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The Journal of Search and Rescue (JSAR) is an open access peer-reviewed electronic journal for the collation and distribution of original scholarly material on search and rescue (SAR).

It is being supported by the in-kind work and contributions of the Editorial Board. There is still the need for a dedicated journal serving those with a direct interest in all disciplines of search and rescue including: rope rescue, water (flat, swift and marine), ice rescue, wilderness search and rescue, structural collapse rescue, trench collapse rescue, cave rescue, dive rescue, motor vehicle extrication, canine search, technical animal rescue, air rescue, search theory, search management, and mines rescue. JSAR exists to fulfil that need.

Article submissions from these and other SAR disciplines are welcome. Launching this journal on the internet offers a relatively cost-effective means of sharing this invaluable content. It affords the prompt publication of articles and the dissemination of information to those with an interest in SAR.

JSAR will provide a forum for the publication of original research, reviews and commentaries which will consolidate and expand the theoretical and professional basis of the area. The Journal is interested in theoretical, strategic, tactical, operational and technical matters.

Advertising within JSAR will be considered in the future to ensure sustainable funding is available to enhance and continue the work of the journal. The publication of an article in the Journal of Search and Rescue does not necessarily imply that JSAR or its Editorial Board accepts or endorses the views or opinions expressed in it.

Cover Image: SAR scientists prepare a drone experiment. Photograph by Derek Rust.

Volume 6, Issue 2, August 2023
Pages 76-142
ISSN 2230-5734

Contents

Volume 6, Issue 2, August 2023
Pages 76-142
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Editorial

This edition of The Journal of Search and Rescue marks the start of an exciting new partnership with the Institute of Civil Protection and Emergency Management (ICPEM).

The field of search and rescue is faced with ever-evolving challenges, ranging from natural disasters and technological emergencies to humanitarian crises, the complexity, scale and frequency of which are sadly increasing. Amidst this backdrop, search and rescue is not a task that can be accomplished in isolation. It will require partnership across multiple organizations. Combining resources, expertise, and skills will create the opportunity for more substantial impact – safer practices, more lives saved, more ability to help people in their moment of greatest need.

The field of Search and Rescue continues to develop. Recent years have seen increasing capabilities such as the usage of unmanned aerial vehicles (UAVs). We are also increasingly reaping the benefits of advances in the use of data analytics and artificial intelligence (AI) algorithms capable of processing vast amounts of information. Amidst developments like these, a multidisciplinary approach is essential. No single organisation is capable of harnessing this vast range of skills and expertise alone. Collaboration and partnership must be at the centre of future working.

The Journal of Search and Rescue and the Institute of Civil Protection and Emergency Management (ICPEM) are driven by a shared vision: seeking to enhance knowledge, foster innovation, and promote excellence in the realm of search and rescue operations.

The collaboration between our two organisations creates exciting opportunities to bring together practical knowledge and scholarly exchange, facilitating the translation of cutting-edge ideas into actionable, on the ground strategies. The Journal of Search and Rescue offers a dynamic platform for the exploration of ideas, while the membership of ICPEM brings a wealth of practical knowledge and experience. The Journal will continue to provide a platform for researchers, practitioners and experts to share their findings, experiences, and innovative approaches, whilst the ICPEM community can then offer a vibrant community of learning and growth to foster these advances.

While research and theoretical frameworks are crucial, the ultimate measure of success lies in their practical application and real-world impact. The collaboration between the Journal and the Institute emphasizes the significance of bridging the gap between theory and practice. By promoting research with direct relevance to the field, we can generate evidence-based insights and practical solutions that improve the effectiveness, efficiency, and safety of search and rescue operations.

In joining forces, the Journal of Search and Rescue and the Institute of Civil Protection and Emergency Management are embarking on a transformative journey. Together, we can make a lasting impact and contribute to the continuous improvement of search and rescue practices, so that when disaster hits, we are ready.

Frank Long

General Secretary Institute of Civil Protection and Emergency Management, UK

A Truncated Sweep Width Exercise: Obtaining Search Planning Data More Quickly and Comparing Sweep Width Values in Subjectively Similar Environments in Ohio and Pennsylvania

Kenneth B. Chiacchia, PhD[1]

Donald A. Scelza, MS[2,3]

[1]Mountaineer Area Rescue Group, Appalachian Search and Rescue Conference, Morgantown, W.V.. U.S.A.

[2]Pennsylvania Strike Team 1, Allegheny Mountain Rescue Group, Pittsburgh, Pa. Mountaineer Area Rescue Group

[3]Appalachian Search and Rescue Conference, Morgantown, W.V.U.S.A.

Email chiacchiakb@gmail.com

Abstract

While the effective sweep width (*W*) method appears to provide accurate, objective probability of detection (POD) for search planning, the need for an extensive library of locally relevant *W* values poses an obstacle to adoption. To investigate means for shortening such data acquisition, we conducted a roughly third-scale sweep width exercise in Bellview, Ohio, U.S.A., leveraging a more data-efficient means of deriving POD-validated *W*s previously described. We compared the results to previous *W*s obtained in a subjectively similar area in Wexford, Pennsylvania, finding that the sparsity of data in the smaller course sometimes results in poor fits. However, when good POD-curve fits can be derived, the *W* values for the similar areas appear to be statistically indistinguishable.

KEYWORDS: SAR, effective sweep width, probability of detection, search theory

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Introduction

The SAR community has made great strides in using lost-person behavior to prioritize which areas to search initially (Koester 2008). But our state-of-the-art lags in re-assessing search efforts in the minority of search incidents in which those initial high-priority areas have been searched without finding the search subject. In theory, the equation

1. POS = POD X POA

tells us that, to maximize our probability of success (POS, finding the subject), we should shift our efforts to new areas as the probability of area (POA, the probability that the subject is in a given area) of searched areas is knocked down by the probability of detection (POD, the probability that search efforts in that area would have found the subject if present there) of the search efforts we've already made (Charnes and Cooper 1958).

One problem with this approach is that asking search team leaders to estimate POD, the traditional means of acquiring that number, produces large errors, averaging about 25% and often larger than that (Koester et al. 2004). The effective sweep width method, pioneered by the military, promises to provide us with more accurate PODs (Koopman 1980, Koester et al. 2004). It provides us with a distance-scaled number, *W*, that describes how a detector (whether a human searcher, a dog team, a drone, or so forth) effectively sweeps a corridor as it moves through an area, detecting as many search objects outside of that corridor as it misses inside (Fig. 1, from Cooper DC et al. 2003).

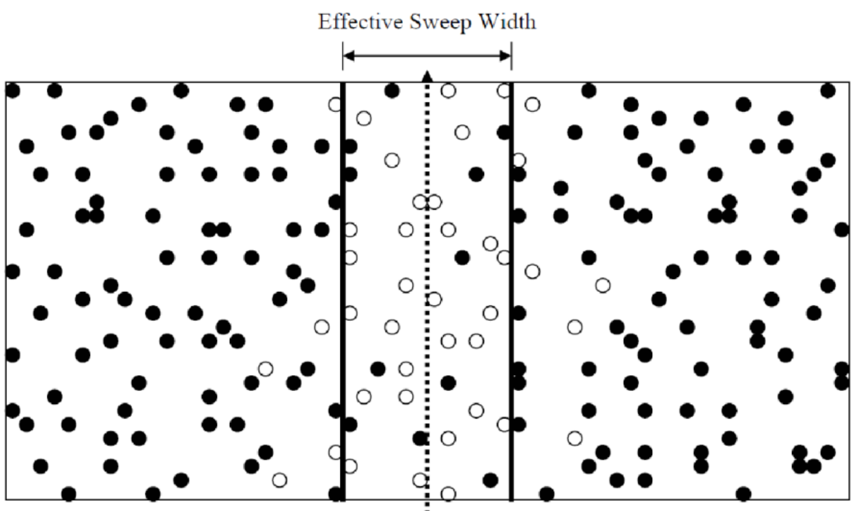


Figure 1: Illustration of a detector "sweeping a path" through a search area. Effective sweep width, or W, is the combined lateral distance to left and right of the detector's path at which misses (black circles) inside the envelope equal detections (open circles) outside.

Two obstacles arise in expanding the worldwide library of *W* values. The first is that it is not clear how sensitive *W* is to minor environmental differences. Broadly differing ecoregions certainly produce different *W* values for the same search object (Koester et al. 2004); so do seasonal differences in the same location (Chiacchia and Houlahan, 2010). But it is not clear if locales that *look* the same to a SAR-experienced observer have similar *W*s. Obviously, if this were true it would enable wider use of a more limited library.

Another obstacle is that sweep width exercises to determine local *W*s are staffing- and time-intensive to carry out. Using three to six workers and 18 to 25 searchers, we are able to set up, conduct, and tear down a sweep width course in four to five days. If it were possible to shorten that time, possibly by shortening the roughly 3,000-meter course length required for our previous sweep width exercises, it would also enable the *W* library to grow more quickly.

Koester et al. 2004 found that 100-200 detection opportunities (DOs, either detections or misses on a given search object) were necessary to obtain a stable *W* value. Recently, one of us reported a new means of deriving *W* that makes more efficient use of detection data, encouraging us to attempt a sweep width exercise at the lower end of this range (Chiacchia and Houlahan, 2023).

On June 11, 2022, we ran a roughly third-scale sweep-width exercise at Hidden Hollow Campground in Bellville, Ohio, to determine the *W* values there. The following report describes the results of that exercise, as well as comparisons with previous data from the subjectively similar State Game Lands 203 in Wexford, Pennsylvania (Chiacchia and Houlahan, 2010 and 2023).

Methods

We conducted the human visual sweep width experiments in the manner of Koester et al. 2004, with modifications previously described (Chiacchia and Houlahan 2010), using the IDEA Microsoft Excel worksheet provided by R. Koester and N. Guerra to automatically generate a randomized plan for a sweep- width course. We calibrated the courses with average maximum detection range (AMDR) values obtained in our earlier sweep width exercises in Wexford, Pa. (Chiacchia and Houlahan, 2010 and 2023). Note that we were able to do this partly because the POD-based derivation of *W* does not require a crossover point and thus is tolerant to inaccurate calibration (Koester et al. 2004, Chiacchia and Houlahan, 2023).

We placed the following search objects in the positions generated by the IDEA worksheet, using the methods of Koester et al. 2004:

- Seven high-visibility adult mannequins: white Tyvek suits, stuffed with packing boxes to give them roughly the same cross-section as a prone human, wearing blaze orange safety vests. Note that three placements generated by the worksheet were not visible from the course due to vegetation or terrain, enabling us to place these mannequins at shorter distances, counting the original random placements as zero-detection “virtual placements” (Koester et al. 2004), for a total of 10 placements for these search objects.
- Seven low-visibility adult mannequins: the same Tyvek suits, spray-painted olive drab.
- Seven high-visibility clues: bright yellow work gloves obtained in bulk from Tractor Supply, Brentwood, TN, USA.

- Seven low-visibility clues: dark brown work gloves from Tractor Supply.

The resulting course was 1,050 m long, beginning at USNG coordinates 17T LE 78496 99590 and ending at 17T LE 78091 99220 (See Fig. 2). The first search object, a high-vis mannequin, was randomized to a position 19 m down-trail from the beginning of the course (though note the actual placement, obtained through a GPS fix, was somewhat farther along the course); the last, a high-vis clue, at 1,024 m. Positions of the placements were corrected via GPS when the uncertainty in the GPS fix (approx. 3 m) was half of the lateral distance from the course or smaller, and the DOs were scored via the map rather than the linear detection scoring log of Koester et al. 2004.

