in their heat tolerance testing protocol (**S5**). This change in clinical practice has improved the sensitivity of detection of individuals with malignant hyperthermia, a potentially fatal condition, and has **enabled the INM to identify a number of patients at increased risk of heat illness, who would previously have been passed as 'fit'.**

(**R4-6**) have changed the employment policies and practices of occupational groups operating on land and water. Prior to the British Government lifting the exclusion on females serving in ground close combat roles in September 2017, females were not able to join the RAF Regiment, whilst the existing 'fitness test' used by this branch of the UK armed forces was not based on the role demands. (**R4**) underpinned a new PES that was adopted by the RAF Regiment as an interim employment standard in October 2017. **This policy change ensured that all RAF Regiment members who met the PES were physically capable of safely undertaking their role and that the RAF Regiment was compliant with UK employment and equality legislation**. According to Squadron Leader Treweek, the introduction of the PES has *'…resulted in physical training being tailored specifically to the requirements of the role, thus optimising the training pipeline, increasing first time pass rates and reducing injuries. The project has benefitted 2000 RAF Regt personnel and importantly, the introduction of this PES has enabled female recruits, who meet the PES, to enter the RAF Regt for the first time*' (**S6**).

(**R5**) and (**R6**) directly underpin RNLI policies that have been in place throughout the census period. (**R5**) **underpins the PES used by the RNLI to ensure that their Beach lifeguards possess sufficient fitness to perform tasks critical to the role** (**S7**). In 2019 alone, this PES supported 1,700 RNLI lifeguards to safely aid 29,334 people and save 154 lives (**S7**). (**R6**) underpins a competency- based fitness standard for RNLI lifeboat crew that **ensures, through appropriate training, that the RNLI's 6,000 crewmembers are physically capable of safely undertaking their critical job tasks** (**S7**). (**R5**) has also had international impact. Lifeguard fitness standards supported by this research (Lifesaving Position Statement 07: Fitness Standards) are recommended by the International Life Saving Federation, which comprises more than 130 national life saving organisations across the world.

(**R7**) **underpinned changes to the policies, practice, equipment and training of Surf Life Saving GB's flood rescue response service**, a third-sector group who undertook over 250 rescues during the 2016 floods in Cumbria and York. As a direct consequence of our research, since January 2019, flood relief technicians have used additional PPE for protection in cold environments and PPE with additional ventilation for hot conditions. In addition, work:rest scheduling has been introduced on hot days to protect workers from becoming dangerously hot and dehydrated, and additional technician training has been introduced to increase awareness of hydration monitoring and personal welfare when operating in hot and cold conditions (**S8**). The dissemination of (**R6**) through the Science of Flood Rescue meeting held at UoP in November 2018 led to the **incorporation of this research into the UK Department for Environment, Food and Rural Affairs (DEFRA) Flood Rescue Concept of Operations (2019)**. This framework defines the national processes for flood rescue management and coordination, and now includes guidance on work:rest scheduling and the use of PPE, with the flexibility to layer up or down, depending on the task and environmental conditions (**S9**).

Offshore helicopter services transfer the majority of the UK's oil and gas industry workforce to and from offshore installations. Between 1976 and 2012, 31 people died from survivable water impacts in a helicopter, with the shortfall in cold-water breath-hold time, relative to helicopter egress time, implicated in this statistic. EUBS extend under water survival time to enable helicopter egress. (**R8**) provided the empirical evidence underpinning the first safety standard for EUBS (CAP 1034), which specifies that EUBS must be easily and rapidly deployable (less than 12s with a single hand) and able to meet the shortfall in breath-hold time for helicopter egress, even in cold water (**S10**). **This standard has now been adopted by the UK Civil Aviation Authority** (September 2014, (**S11**)), **the Irish Aviation Authority** (March 2016, (**S12**)), **and incorporated into European Standard (EN-4856)** in 2018. The benefits of this legislation are evidenced by Mark Swan (Director, Safety and Airspace Regulation, UK Civil Aviation Authority), who confirmed that it '*will contribute to lives being saved in the UK offshore industry in the years to come*' (**S11**). The reach of this legislation is pronounced; **EUBS that meet the new safety standard are mandatory for all helicopter occupants flying offshore over the UK Continental Shelf**. In the UK alone, there are approximately 850,000 offshore helicopter passengers each year within the oil and gas industry. **Everyone flying offshore must be trained to use EUBS meeting the safety standard**, with 57,000 people receiving this training in the 6-weeks prior to introduction of the UK regulations (**S11**).

In summary, original research from the UoP has: i) informed the design, specification and evaluation of a new body armour system; ii) improved the diagnosis and treatment of clinical conditions affecting workers in hot, or cold, environments; iii) defined new physical employment standards for a range of occupational groups; iv) changed occupational practices and operating procedures; and v) underpinned new UK and international aviation-safety standards and legislation. Together, these impacts have improved the protection, health, and safety of many thousands of workers across the world, undertaking a range of arduous, physically demanding roles, within defence, emergency services, the third-sector, and the oil and gas industry.

5. Sources to corroborate the impact

S1. Letter from [text removed for publication], Defence, Science and Technology Laboratory, 30/09/2019

S2. Fight Lighter VIRTUS infographic, Ministry of Defence https://des.mod.uk/what-we-do/army-procurement-support/virtus/ accessed 13/09/2019

S3. Email from [text removed for publication] to Professor Mike Tipton, University of Portsmouth, 11/06/2018

S4. Letter from Dr Sarah Hollis, Clinical Lead for Non Freezing Cold Injury in Defence Medical Services for the British Armed Forces, 12/02/2020

S5. Letter from Senior Medical Officer, Environmental Medicine and Sciences, Institute of Naval Medicine, 05/03/2020

S6. Letter from Squadron Leader James Treweek, SO2 Physical Training Research, RAF Regiment, 17/09/2020

S7. Letter from Lifeguard Manager, RNLI, 14/1/2021 and RNLI Beach Lifeguard fitness standards https://summerjobs.rnli.org/become-a-lifeguard/requirements-and-training accessed 05/11/20

S8. Letter from National Operations & Safety Manager, Surf Life Saving GB, 06/11/2020.

S9. Flood Rescue Concept of Operations, Department for Environment, Food and Rural Affairs, November, 2019, p55 & p59

S10. CAP 1034 Development of a technical standard for Emergency Breathing Systems, Civil Aviation Authority, May 2013

S11. CAP 1243 Safety review of offshore public transport helicopter operations in support of the exploitation of oil and gas, progress report, Civil Aviation Authority, January, 2015. Pg 4 & 9

S12. Irish Aviation Authority, Aeronautical Notice; O.74, Issue 3, 15/03/2016.