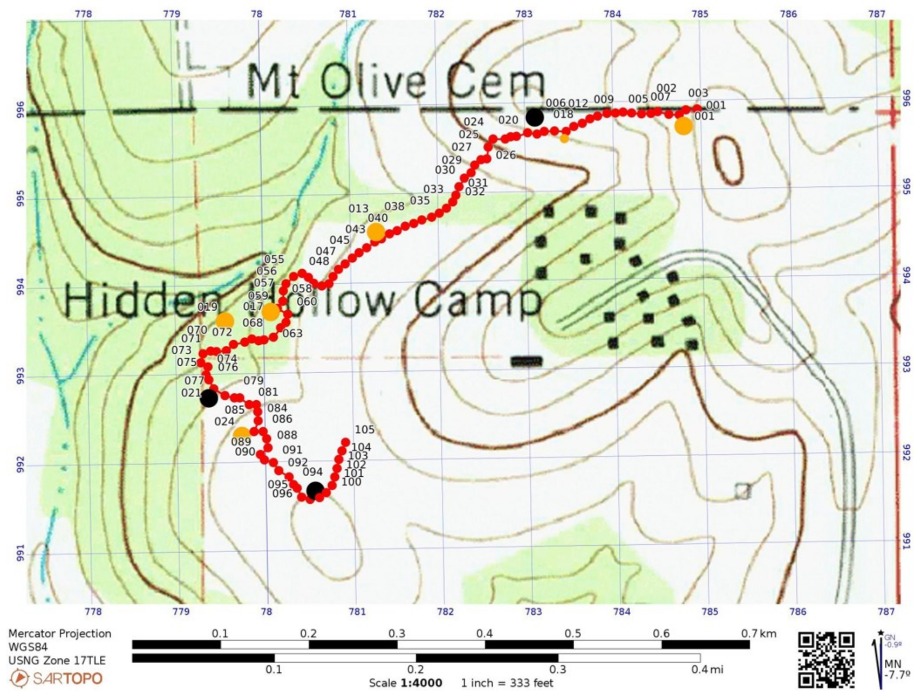


Figure 2: Hidden Hollow Camp sweep width exercise. Red dots show distance flags marking the course (distance down the course is 10X the number beside each flag position in meters); large orange dots are high-vis mannequins, small orange high-vis clues, and large black dots low-vis mannequins. Note that for clarity, search objects that were too close to the course to resolve on the map are not shown. Image generated with SARTopo (CalTopo LLC, Truckee CA, USA).

Fourteen members of the Ohio Special Response Team walked the course, accompanied by data loggers who helped them stay on the flagged course and recorded sightings or suspected sightings of clues (note false sightings were also recorded but by design did not affect the results). Of these, 13 produced usable logs, with one incomplete form that was difficult to score and so was disregarded. This produced 130 DOs for the high-vis mannequins and 91 each for the other search objects.

In keeping with our plans, the course took one day for the two authors to set up, half a day to conduct, and half a day to tear down, albeit the latter with help from the participants and Hidden Hollow Camp staff.

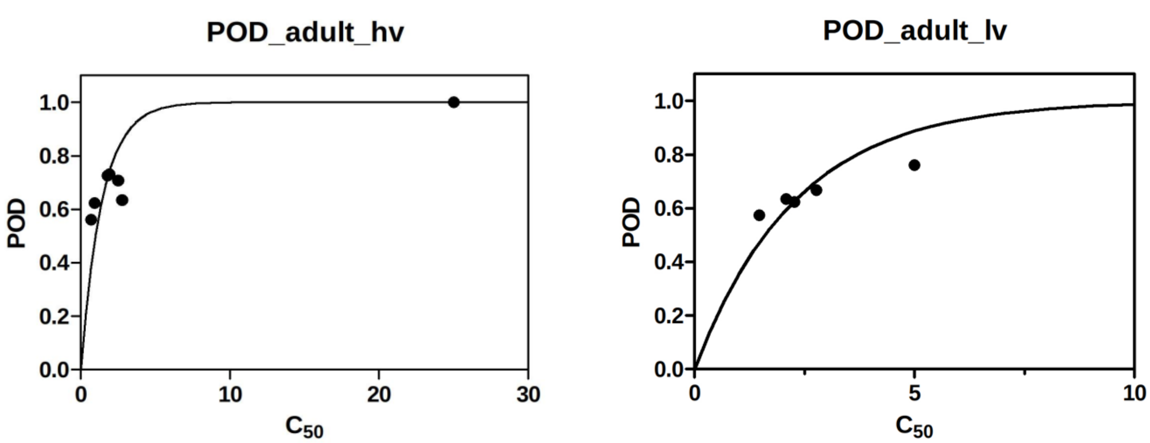
For each search object and as previously described (Chiacchia and Houlahan, 2023), we generated a curve that related PODs observed, cumulated from the marked course each searcher followed outward to C_{50} (coverage, where C = *W*/L, *W* = an arbitrary sweep-width value of 50 m, and L = lateral distance from the detector's path). By plotting the PODs against C_{50}, we obtained the true value of W from a least-square fit to POD versus C_{50} using the "random search model" equation:

2. $POD = 1 - e^{-(C_{50} W/50m)}$

Mapping was accomplished using a Garmin GPSMap 62sc GPS receiver (Garmin International, Olathe, KS, USA) and the SARTopo online mapping software (CalTopo LLC, Truckee CA, USA). For the least-square fit and subsequent analyses, we employed GraphPad Prism version 5.00 for Windows (GraphPad Software, San Diego, CA, USA, www.graphpad.com) to perform statistical testing. Data are expressed as mean±standard deviation (SD). All tests were two-tailed, with P<0.05 set as the threshold for statistical significance.

Results

For each search object, we generated a curve that related POD as measured in the field to C_{50} (Fig. 3).



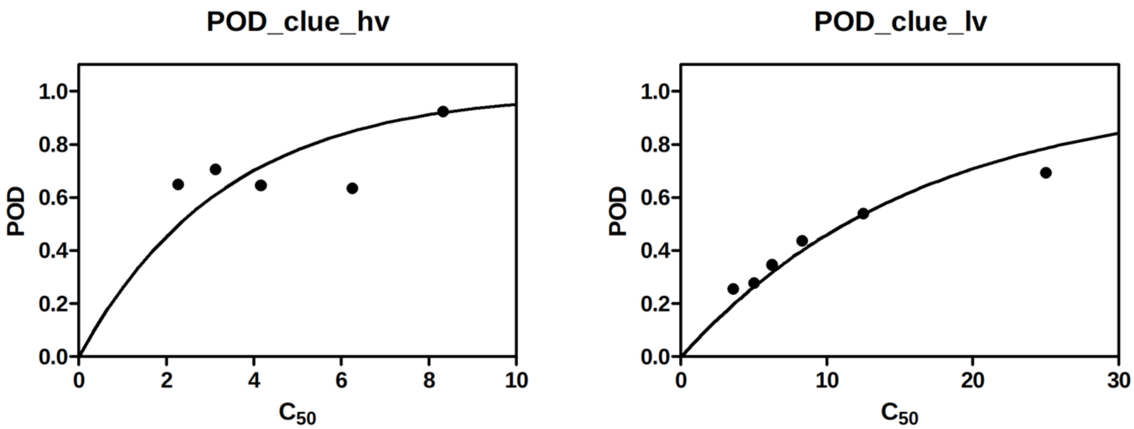


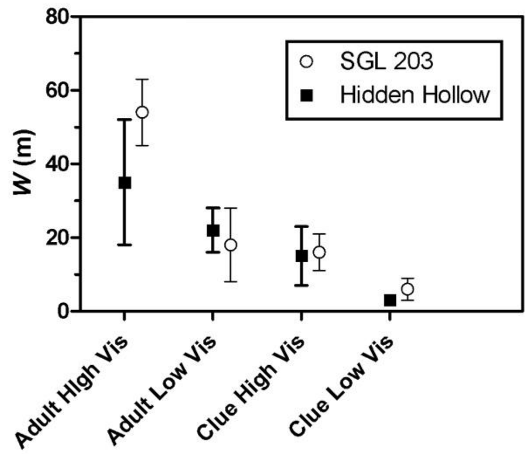
Figure 3: POD curves for each of the search objects. Note that some of the curves have fewer points than the total number of placements for each (10 for the high-vis mannequin, seven for the others) because of identical lateral distances for some of the placements.

The resulting *W* values of the least-square fit to equation 2 were:

Search object	*W* (meters)	R-square
High-vis adult	35±15	0.053
Low-vis adult	22±6	0.569
High-vis clue	15±7	-0.400
Low-vis clue	3±1	0.899

In setting up the exercise, it struck us that the terrain and vegetation were more than reminiscent of those at the Wexford, Pennsylvania, site. To investigate this subjective impression further, we conducted a two-way ANOVA of the Ohio data versus the earlier Pennsylvania summer data reported previously (Fig. 4, Chiacchia and Houlahan, 2010 and 2023).

Figure 4: ANOVA comparison of Ohio (Hidden Hollow) and previous Pennsylvania (State Game Lands 203) W



*values. ***=P<0.001; other comparisons no significant difference.*

The two-way ANOVA generated P<0.0001 for the row factor (corresponding to search objects), and P=0.027 for the column factor (locations). There was interaction between the two, with P=0.0015. A Bonferroni post-test comparing the results at Hidden Hollow and State Game Lands 203 for each search object showed P<0.001 for the adult high visibility mannequin, and P>0.05 for the other search objects. (The high-vis mannequin having a different *W* in the two locations, while the others did not, is the likely cause for the significant interaction P-value.)

Discussion

The shortened sweep width course produced what we believe to be usable numbers, though the high-vis search object data had an objectively poor fit to the curves. This is a risk in collecting relatively small data that should be kept in mind; our attempt to produce strong *W* values with a smaller course was a mixed bag in that regard.

Interestingly, except for those for the high-vis mannequin, none of the numbers from Hidden Hollow were significantly different from what we saw at State Game Lands 203. Our suspicion is that *W* values for the two sites — and, probably, the two regions — are essentially identical; certainly, the relatively good fits and lack of significant difference for the low-vis mannequin and clue would support this interpretation. Given the poor fits for the high-visibility search objects, neither the significant difference seen with the mannequin nor the non-significant difference seen with the clue can be interpreted in a straightforward manner.

Consider, in addition, the fact that the POD curve method often detects significant differences between *W* values that in turn result in minimal changes in PODs (Chiacchia and Houlahan 2023). In Fig. 5 we see the Ohio data for the high-vis mannequin, plotted with both the fit curve (solid line) and the curve that would have resulted with an identical *W* to the Pennsylvania data. Indeed, the POD differences are minimal, at most on the order of 10-15%. At the critical 50% POD point, where search efforts are likely to shift the POA for a given area in favor of other areas (Charnes and Cooper 1958), that difference is ~10%. Again, we favor the interpretation that the *W* values for the two sites are not different enough to be operationally significant.

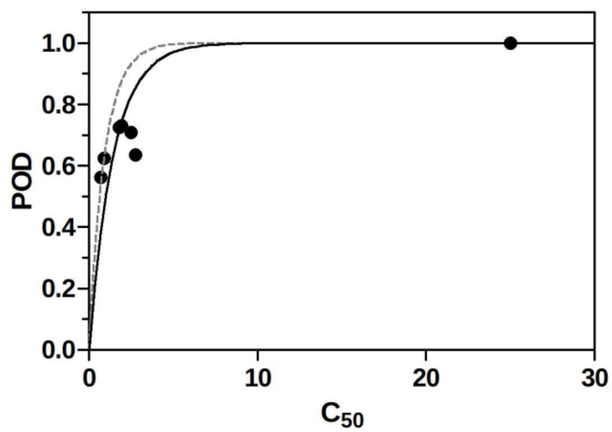


Figure 5: Comparison of Ohio (black solid line) and Pennsylvania (gray dashed line) random-search-model curves for the high-vis mannequins plotted against the Ohio data.

Limitations of the Current Study

The Pennsylvania full-vegetation data were acquired in the late summer, while the Ohio numbers were from the late spring. While there's a possibility of a seasonal difference here, we expect it will be minimal, as the woods in Hidden Hollow were clearly fully leafed out and thus similar to the summer conditions in Pa.

Another caveat to bear in mind is that we didn't collect enough data to separate the search objects placed in open (open field, woods with light undergrowth) versus thick (heavy-undergrowth woods, brush) vegetation. While the placement of the search objects along the course was random, the course itself was not, and so the *W* figures will depend on whether the mix of open and dense in the course is representative of the area.

It has been our experience that searchers have a kind of epiphany when they see their first mannequin. It isn't clear whether obtaining a search image in this way improves on their sweep width before that first detection, but as the randomization typically places at least one mannequin fairly early in the course, it should have a minimal effect. Nonetheless, the possibility exists that searchers improve while walking the first fraction of the course, and so a shorter course may be more affected by any such phenomenon than a longer one.

Conclusions

While the effective sweep width (*W*) method appears to provide accurate, objective probability of detection (POD) for search planning, the need for an extensive library of locally relevant *W* values poses an obstacle to adoption. To investigate means for shortening such data acquisition, we conducted a roughly third-scale sweep width exercise in Bellview, Ohio, USA, leveraging a more data-efficient means of deriving POD-validated *W*s previously described. We compared the results to previous *W*s obtained in a subjectively similar area in Wexford, Pennsylvania, finding that the sparsity of data in the smaller course sometimes results in poor fits. However, when good POD-curve fits can be derived, the *W* values for the similar areas appear to be statistically indistinguishable.

Acknowledgments

Thanks go to the Ohio Special Response Team, for hosting the sweep width exercise and for funding the consumables for setting up the course. The final development of the IDEA worksheet was supported by contract HSCG32-04-DR00005 from the U.S. Coast Guard. GraphPad Software donated its Prism software.

About the Authors

Kenneth B. Chiacchia has been an operational SAR dog handler since he first certified with Search Dogs Northeast of Antrim, NH, in 1992. He is currently a dog handler and search manager with Mountaineer Area Rescue Group (MARG), Morgantown, W.V., of the Appalachian Search and Rescue Conference, as well as a firefighter/EMT with Harmony Fire District in Butler County, Pa. He is also a lead evaluator and instructor in the National Association of Search and Rescue (NASAR) GSAR program and an evaluator with the Pennsylvania SAR Council air-scent dog testing program. Ken has responded to searches in Pennsylvania, West Virginia, Ohio, and elsewhere. A professional nonfiction and fiction writer, Ken trained originally as a biochemist. He is currently the senior science writer at the Pittsburgh Supercomputing Center.

Donald A. Scelza, EMT-P, is the task force leader and a medical specialist & rescue specialist in the Pennsylvania Strike Team 1 US&R team. A Fellow of the Appalachian Search and Rescue Conference, he is a search manager for Allegheny Mountain Rescue Group of Pittsburgh, Pa., and MARG. His business management experience includes management of small and large teams in the development of new products using advanced technologies. He has previously been chair of the Appalachian Search and Rescue Conference and president of Cranberry Township Emergency Medical Service, Pennsylvania.

Abbreviations

AMDR: Average maximum detection radius, the mean distance at which an observer cued to the location of an object can see it.

C: Coverage, the ratio of effective sweep width times the path length of a detector within an area to its size.

C_{50}: Coverage assuming an effective sweep width of 50m.

DO: Detection opportunity, a detection or miss of a search object at a right angle (lateral) to the detector's path.

POA: Probability of area, the estimated probability that a search object is contained within a given area.

POD: Probability of detection, the probability that a given detector will detect a given search object within an area under certain environmental conditions, assuming that object is in the area.

POS: Probability of success, the probability that a given search effort will detect a search object within a given area being searched (a "segment"). Equal to POA X POD.

W: Effective sweep width, a distance-denominated term defining the envelope within which a given detector's number of misses on a search object equals the number of detections outside, under specific environmental conditions.

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A Pilot Program Evaluation for a Backcountry Search and Rescue Stress Injury Awareness Course

William Mundo MD, MPH [1], **Zachary Ryan** MS[2], **Paul Cook** PhD[3], & **Laura McGladrey** PMHNP, FAWM[4]

[1]Department of Emergency Medicine, Denver Health Medical Center, Denver, CO, USA

[2]Eldora Ski Patrol, Eldora Mountain Resort, Nederland, CO, USA

[3]College of Nursing, University of Colorado Anschutz Medical Campus, Aurora, CO, USA

Email: william.mundo@cuanschutz.edu

Abstract

- This project was designed to evaluate the effectiveness of a stress awareness pilot program in reducing stress and burnout among Backcountry search and rescue (BSAR) volunteers. BSAR volunteers in Colorado experience taxing work demands with routine exposures to stressors. There are limited interventions available for preventing and reducing burnout among BSAR volunteers. We conducted a program evaluation using secondary data from a Wellness and Stress Awareness Pilot course conducted between July 2021 and December 2021. The survey included 65 questions to assess participants' understanding of stress injuries and level of stress and burnout across Colorado BSAR groups including the Southern Rocky Mountains, Colorado Plateau, and Middle Rocky Mountains. BSAR volunteers reported increased capacity to cope with stress after participating in the program, improving on all target learning objectives ($P < .001$). The percentage of BSAR volunteers who rated their current level of burnout as either high or very high dropped from 27% to 20% after participation in the course. Wellness and stress prevention programs may help raise awareness about chronic stress and reduce burnout among BSAR volunteers. These programs are needed to identify and prevent burnout and stress injuries among the BSAR community.

KEY WORDS: *mental health, burnout, operational stress injury, PTSD, Acute Stress Disorder, stress continuum*

Introduction

Preventing burnout and dealing with stress have increasingly been topics of interest for first-responders, clinicians, and allied health professionals due to the direct impact of burnout on health and work productivity. Backcountry search and rescue (BSAR) volunteers are exposed to traumatic events and scenes in their work, leading to increased risk of adverse mental health outcomes and burnout and stress injuries (Berger et al., 2012; Greinacher, Derezza-Greeven, Herzog, & Nikendei, 2019; Palgi, Ben-Ezra, Essar, Sofer, & Haber, 2009; van der Velden, van Loon, Benight, & Eckhardt, 2012). Stress injuries have been described as a broad range of psychological conditions resulting from duties performed that interfere with a person's professional and personal life (Antony et al., 2020). Although stress injuries are not a mental health diagnosis, they may be risk factors or precursors to the development of anxiety, depression, post traumatic stress, and substance use disorders.

Stress injuries and burnout are particularly important risk factors among first responder and BSAR groups that are vulnerable to chronic and traumatic stress. There is evidence that mental health conditions are significantly higher among first responders than in the general population (Berger et al., 2012; Dominguez-Gomez & Rutledge, 2009; Firew et al., 2020; Ratrout & Hamdan-Mansour, 2020; Shah, Garland, & Katz, 2007; Ward, Lombard, & Gwebushe, 2006). As a group, first responders are at higher risk than the general population for experiencing traumatic events, including life-threatening situations, grave injuries, and secondary trauma from deaths of colleagues and civilians. They experience taxing work demands with routine traumatic exposures to stressors that have been linked to the development of new mental health conditions or exacerbation of pre-existing conditions (Berger et al., 2012; Firew et al., 2020; Forman-Hoffman et al., 2016; Kshtriya, Kobezak, Popok, Lawrence, & Lowe, 2020; Palgi et al., 2009; Soffer, Wolf, & Ben-Ezra, 2011; Ward et al., 2006).

The literature is limited on stress injury awareness and prevention amongst austere first responders such as BSAR volunteers. The impact of stress and burnout is gaining recognition in the first responder community due to its implications for well-being and work productivity (Berger et al., 2012; Cieslak et al., 2014). There is data showing that 1/3 of BSAR volunteers have one or more symptoms of post-traumatic stress disorder (PTSD), and more than 50% report binge drinking which may lead to increased turnover rates (Alma A, 2022). With the probable loss of years of institutional knowledge in each burnout case, it is imperative that prophylactic measures be taken to enhance longevity and job satisfaction in BSAR communities. If such operations are to continue uninterrupted, the mental health of existing and incoming BSAR volunteers must be held preeminent to reduce attrition. A stronger focus on mental health could also help to recruit new volunteers into the BSAR pipeline and increase involvement in these communities of volunteers. Education programs may be used to achieve this goal.

Despite the existence of mental health disparities among BSAR volunteers, there are limited interventions for preventing and rehabilitating stress injuries among first responders, and none in the literature that are specifically focused on BSAR workers. Wellness and stress awareness programs are needed among BSAR volunteers. This program evaluation was designed to evaluate the effectiveness of a wellness and stress awareness pilot program to reduce stress and burnout levels and raise awareness about stress injuries among BSAR volunteers.

Method

Institutional approval

The General Assembly of the State of Colorado required a pilot stress injury prevention program under Senate Bill 21-245. Legislators created this program to address some of the immediate needs of BSAR organizations by offering mental health training to BSAR volunteers. This program evaluation was exempt from institutional review (not human subjects research) based on the Colorado Multiple Institutional Review Board (COMIRB)'s quality improvement and program evaluation guidelines.

Description of intervention

This is a program evaluation with secondary data analysis that is collected as part of the stress awareness pilot course. The pilot was an eight-hour training that included four modules, two hours each. The four course modules included psychological first aid, stress injury awareness for the rescuer, stress injury awareness for the team, and incident support for the rescuers and teams. Descriptions of each of the course modules are found in **Table** 1 (McGladrey, 2018) . Participants who agreed to participate in the course were enrolled between July 2021 and December 2021. There was a total of five cohorts and on average 25 participants in each cohort. The course was completed in two days and consisted of both virtual and asynchronous learning.

Table 1. Foundations of Stress Injury Course Description (McGladrey, 2018)

Module	Description
Psychological first response for rescue	This module is an asynchronous skill based online course to identify patients at risk for psychological injury, with or without physical injury. This module follows the medical first response model to support on-scene tools to recognize and mitigate distress to support the prevention of stress impact and post-traumatic stress injuries. This module takes a novel approach at self-reflection by the rescuer to identify exposure in themselves with awareness and mitigation techniques.
Stress injury awareness for the rescuer	This module is a two-hour live video conference and provides an overview of stress injury in search and rescue. The focus of this awareness level course is recognition of injury formation, the stress continuum, and supportive tools, such as the individual resiliency plan and green choices for resilience and stress mitigation for the rescuer. Predictive awareness of the interface between depletion stress, mission stress and traumatic stress is also discussed.
Stress injury awareness for the team	This module is a two-hour live video conference that provides an overview of stress impact on rescue teams following traumatic stress and loss, leadership injuries, depletion stress related to external pressures and the impact of wear and tear on team dynamics. This course explores depletion stress, mission stress and traumatic stress in the team framework, as well as tool-based approach for supportive practices and rituals for mitigating stress and planning for resilience.
Incident support for rescuers and teams	This is a two-hour live video conference that defines and addresses the impact of major incidents and potentially traumatizing events in rescue response. This module looks at best practices and tangible tools for trauma integration following major events, loss, and line of duty events.

Participants and setting

Participants who self-identified as volunteer first responders and members of nonprofit search teams were invited to participate in the pilot course voluntarily. The pool of participants consisted of not-for-profit search team members, as well as various Sheriff's Department assets. Responders are volunteer teams that work alongside fire, law enforcement, emergency medical personnel, the Colorado National Guard, and other government employees in disasters or emergencies. Program staff at the University of Colorado (CU) College of Nursing worked with the Colorado Search and Rescue Association (CSAR) and the Responder Alliance, two community groups that advocate for the needs of BSAR volunteers in the state, to identify target agencies with BSAR volunteers who could potentially benefit from a stress impact course. Several agencies were selected, representing a continuum of large and small agencies in urban and rural areas. These agencies then sent their members an invitation to participate. We had representation from various geographical regions of Colorado including the Southern and Middle Rocky Mountains, and the Colorado Plateau.

Outcome measures

Participants filled out surveys sent out via email after course completion, with two sets of items that asked about understanding of learning objectives, their experiences before taking the course, and then the same experiences after taking the course. All participants' responses were anonymous, with no identifying data collected, including IP addresses. No items that could be considered PHI, such as birth date or zip code, were included in the data collection tool, and respondents were assured that there was no way to link them to their responses. This level of anonymity was considered necessary when asking BSAR volunteers about mental health experiences that might be stigmatized in their work or community. The survey consisted of 65 questions composed to assess the overall understanding of stress injuries and the level of stress on the stress continuum. Outcome measures were rated on a Likert-type scale (1-5), where 5 was the highest and 1 was the lowest. Items on overall training satisfaction, achievement of learning objectives, and intention to make changes were drawn from the Kirkpatrick program evaluation framework used in many continuing professional education activities (Ulum, 2015). The specific items on the survey were adapted from course objectives that the University of Colorado School of Medicine Department of Psychiatry had previously identified for a stress impact course focused on health care providers' experiences with COVID-19. We calculated Cronbach's alpha score for reach of the survey question sets to assess for internal reliability, where each were assessed on a range of alpha coefficients: < 0.70 not adequate, 0.7-0.8 OK, 0.8-0.9 good for research, and > 0.9 good for clinical research (Heo, Kim, & Faith, 2015). Knowledge was measured with 9 items about participants' understanding of stress injuries, such as "I am able to recognize depletion in myself," (alpha = 0.92). Participants' current experiences of stress and coping were measured with 10 items such as "I feel overwhelmed," (alpha = 0.9). Participants' perceptions of their BSAR organization's culture around stress injuries were measured with 6 items such as "I am able to talk with coworkers about my own stress level," (alpha = 0.73). In addition, participants completed a single-item burnout measure that has established validity based on correlations with the well-established Maslach Burnout Inventory and based on its ability to predict negative outcomes of stress among health care workers (West, Dyrbye, Sloan, & Shanafelt, 2009).

Data analysis

Descriptive analysis of quantitative data was conducted using SPSS version 28 (Armonk, NY: IBM Corporation), and graphics were prepared using GraphPad Prism v. 8.3.1 (GraphPad Software, Inc., La Jolla, CA). For continuous and normally distributed data, means with standard divisions were calculated, and numeric counts with a percent were calculated for categorical variables. The mean values or frequencies for variables were compared between groups using independent Student's t-test, chi-squared, or Mann-Whitney nonparametric statistics as appropriate. Data are expressed as means ± SD or the 95% CI for proportions in the text, tables, and figures. We conducted a retrospective pre-post analysis to assess for changes in learning objectives. A two-sided P-value < 0.05 was considered evidence of association or difference in sample means or frequencies, and trends were reported when $0.05 \leq P < 0.10$.

Results

A total of 136 participants were included in this program evaluation. The usefulness of the course was rated on a scale from 1-5, where 5 indicated it was excellent and 1 was poor. Most participants had a positive experience, where 89 (65%) said it was excellent, and 34 (25%) said it was very good. No participants rated the course as poor, and only 1 (1%) participant noted it was fair. The overall usefulness of the course was rated very high, with a mean score of 4.6 (SD ± 1).

The primary outcome for this program was a change in knowledge based on the learning objectives. As shown in **Figure 1**, we saw a significant increase in knowledge for all learning objectives. On average, most learning objectives increased by 1.5-2 points from before participating in the course to afterward. All pre-post changes in knowledge were statistically significant ($P < 0.001$). We saw the largest increase in the item that asked about trainees' ability to use a common language when discussing stress injury awareness and mitigation.

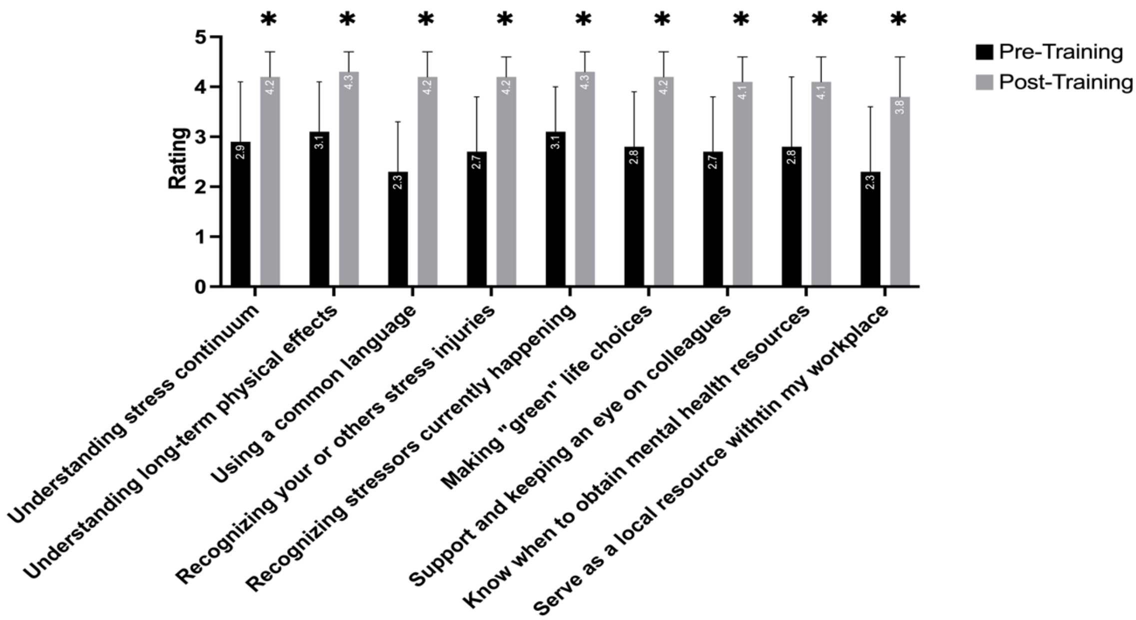

Figure 1. *Self-reported mean assessment of achievement of learning objectives for pre and post training. Rating scale was based on a 1-5 scale, where 1 = beginning level of knowledge, 3 = intermediate level of knowledge, and 5 = advanced level on knowledge. There was a statistically significant increase in all learning objectives among participants. Significance value for comparison is shown in the figure where * = P < 0.001 using a paired t-test.*

When participants were asked to what degree they were able to identify stress injuries in their personal and professional work environments, we saw a significant increase in all measures except for one statement (**Figure 2**). All pre-post changes were statistically significant ($P < 0.001$) except for the item, “My organization supports workers who develop stress injuries,” where the results approached significance ($P = 0.06$). Most participants rated their pre-training experiences between 3.5 and 4, indicating that, in general, most participants either were neutral or agreed with the statements; however, after the training, all participants at least agreed or strongly agreed with the statements listed below in **Figure 2**.

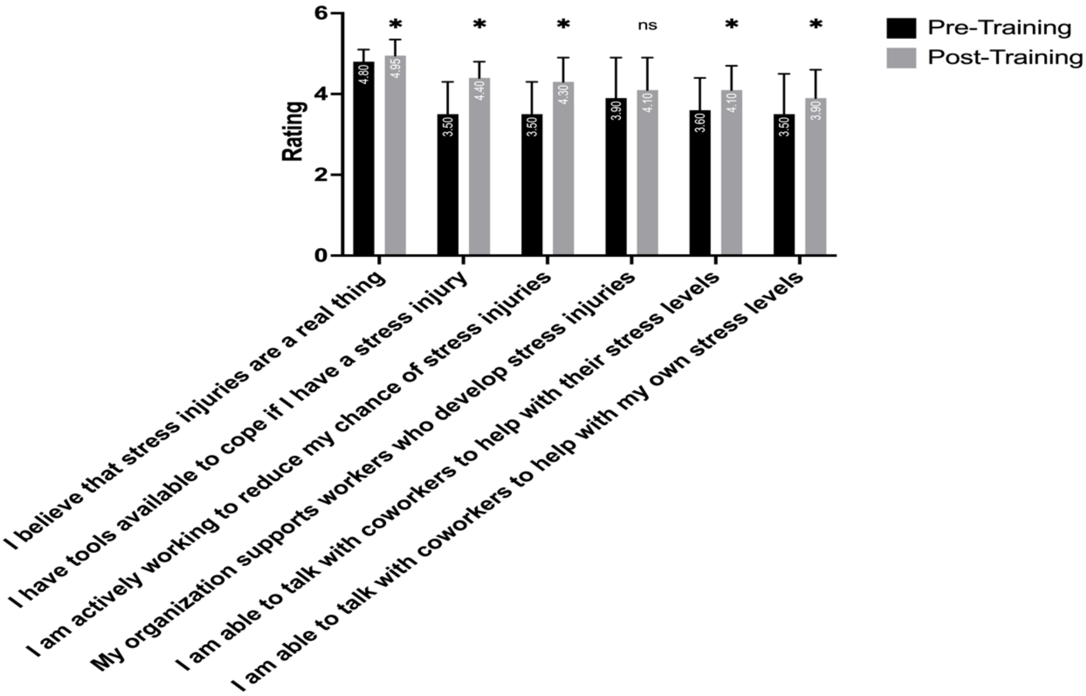

Figure 2. *Self-reported mean rating of current perspectives for pre and post training. Rating scale was based on a 1-5 scale, where 1 = strongly disagree, 2 = disagree, 3 = neither agree or disagree, 4 = agree, and 5 = strongly agree. Significance for comparison using a paired t-test is shown in the figure where * = P < 0.001 and ns = non-significant.*

There were no significant changes on most of the emotion-focused items about participants' typical experiences over the past 7 days. As shown in **Table 2**, when asked about their experiences, we saw positive changes on all items; however, these were not statistically significant in most cases. We saw significant differences on the items, "I feel overwhelmed" (3 vs. 2.8, $P < 0.05$), and "I feel prepared to manage stressors that I encounter at work" (3.8 vs. 4.1, $P <0.01$).

Table 2. Self-reported current experiences pre-post changes

Item Rated	Pre-Training M (SD), N = 136	Post-Training M (SD), N = 136	*P*-value
I feel calm	3.8 (1)	3.9 (0.9)	0.07
I feel connected to others	3.7 (0.8)	3.8 (0.9)	0.07
I can manage my worries	3.9 (0.9)	4 (0.8)	0.07
I feel capable of dealing with challenges that occur each day	4.2 (0.8)	4.2 (0.8)	0.11
I feel a sense of autonomy	3.9 (0.9)	4 (0.8)	0.15
I feel content	3.8 (1)	4 (1)	0.05
I feel a sense of hope	4 (0.9)	4.2 (0.9)	0.05
I feel overwhelmed	3 (1)	2.8 (0.9)	<0.05
I feel supported by my supervisor	3.8 (1)	3.7 (1)	0.2
I feel prepared to manage stressors that I encounter at my work	3.8 (0.8)	4.1 (0.9)	<0.01
I feel isolated	2.4 (1.1)	2.3 (1.1)	0.2

Satisfied in my work role	3.7 (0.9)	3.9 (0.9)	<0.05

Participants' pre-training level of burnout was 29% based on the highest 3 levels of the 5-level burnout item. This rate decreased to 20% after the training. The training program's effect in reducing current burnout level was *OR* = 0.40 (CI: 0.30 – .99, *P* = 0.04) by participating in the course (**Figure 3**). When asked about levels on the stress continuum, 64% (87) of participants noted some level of stress injury during the pre-training survey, compared to 46% (62) at post-training. By participating in the course, we found that the program's effect in reducing stress injury levels was *OR* = 0.50 (CI 0.30 - 0.80, *P* = 0.002) (**Figure 4**).

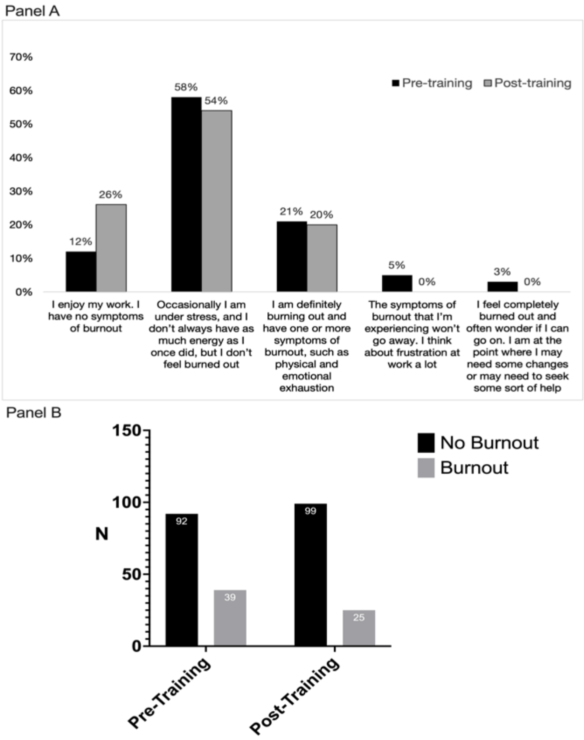

Figure 3. *Self-reported number of participants experiencing signs of burnout for pre and post training. Panel A shows total pre and post levels of burnout measures. Panel B showing pre-training burnout was 29% (39), while 70% (92) had no symptoms of burnout. Panel B showing post-training burnout was 20% (25), while 80% (99) reported no symptoms of burnout. The reduction of burnout by participating in this course was OR = 0.6 (CI: 0.3-1), P = 0.04) using Chi-squared difference.*

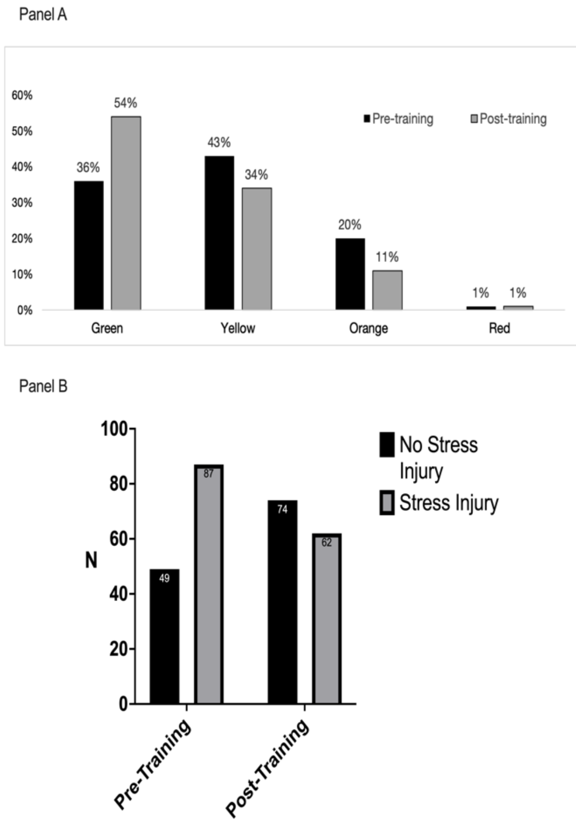

Figure 4. *Self-reported level of stress on the stress continuum for pre and post training. Panel A showing pre and post indicators on the stress continuum. Panel B showing pre-training level of no stress "green" was 36% (49), while 63% (87) had some level of stress injury ("yellow" + "orange" + "red"). Panel B showing post-training level of no stress was 54% (74), while 46% (62) had some level of stress injury. The reduction of stress injury by participating in the pilot course was OR = 0.5, CI 0.3-0.8, P = 0.002 using Chi-squared difference.*

Discussion

Summary of findings

We piloted an online stress injury prevention course and an online support group with BSAR volunteers. This group of participants included many BSAR volunteers with current burnout and/or stress injury. BSAR volunteers in this pilot program showed improvement on each of the learning objectives and said they had increased capacity to cope with stress and were less overwhelmed after participating in the program. They also reported improvement on most items related to the culture of their BSAR organization, suggesting that organizations whose members participated in this program became more responsive to their members' mental health concerns. Most participants found the course to be useful, and most importantly, fewer people reported high levels of burnout after the course. There was also a decrease in stress injuries based on participants' reported drop on the color-coded stress continuum for nearly all the participants.

The stress injury course used a structural framework relying on a color-coded, "Stress Continuum," an awareness tool first developed by William Nash and colleagues for use in combat operations and later adapted by Laura McGladrey at CU Anschutz for use in the first responder population and for team stress mitigation. The basic tenant of the tool allows responders to self-identify from a ready to critically injured state in relation to stress and depletion exposure, noting opportunities for recognition and early mitigation at each color change on the stress continuum. Given the known predictive nature of overwhelm and isolation on the formation of traumatic stress injuries such as PTSD, this awareness is useful and may be predictive of the development of traumatic stress in rescuers such as BSAR volunteers.

The high levels of burnout and stress injuries at baseline support the idea that BSAR volunteers experience a baseline level of stress as part of their work. Positive outcomes from the pilot program suggest that bringing awareness to that baseline state can facilitate decision-making to mitigate BSAR worker's stress. Similar to the current results, a longitudinal study of 869 employees in Australia found that awareness of stress-reduction interventions led to decreased psychological strain and higher job satisfaction than those among employees who were unaware of stress interventions (Pignata, Boyd, Gillespie, Provis, & Winefield, 2016). Similarly, there is evidence that workplace stress and mental health outcomes are directly related to the availability of stress management training and education (Fernandez et al., 2016; Parkyn & Wall, 2020a, 2020b). Among factors that help to mitigate the development of such mental health complications are "good team functioning, job satisfaction, and recognition,"(van der Velden et al., 2012) all of which were organizational factors targeted by the pilot course. Our findings corroborate the idea that stress injury education is an essential mitigation strategy for first responders, including BSAR workers.

Participants' initial rate of stress injuries was higher than their initial rate of burnout, which is consistent with the idea that stress injuries are sub-clinical symptoms that suggest increased risk for more severe mental health problems. However, the stress injury item and the burnout item both improved to a similar degree, about 40% to 50% based on odds ratios. Individuals who reported being in the “orange” or “red” level of the stress injury continuum are likely already experiencing some degree of burnout, emotional exhaustion, or symptoms of posttraumatic stress (Bridgeman, Bridgeman, & Barone, 2018; Cieslak et al., 2014; Ford, 2019). In other studies, pre-hospital emergency medical service workers, a group whose work has significant overlap with BSAR workers’ responsibilities, have a higher prevalence of burnout and PTSD than other first responders such as police officers or firefighters (Berger et al., 2012). BSAR volunteers are at higher risk for developing mental health issues due to facing injured or dead people, smelling the deceased, and unsuccessful operations, among other reasons (van der Velden et al., 2012). Such burnout and stress injuries are correlated to adverse mental health outcomes and can require different therapies and management to mitigate or resolve such conditions. If these conditions are not addressed in a timely and pointed manner, work productivity and longevity may be threatened. We did not evaluate formal diagnostic criteria for post-traumatic stress disorder or secondary traumatic stress in the current study, which might require formal mental health treatment.

Implications for practice

Prevention programs as in the current study can complement but not replace formal mental health care, but both components should be part of a comprehensive solution to meet BSAR volunteers’ mental health needs. This pilot course sought to educate BSAR workers that stress injuries are also physical injury types and can be fatal when not recognized. This type of ‘fair warning’ of occupational exposure is the right of every professional and has been lacking in BSAR culture until present. If stress injuries are discovered early (in the “yellow” level) and prophylactic measures, such as medication or lifestyle changes can be initiated through stress injury education programs, clinicians can help patients blunt the progression of the disease. However, if a stress injury is not identified at the onset and is allowed to increase (moving from “yellow” to “red”), then the consequences could potentially become irreversible and even fatal. Based on a nationwide cohort study of traumatic stress, compelling data suggest that severe stress and trauma are associated with a higher rate of all-cause mortality and have strong associations with suicide even after controlling for confounding variables (Gradus et al., 2015). Stress injury education such as that in our pilot program can educate individuals on how to prevent the development of adverse mental health outcomes, how to implement mitigation strategies, or when to seek clinical help, thereby potentially reducing the immediate and long-term adverse health consequences associated with traumatic stress.

Implications for practice

Although the current results are promising, further research is needed on the BSAR stress injury prevention course using more rigorous experimental methods, such as a randomized controlled trial. Based on the success of a stress injury prevention course with BSAR volunteers, such education also could be tested in other arenas where stress injury occurs, such as in healthcare, specifically residents and medical/nursing students. These different populations might benefit from preventive training ahead of any experience of burnout, which is a significant threat to healthcare professionals (Bridgeman et al., 2018). Such research also could examine similarities and differences in the type of stress injuries, coping mechanisms, or mitigation strategies across different types of first-responder work.

Finally, as this research continues to evolve and grow in the BSAR industry and beyond, it will be paramount to develop a formal definition of the term "stress injury". Because this is not a formal diagnostic term, it is difficult to quantify stress injuries and the degrees to which they affect the daily lives of those who suffer from them. By continuing this research and gathering supporting information, we can work towards producing a vocabulary that is in line with the type of injuries that individuals might see in their careers as BSAR volunteers and corresponding mitigation strategies to serve those who are most susceptible. Once a widely accepted definition is in place, organizations can seek to bring more awareness and provide further resources for their workers to stay ahead of and treat stress injuries.

Strengths and Limitations

This program evaluation had three major strengths. The first is that a large cohort of BSAR volunteers participated, which provided enough information to determine the effectiveness of this course. Second, participants' demographics mirrored those seen in a statewide survey of BSAR volunteers, which suggests that the pilot participants were a representative group. Third, we conducted a retrospective pre-post analysis for learning outcomes where participants rated themselves before and after training in a single collection event. Using a retrospective pre-post analysis has been shown to allow participants to determine their level of knowledge before and after an intervention more accurately and reduce response-shift bias (Geldhof et al., 2018; Thomas et al., 2019).

While we had some very supporting results, this program evaluation also had important limitations. First, there is a concern about confirmation bias from experienced BSAR volunteers who might have wanted to please the group leader by providing a positive evaluation. Second, the recruitment of volunteer participants means that the results might have been affected by selection bias, either because we recruited participants who were particularly receptive to the intervention, or because BSAR workers with more severe stress injuries were unwilling to partake in this optional training. The latter possibility is partially mitigated by the high level of stress injuries observed at baseline among our participants. History effects are also a possible confound, because some participants in the group had previously received stress injury training while others had not. Such differing levels of education on this topic may have led to bias in the survey answers in one way or another.

The nature of BSAR groups is that very few are paid personnel. Most responders are unpaid professionals who are otherwise employed as ski patrollers, doctors, nurses, firefighters, mountain guides, lawyers, accountants, IT consultants, etc. Given this wide range of education and technical training, further demographic information should be collected in future studies, and analyzed to determine whether there are differences in results for BSAR workers who are paid vs. unpaid, rural vs.

urban, career-related vs. non-career-related, men vs. women, or other sub-categories of participants. A final limitation of this study is that there was no comparison group, so we cannot rule out history, maturation, or other potential confounds based on the passage of time.

Conclusion

Findings from a stress injury pilot course for BSAR workers indicated that this program had a significant impact on participants' ability to identify stress injuries and mitigated the level of burnout and stress injuries among BSAR volunteers. We saw increased knowledge based on all learning objectives. We found that baseline stressors are prevalent among BSAR volunteers, and that these stressors can be reduced through a training program focused on the stress continuum and psychological first aid. The findings also suggest that BSAR organizations whose workers participated in this program became more open to conversations about stress injuries and perhaps better able to address these problems when they occur. Our findings suggest that a stress awareness course is a potentially useful intervention that could be scaled to reach a larger group of BSAR volunteers as well as groups outside the BSAR community.

Acknowledgements

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Abbreviations

BSAR	Back-country Search and Rescue
CU	University of Colorado
CSAR	Colorado Search and Rescue
IT	Information technology
SB	Senate Bill
PTSD	Post-traumatic stress disorder

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How well do we search for missing people in Queensland, Australia?

Jim Whitehead APM M.Emg.Mgt, B.Soc.Sc.[1], **Professor Richard Franklin PhD**, FPHAA, FARL, FACTM, MSocSc (Queensland Health), BSc, GCertAustRurLeadership, GradCertEd, MACTM **& Dr Tracey Mahony** (PhD (Commerce-Marketing), MPA, LLB[2]

[1] Retired Queensland Police State Search and Rescue Coordinator, Australia
[2] James Cook University, Australia

Email: ssarcoqld@hotmail.com

Abstract

Most countries, states or counties have an organised Search and Rescue (SAR) response to reported missing people, whether it is by statutory authorities such as the police or by volunteer groups. The success or otherwise of the ensuing searches is often dependent on the training of the coordination team and the adherence to known and proven search strategies. It would be realistic to assert that the chances of a successful search are reduced if the coordinator cannot put those searchers in the right location. This paper examines the functionality of the SAR system in Queensland, looking at the coordination structure, the strategies utilised in determining search areas and whether they are still fit for purpose. The response to SAR is a police responsibility with the assistance of volunteer groups such as the State Emergency Service, and to this end a significant effort is undertaken to train both police coordinators and volunteer searchers.

KEY WORDS: *Search, Rescue, Theoretical, Statistical, Subjective, Deductive*

Introduction

The aim of this study is to provide an analysis of a single jurisdictions use of search techniques in searching for missing persons in a land environment, and the success thereof. The focus of this paper is on the state of Queensland, Australia, and is the first known study that encompasses an entire policing jurisdiction. At 1.8 million km² Queensland represents 23% of Australia's landmass (Roberts, 2007) and has 34% of the nationally reported missing people (National SAR Council, 2022). Missing people in Queensland have an excellent chance of being found and recovered due to the continual refinement of the search and rescue (SAR) system and associated technology, including mobile telephone location systems, night vision and thermal imaging devices (Queensland Police Service, 2021). The collection of data on SAR commenced in 1976 and identifies that police in Queensland have coordinated an average of one land search daily (Queensland Police Service, 2021). This has resulted in approximately 17,300 missing people being located and recovered and a further 481 who have never been found (Queensland Police Service, 2021).

Search methods are similar across all Australian police jurisdictions; however, Queensland's SAR system is unique compared to other states/territories. It has four levels of SAR Coordination based on the level of training undertaken by each officer as contained in Table 1. At the apex is the State SAR Coordinator, who has the responsibility of managing the state for all SAR incidents including reviews of operations and presenting evidence at coronial inquests where people were not found or found deceased. This position also provides the other three levels of SAR training. Additionally, the position represents the state in the national SAR forum.

Table 1 *SAR Coordinator level and roles*

SAR Coordinator Level	Title	Role	Qualification
1	State Search and Rescue Coordinator & Training Officer (SSARCTO)	Managing SAR System and providing training	Advanced Diploma of Police Search and Rescue Management Certificate IV – Training and Assessment
2	Senior Search and Rescue Officer (Sen SARO)	Marine, Aviation and Land SAR (SAR Management)	Advanced Diploma of Police Search and Rescue Management
3	Search and Rescue Officer (SARO)	Marine, Aviation and Land SAR (Coordination)	Diploma of Police Search and Rescue Coordination
4	Field Search Coordinator (FSC)	Land SAR only	Internal Police SAR Course

The first three tiers require officers to complete formal nationally recognised qualifications in SAR, while the FSC role is an internal course. This role was developed to provide a SAR capacity in those areas away from the coastline and in the more remote parts of the state. A flow chart of the system is shown in Figure 1.

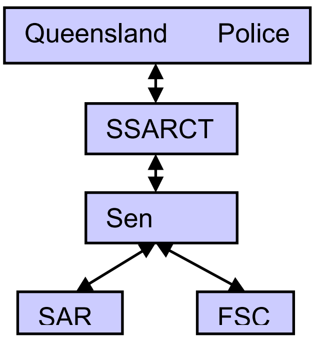

Figure 1 *Flow chart of Queensland SAR Structure*

The National SAR Manual (Whitehead, 2021) is the standard reference document for use by all search and rescue authorities and organisations that provide search and rescue services to Australia. It is an open-source document and represents the collective SAR knowledge of Australia and is continually being updated through incident debriefs and coronial findings, an example being the Inquest into the death of Darrell Simon and the necessity to electronically record all search efforts (Lock, 2018). The manual provides the methods, options, working papers and data for all Australian SAR operatives. It is sponsored by the National SAR Council and maintained within the Australian Maritime Safety Authority (AMSA). While the International Aeronautical and Maritime Search and Rescue Manual (IMO. & ICAO., 2016) provides a broad overarching international manual for SAR, the National SAR Manual is only one of three that covers an entire country, and in Australia's case, a continent.

Aim:

This paper is an overview of the search and rescue (SAR) methods and strategies used by the Queensland Police in the search for missing people within that state. The paper will discuss the various search strategies as outlined within the National SAR Manual, with a view to determining the efficacy of their use, the results of these searches and the necessity for any changes to operational procedures. This is the first known state-wide study into a single jurisdiction SAR system

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Overview:

There has been a significant body of work devoted to search and rescue (Koester, 2008; NASAR, 2018; Stoffel, 2006; Syrotuck, 2000) but no single jurisdiction study of how SAR is undertaken. The dictionary definition of lost is not knowing ones whereabouts or able to find a way out, whereas missing is absent from a place and in an unknown location (Gwynn & Laugesen, 2020). The National SAR Manual refers to targets of the SAR system as missing (Whitehead, 2021). This study will use the term 'missing' to refer to both missing and lost people as the same search strategies are used for both types. Organised searching for these persons is based on two contingent steps, a reflex search, and if unsuccessful, a formal search (Whitehead, 2021). A reflex search provides a rapid response with minimal planning. As an aid it is based on a bicycle wheel where the hub represents the last known point of the missing person, or if this is not known, an initial planning point based on the intelligence gathered as shown in Figure 2.

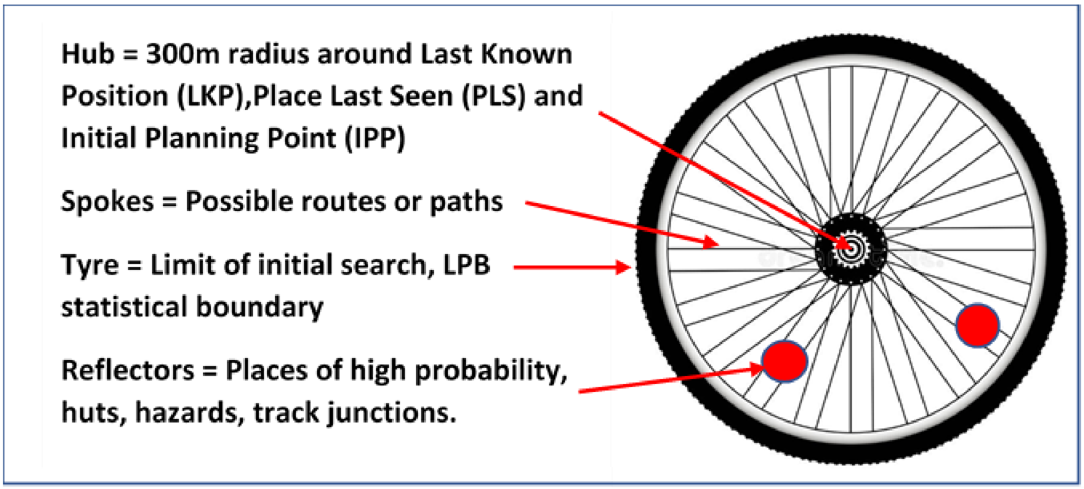


Figure 2. *Reflex search. Note: Sourced from Koester (2008)*

The spokes represent the options of travel available to the missing person, in some locations there may only be one direction of travel possible so the wheel would have only one spoke, while at other locations there may be dozens of possible routes with an associated number of spokes. The hub is the inner boundary of the search and may be as close as 300-600 metres from the last known location depending on the terrain and vegetation. The boundary radius determined by the coordinator through experience and available data. The tyre represents the Missing Person Behaviour (LPB) statistical boundary, which is the furthest distance a person in any particular category could statistically travel. Any points or places of interest are represented by the wheel reflectors.

The 19% of missing people not found by the reflex search require a more extensive process of search area determination (Queensland Police Service, 2021). This extensive process is called the Formal Search(Whitehead, 2021). The Formal Search comprises four separate, but mutually inclusive search strategies; theoretical, statistical, subjective and deductive. The strategies are layered to provide the best possible area in which to put the search resources.

Search Strategies

The Theoretical search strategy was initially derived by Scotsman William Naismith, in 1892 (Thompson, 2010). Naismith escorted the wealthy gentry on walks through the Scottish Highlands and developed his rule as a means of working out how long it would be expected to take for each particular walk (Thompson, 2010). Although it has been used since 1892 for walking and hiking activities it appeared in official print for the first time in 1996, however it was not referred to as the Theoretical search strategy (UK Statutory Instruments, 1996). This rule is used in reverse for SAR, seeking to identify a maximum distance that could be travelled in a particular time period, and was first named as Naismith's Rule in Australia in the 2008 National Land Search Operations Manual (Whitehead, 2008). While there are incidents where this strategy will be of little use, such as shoreline incidents and locating flood victims and physically impaired dementia patients, it is one of the four formal strategies. The major drawback with this strategy is its inflexibility. The strategy cannot easily be varied to consider the missing person, experience and weather, often providing a very large diameter circle inside which the missing person will be found. Additionally, this rule also does not consider a person's fitness, weather, daylight or any other considerations. However, it does provide the largest possible initial search area based solely on a person's ability to walk in a straight line within a calculated time period.

The Statistical search strategy was initially based on the International Search and Rescue Incident Database (ISRID) (Koester, 2008). The ISRID is a statistical analysis of over 50,000 missing persons mainly from the USA, New Zealand, UK and Canada and where they were found. A similar Australian missing person study was undertaken between 2000 and 2006 (Twardy, 2006) with the results tabled at the National SAR Council. As this was the first study of this nature it was not comparable to anything but has since been validated by ISRID. The current Australian Missing Person Behaviour (LPB) Database has been collecting Australian data since 2010 (Whitehead, 2021) and forms the basis for Australian LPB as contained within appendix E-5 of the National SAR Manual. This model is continually being updated with data from the Australian Missing Person Behaviour Database and is based on the ISRID data (Koester, 2008), although not as detailed. Over the last two years sufficient data has been obtained to include two new categories of missing person, prospectors and children with ADD, ADHD, Asperger's and autism (Whitehead, 2021). A minimum of fifty incidents in a category has been the trigger point for analysis. Overall, this may be considered a small number of incidents, but it is the start point for the development of new categories. As more incidents are entered the LPB category is continually modified and as such more effective at finding missing people.

The third search strategy, 'Subjective', is based on a search coordinator's ability to interpret a map, their personal knowledge of the locality and experience to identify natural or man-made barriers (Whitehead, 2021). Identification of these barriers can provide areas that would either limit a missing person's options of travel or that would funnel or force them to move in a particular direction, such as being confined to a steep sided valley system. This strategy also includes decision points, locations where the missing person has an option of two or more directions of travel.

The final strategy is 'Deductive', which is looking at the facts of the situation, such as intentions and distance of the bush walk if that was the case, and from this, undertake an appreciation to determine potential routes and actions of the missing person (Whitehead, 2021). This is often more akin to making logical assumptions of the missing person's behaviour given the situation and can be very valuable when the person's intentions are not known, such as where they were going. The difference between subjective and deductive is that subjective is reliant on the topography of the search area to identify potential routes. Deductive is using the facts of the situation to determine what the missing person may have been attempting, ie a walk between A and B, to find a suitable location for photographs or if afflicted with dementia possibly a home lived at in the past. Table 2 highlights the benefits and detriments of the four strategies.

Table 2 *Benefits and Detriments of formal strategies.*

Strategy	Benefits	Detriments
Theoretical	Relatively simple mathematical calculation. Provides largest search area possible under circumstances.	Does not take into account target ability, weather, daylight/darkness, topography or vegetation.
Statistical	Based on what most targets in similar situations do. Relatively easy to calculate search radii using tables.	Relies on ongoing accurate data input.
Subjective	With experience can be done through map interpretation quickly.	Relies on a coordinators map reading and interpretation abilities.
Deductive	Looks at the situation facts to determine options for target. Can be enhanced through judicious questioning of family, friends etc.	Does require some skill in identifying facts and making rational interpretations.

No single strategy should be used in isolation as all four strategies act in a layered formation. Using all four strategies together it is possible to determine the area of highest probability, which becomes the basis for being able to sub-divide the search into smaller, searchable areas and tasking to search teams (Whitehead, 2021).

Methodology

This study is part of a much larger project based around the disposal of homicide victims and how to better search for them. In order to do so, an understanding of current SAR methods was necessary to determine if the same search approaches could be modified to locate disposed homicide victims. A fourteen-question survey was developed using a combination of Likert type data (Boone & Boone, 2012), binary and a single free text open-ended question (Loc Phuoc & Ngamnij, 2013). This survey was electronically distributed to all police officers (n = 310) who undertake a SAR coordination role in Queensland. At the conclusion, grouping was undertaken to reduce responses to yes/no to simplify tabulation. The survey sought to answer questions such as SAR role, experience, use of the five SAR strategies, success rate of the strategies and use of the National SAR Manual. Examination included univariate and chi squared analysis using IBM SPSS ™ Version 27.

There are 310 SAR trained police throughout the state of Queensland, and the response rate was 77%, of which 73 (30.4%) respondents noted that they had not coordinated a search and rescue incident and could not respond to the remaining questions. These responses have been removed from the analysis leaving 167 responses. The survey response rate was very high for both FSC's and Senior SARO's, 95% and 97% respectively. It is unknown why the SARO response rate is lower, although the overall response rate is acceptable according to Hendra (2019).

The free text data was cleansed though data grouping of like subjects and removing syntax differences. There was also coding and data grouping of the five questions relating to strategy usage to enable improved analysis. This involved grouping the terms '*All of the time, Most of the time and Some of the time'* into a single 'yes' grouping for the strategy usage analysis.

Results

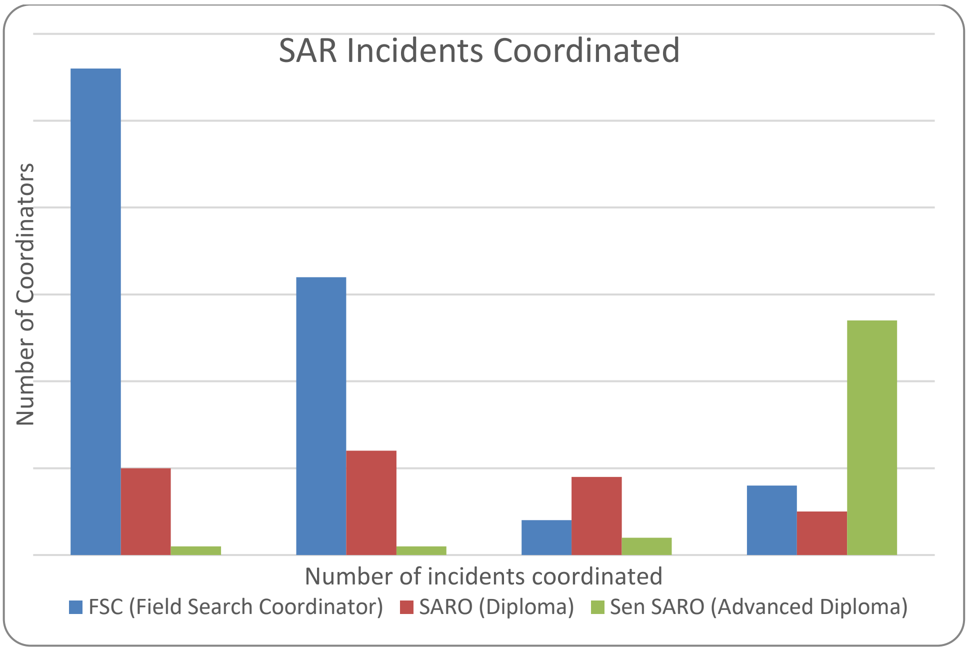
Of the 167 SAR Coordinators who had coordinated at least one incident, 36 (21.6%) have a SARO diploma, and 31 (18.6%) have an advanced diploma. (Table 3)

Table 3 *SAR Coordinator Composition and education levels.*

	Current SAR level			
	FSC	**SARO**	**Sen SARO**	**Total**
Number of SAR People	165	113	32	310
Number of responses (+1 SAR incidents)	100	36	31	167
Number of responses (Nil SAR incidents)	56	17	0	73
% of Responses	95%	47%	97%	77%

Sen SARO's are more likely (X^2=103.16; $p < .01$) to have undertaken 'more than 50 SAR incidents'. Diametrically, FSC's have the highest number of those with 1-10 incidents, again aligning with their relative juniority within SAR. Several anomalies are evident, two Sen SARO's with less than 30 incidents and 8 FSC's with over 50 incidents to their credit (Figure 3).

Figure 3 *SAR incidents coordinated.*



There were no SAR members who had only coordinated marine and aviation SAR incidents. Predominately (61%) Sen SARO's have undertaken all three disciplines. Among all levels of training two thirds (67%) of respondents had only coordinated land SAR incidents, including air crashes (Table 4). FSC's are more likely to undertake land searches ($X^2 = 1.0408$; $p < .05$).

Table 4 *SAR incidents coordinated.*

		Current SAR level			
		FSC	SARO	Sen SARO	Total
What type of SAR incidents have you coordinated ?	Land	94	13	5	112 (67%)
	Land and aviation	6	1	1	8 (5%)
	Land and marine	0	19	6	25 (15%)
	Land, marine and aviation	0	3	19	22 (13%)
Total		100	36	31	167

All search strategies are used in the majority (91-98%) of instances, with very few instances where they have not been used (2-9%). The Reflex search is the first option, utilising the initial search teams and providing a rapid response to the situation, and historically, this has been successful 81% of the time (QPS 2021) ($X^2 = 2.4316$; $p < .05$). Table 5 shows that FSC's are less likely to use all four strategies ($X^2 = 8.326$; $p < .05$). An average of 94.5% usage rate for all strategies combined is significant to the success of SAR in Queensland.

Table 5 *Comparison of Search Strategies used by SAR skill level*

		SAR level			
		FSC	**SARO**	**Sen SARO**	**Total**
Have you used the Reflex/Initial Search Strategy?	Yes	91	35	31	157 (94%)
	No	9	1	0	10 (6%)
Total		100	36	31	167
Have you used the Theoretical Search Strategy?	Yes	96	33	30	159 (95%)
	No	4	3	1	8 (5%)
Total		100	36	31	167
Have you used the Statistical Search Strategy?	Yes	94	36	31	163 (98%)
	No	6	0	0	6 (2%)
Total		100	36	31	167
Have you used the Subjective / Decision Point Search Strategy?	Yes	92	35	31	158 (95%)
	No	8	1	0	9 (5%)
Total		100	36	31	167
Have you used the Deductive Search Strategy?	Yes	87	35	30	152 (91%)
	No	13	1	1	15 (9%)
Total		100	36	31	167

With respect to the use of the National SAR Manual the respondents indicated that it had been useful in the majority of instances, with only a small percentage (13%) of coordinators either having never used it or found it not useful ($X^2 = 0.5127$; $p < .05$), (Table 6). There is no obvious explanation why more FSC's are not using the manual compared to the other SAR levels, except that they may be using the old National Land Search Operations Manual, although this was merged with the National SAR Manual in 2017.

Table 6 *Use of National SAR Manual*

		Current SAR level			
		FSC	SARO	Sen SARO	Total
Has the National Search and Rescue Manual been useful in assisting with the development of search areas?	Never used it	16	3	0	19 (11%)
	No	2	1	0	3 (2%)
	Yes	82	32	31	145 (87%)
Total		100	36	31	167

Most missing people are found within the areas of the respective search strategies ($X^2 = 41.79$; $p < .05$). There are several identified anomalies within the responses, particularly with the theoretical and statistical responses, which will be discussed later. Coordinators with the most experience, SARO's and Sen SARO's, developed search areas that were more appropriate as shown by the small number of missing people found outside the individual strategies. (Table 7)

Table 8 shows the additional methods that have been suggested by a small percentage (16%) of the respondents. The majority, 84% (n=140) identified that they could offer no further suggestions for search tactics.

Table 7 *Validation of the five search strategies.*

		Current SAR Level			
		FSC	SARO	Sen SARO	Total
Was the target found within the Reflex Search Strategy area?	Yes	67	25	25	117 (70%)
	No	33	11	6	50 (30%)
Total		100	36	31	167
Was the target found within the Theoretical Search Strategy area?	Yes	73	33	29	135 (81%)
	No	27	3	2	32 (19%)
Total		100	36	31	167
Was the target found within the Statistical Search Strategy area?	Yes	94	36	31	161 (96%)
	No	6	0	0	6 (4%)
Total		100	36	31	167
Was the target found within the Subjective / Decision Point Search area?	Yes	81	36	31	148 (89%)
	No	19	0	0	19 (11%)
Total		100	36	31	167
Was the target found within the Deductive Search area?	Yes	71	33	31	135 (81%)
	No	29	3	0	32 (19%)
Total		100	36	31	167

Table 8 *Additional SAR methods identified.*

		Current SAR Level			
		FSC	SARO	Sen SARO	Total
Have you identified additional methods of determining a land search area?	No	81	36	23	140
	Combined SAR practices	6	0	3	9
	Improved local knowledge	8	0	1	9
	Increased use of SAR Technology	4	0	3	7
	Social Media	1	0	1	2
Total		100	36	31	167

Discussion

SAR coordinators are actively using the search strategies as contained within the National SAR Manual to good effect, with a 96.9% success rate in finding missing people in land situations within Queensland (Queensland Police Service, 2021). This success rate is comparable with New Zealand at 98.1% (Ferner et al., 2022) and more so with Queensland being 6.9 times larger, has a greater population and approximately the same number of active SAR coordinators (Ferner et al., 2022). There are no other comparable country SAR rates known. This demonstrates that the current search strategies, when used, are providing a sound basis for locating missing people. Respondents identified few other search strategies beyond those described in the National SAR Manual (Whitehead, 2021). The larger number of FSC's reflects the vastness of Queensland and the necessity to have trained police in as many locations as possible.

Coordination

The number of incidents coordinated provides a broad overall picture of the experience among SAR coordinators. While the coordination is undertaken by police, the actual searching is done with a combination of police (General duties, dog handlers, helicopter crew, divers and off-road motorcycle riders) and volunteers from the State Emergency Service, and on very rare occasions by the general public, depending on the location. As training of SAR members is consistent and in accordance with the National SAR Manual, this ensures a common outcome and where lessons are learnt they can easily be distributed across the network. The benefit of this system is the seamless ability for a SAR incident to be managed anywhere throughout the state. A study by Ferguson (2021) identified that respondents to their SAR training survey came from 17 different departments across three regions of Canada. The respondents for this paper all came from the same jurisdiction.

Strategic usage

The reflex search strategy, (Whitehead, 2021), was designed as a quick way to initiate a search with limited resources and information. Its use by the majority (89%) indicates that it is a well-tested strategy that provides an immediate response to a SAR situation. While more prolific with the younger SAR members than older ones its usage is validated through the finding of 81% of missing people without the need to resort to a more formal search (Queensland Police Service, 2021). A version of this strategy has been around for many years, although it never had a particular name until 2015 and was solely used by land searchers as there is no equivalent marine version (Whitehead, 2021).

Theoretical strategy (Whitehead, 2021), was used by almost all land SAR coordinators (95%) and was the backbone of SAR for many years. At first glance this strategy could easily be dispensed with but there are a few occasions when this strategy is likely to provide a smaller search area than that of the Statistical strategy, mostly when the time elapsed by the missing person is relatively short (Whitehead, 2021). If there has been no intervention with the missing person by others then the theoretical calculations should represent the greatest distance, and therefore area, that the missing person could travel in the time they have been missing. FSC's are the largest grouping where this strategy has not worked, and while there is no obvious reason for it several possibilities arise; the calculations were incorrect in that insufficient weight was given to speed of travel or time elapsed or that the initial LKP was incorrectly determined.

The statistical strategy is the most used of the four formal strategies (98%) and as it relies less on calculations, appreciations or deductions is possibly the easiest to initiate. The area resulting from the application of the statistical strategy is commonly smaller than that of the theoretical, providing a search area that is reasonably able to be searched quickly. The high rate of usage reflects its importance within SAR, notwithstanding that it is one of four interdependent strategies. References to the statistical strategy are easy to locate within the National SAR Manual and a significant period of training is devoted to it, again, reflected in the usage rate. Only 4% of missing people were located outside the statistical search area, and given that it is based on what most missing people have done in the past this is a remarkable achievement. Entry of this data into the database ensures that the statistics relied on to develop the strategy are as up to date as possible.

The subjective strategy was used by 159 (95%) responding coordinators. Initial and refresher training has identified that map reading skills are becoming less prevalent among SAR coordinators, and possibly younger people in general (Whitehead, 2020b). Evident through training courses and real-time incidents is that newer SAR Coordinators rely heavily on electronic aids such as Google Earth and GPS devices (Queensland Police Service, 2021). While it is necessary to have an appropriate level of technical or computer skill, SAR is heavily reliant on the ability of a coordinator to identify land topography and features when developing a search area (Whitehead, 2021). The depreciation of this skill is reflected in the 11% of missing people who were found outside of this strategy. As a result of this, map reading and the skills to do so have become a larger part of training and is included in the biannual skills competency workbooks completed by all QPS SAR Coordinators (Whitehead, 2020a).

Utilising the known facts to make judgement-based assessments on the possible movements of the missing person is the basis for the Deductive Strategy (Whitehead, 2021). In doing so it is possible to narrow down the travel and intention options to a small number of possible courses of action by the missing person (Whitehead, 2021). This allows the often-limited resources available to a coordinator to be used to better effect on a smaller number of search areas. Undertaking a deductive analysis is a skill that needs to be learned, in the way a detective needs to look at the facts, and this survey identified that 19% of incidents resulted in the missing person being in a location other than what was deduced. More work in this space will need to be planned for.

It is encouraging to note that the majority of search coordinators are using all five strategies, and this may be a significant contributing factor to the 96.9% success rate in finding missing people in Queensland (Queensland Police Service, 2021).

Success

In theory, more people should be found outside of the statistical search area, than the theoretical search area, however this survey indicated that more people were found outside the theoretical search area (19%) when compared to the statistical (4%). It is impossible for more missing people to be outside a generally larger circle than a smaller circle within the larger circle. This would perhaps indicate the poor wording of the question, which should have asked how many people were found outside each strategy search area rather than a yes or no answer.

The statistical strategy, while being well used, does have some inherent problems. Being a statistics-based strategy, it is very much dependent on the information from SAR incidents being inputted by SAR coordinators, and there can never be a guarantee that all incidents are captured. There have been a small number of incidents where the missing person was found outside this area. While the 80% statistical distance ring is the most often used search distance (Whitehead, 2021), the LPB categories also include greater distances out to 95%. As not all land SAR incidents are entered onto the Australian Missing Person Behaviour Database it is not possible to determine the entirety of distances that missing people are found at (Whitehead, 2019). Further investigation into these figures will determine if greater statistical distances are being used.

A small number of targets were found outside the subjective and deductive search areas, 11% and 19% respectively. These figures underlie the need for a SAR coordinator to practice map reading and intelligence gathering skills in order to make valid assessments of the terrain and intentions (Whitehead, 2020b). In several of these instances where the missing person was found outside of the search area there is doubt about the initial starting point, which itself is often based on limited intelligence gathering, and this was frequently confirmed with follow-up interviews with the missing people after the incident (Whitehead, 2021).

From the data available, it is possible to develop search area determination, which is a combination of all strategies, noting that time has an impact. The chances of a missing person being outside a search area decrease as each strategy is applied, and when all four formal ones are used concurrently the highest probability search area should be apparent (Whitehead, 2021). In a perfect world no missing person should be outside a theoretical search area if it has been applied properly, and a small number outside a statistical search area as the LPB is reliant on what most missing people have done in the past. The fact that some missing people are never found suggests that they have done something out of the ordinary. The aim of these strategies is to develop a search area that has the highest probability of finding the missing person and can withstand coronial and community scrutiny in the event the missing person is not found. This survey indicates that most SAR Coordinators use all available strategies at their disposal.

SAR Manual

The information contained in the National SAR Manual was found to be useful by 87% with the remainder indicating that it either wasn't or they had not used it. The National SAR Manual is the single point of reference for all SAR within Australia, and is a guide with many alternative methods to assist in gaining a successful conclusion to an incident (Whitehead, 2021).

Other strategies

Respondents were asked to provide information on other strategies that they had found useful during SAR incidents via an open-ended free text question. A negative response was provided by 140 (84%) while the rest were grouped into four areas. The use of combined search practices based on circumstances and search asset availability was identified by 9 (5%) respondents, and this appears to relate to the use of all available strategies taking into account the individual SAR circumstances, and, as identified, is a standard SAR tactic. A further 9 (5%) suggested using improved local knowledge, and from experience this would include landowners, National Park Rangers, State Emergency Service members and civilians who have previously searched in that location. The increased use of SAR technology had a response rate of 7 (4%). Two responses quoted 'Technology and IT mapping/triangulation programs' and 'GPS tracks and telephone pings'.'Technology such as drones, electronic mapping, telephone triangulation and increased use of GPS devices has been addressed over the period since the survey was taken as a result of Coronial recommendations (Queensland Treasury, 2021). The final suggestion was the use of social media, made by 2 respondents. This area of SAR is continually improving as methods of accessing the social media accounts of missing people are developed, often requiring specialist electronics knowledge.

Survey limitations

Several limitations were identified with this survey, which has the potential to affect the results. The response rate was only 70% of eligible coordinators who had coordinated at least one search from a potential pool of 238 (72 had not coordinated a SAR at the time of this survey). Although, as identified in Hendra and Hill (2019) it is not believed that this will cause any significant bias to the results. The second limitation was the wording for several questions, allowing only for a yes/no response, leaving little ability to investigate anomalies further. This situation will be addressed in a future survey.

Conclusion

The usage of all five land search strategies has been relatively high across all SAR coordinators and the results, locating missing people, have been commensurate with this. The search strategies were not designed to be used alone, working far better when done concurrently to produce a valid search area that can withstand scrutiny and provides a high probability of success.

This survey has been beneficial in several ways. It has provided valuable data into the usage of the current search strategies, and perhaps the need for continual ongoing training of coordinators on the value of using these strategies. Also, it has identified that the current methods of searching are producing the results expected from coordinators by the community, although, as in most endeavours involving people, the human factor can make it difficult.

The National Search and Rescue Manual provides all SAR coordinators with the strategies to resolve a SAR incident and to achieve the best possible outcome and is based on the collective experiences of coordinators. This survey, while restricted to Queensland, shows that the current methods of land search are valid and are being actively used. The strategies are guiding principles and when augmented with the experience of a SAR coordinator provide the missing person with the greatest chance of being located and rescued.

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Ethics

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Effects of Exertion and Distractions on Search Efficiency in Riverine Search and Rescue (SAR)

Hannah J. Moir, PhD[1], Alex Tasker, PhD[2,3], Christopher C.F. Howe, MSc[1] & Ian Greatbatch, PhD[4]

[1]School of Life Sciences, Pharmacy and Chemistry, Faculty of Health, Science, Social Care & Education, Kingston University, London, UK

[2]The Science Policy Research Unit (SPRU), University of Sussex, UK

[3]Department of Anthropology, Faculty of Social & Historical Sciences, University College London, UK

[4]School of the Environment, Geography and Geosciences, University of Portsmouth, UK

Email: Hannah.Moir@kingston.ac.uk

Abstract

This work sought to examine the impact of physical exercise, and mental exertion prior to launch on lifeboat search effectiveness.

Four three-person volunteer crews from the United Kingdom's Royal National Lifeboat Institution (RNLI), were exposed to combinations of physical and mental exertion tasks before launch and performance measured during riverine scenario-based search and rescue training. Two unchallenged groups (control) were deployed for comparison. Half the deployed crews were subjected to a distraction exercise completed during the search to simulate real-world conditions to place demands upon the attention of the crew (such as passing radio traffic, navigating or planning search tactics). Heart rate, GPS tracking and search success were monitored, with success defined as the location and transmission of an identifying code of each placed target.

Heart rate monitoring showed clear association between measured psychological stress and the physical challenges presented to the crews and demonstrated that the exertion and distracting elements of the experiment had a measurable effect on the participants, where lower heart rates corresponded to greater success in searching. Overall, results showed that exercise and mental activity generally improved perceptual performance of the crew in the pre-scenario-based training, whilst the distracting element (alone and in combination with exertion) diminished performance during the scenario-based training.

Increases in alertness and search performance have significant implications for those involved in search and rescue. This study contributes to an increasing body of cross-disciplinary work exploring team performance in high-pressure situations.

KEY WORDS: maritime search and rescue, Royal National Lifeboat Institution (RNLI), physiological stress, lifeboat, volunteer

Introduction

Riverine Search and Rescue responses for missing, and often vulnerable people, are complicated by both operational, environmental, and personnel-related factors. Operational problems include receiving limited or confused information about location (Johnson, 2008), the behaviour and appearance of the victim and witnesses (Fritz & Mathewson, 1957), and the use of generalised search techniques in non-standard environments (Correia, Moura, & Fonseca, 2020; Yan, Wu, Zhang, & Zhang, 2017). This study focuses on the activities of riverine Search and Rescue (SAR) crews, specifically the impacts of fatigue, stress and overloading of complex tasks places on those searchers.

Riverine search locations are complex, technical, and high energy environments (wide search area, fastest route, coordination of hazards). In many cases, operations will involve extensive periods of technical searching followed by shorter recovery actions. The swift, safe, and successful completion of a search requires clear communication, geographic understanding, and navigation, although other factors will be relevant (such as available light, weather or sea conditions, temperature, water speed, watercourse type and characteristics). Accurate assessment of factors influencing search and rescue success / effectiveness is of paramount importance for improving SAR outcomes through reduced operation times and improved target identification.

The Royal National Lifeboat Institution (RNLI) was founded in 1824 operating around the coasts of the United Kingdom (UK) and Republic of Ireland (ROI) and carries out the majority of the boat SAR operations on behalf of the two Nation's Coastguards. The RNLI has 238 stations in the UK and ROI; and in 2003, four new lifeboat stations were established on the River Thames, in response to the Clarke Report into the Marchioness disaster (Clarke, 2001).

The RNLI is a not-for-profit organisation consisting largely of volunteer crews that operate a lifeboat SAR service 24 hour per day, 365 days a year. The lifeboat crew are not station-based and are alerted by pager to respond (albeit there are four station-based, full-time stations). They are obliged to remain within a certain time-distance of the station when on duty. There are also between 80 and 100 'independent' lifeboat stations not affiliated with the RNLI. This mode of response has some potential risks associated with it. There is the potential for road traffic accidents, or other accidents associated with rushing to the station. There are also risks associated with lack of sleep, and the spike in stress associated with a sudden alert.

Limited research has been conducted on the influence of operational factors; those that do, primarily focus on environmental variables such as wave height, to calculate a statistical 'probability of containment' (Frost & Stone, 2001; Koester & Greatbatch, 2016; Koopman, 1979). Whilst a significant body of work exists addressing the role of human variability in task success such as human factors and situational awareness studies (see, for example, Endsley, 1995), many of these studies retain a tight disciplinary focus within transport, engineering, or medical contexts. Personnel-related factors in SAR have received less academic attention, however, literature does suggest that the appropriateness and levels of training of searchers, levels of fatigue, and degree of overworking of a search team may limit the chances of a successful search (Covassin, Weiss, Powell, & Womack, 2007; Hancock & McNaughton, 1986). Given the complex nature of SAR operations it is important to differentiate the goals of this paper in study success versus efficiency or effectiveness. These terms have been used in previous work (Greatbatch et al, 2014, Meredith & Greatbatch 2022) to understand SAR operations, whereby success is defined as the number if correct targets identified out of the total possible targets, and effectiveness is the total number of targets identified, out of a combined total of possible targets plus positives. To increase the clarity of the design and interpretation, success in this context is here defined as the location and transmission of a correct identifying code for placed targets.

A growing body of literature acknowledges the effects of physical and emotional stress on individual and team operations (Jeung, Kim & Chang, 2018; Murphy & Burke, 2005; Paton, 1994). From healthcare to aviation, significant research time has been dedicated to better understanding how these conditions may influence task performance (Barnettn & Kring, 2003; Alexander & Klein, 2009; Martin, Murray, Bates & Lee, 2015; Lawn et al., 2020), though less attention has been directed at SAR professionals or volunteers. The results of these academic investigations have driven changes across disciplines to adapt training practices to better reflect the stresses of ‘live’ situations (Kaddoura, 2010) and helping to improve skill and knowledge transfer (Maran & Glavin, 2003). For researchers interested in evaluating SAR responses, this move to closer emulate real-world incidents in training provides a welcome opportunity for researchers to sidestep the ethically complex task of exploring high-stress events, and instead experimentally evaluate the effect of these stressors on task performance. To date, literature on the relationship between stress and performance in SAR responders is scarce and often contradictory; for example literature linking individual-level stress and performance suggests anxiety can both improve (Fernández-Castillo & Gutiérrez Rojas, 2009) or inhibit (Robinson, Vytal, Cornwell, & Grillon, 2013) attention on the task in hand. Beyond the individual level the picture is further complicated by the influence of teamwork and communication on stress and performance (see, for example, Sonoda, Onozuka, & Hagihara, 2018), establishing a challenging foundation from which to build research.

The aim of the project was to map the impact of some of the human contributors and distractors to search effectiveness, specifically physical and mental exertion, and distractions. The study sought to examine the impact of physical exercise, and mental exertion prior to launch on lifeboat search effectiveness.

Methodology

Participants

A total of twelve crew members (consisting of eleven males and one female aged 48.9±6.6 years) from Teddington RNLI (covering the River Thames, United Kingdom) were recruited through their involvement in habitual search and rescue (SAR) training. The study was based on observing the current training practices of RNLI crew members. Participants were recruited/observed during typical training sessions and met inclusion based on their active crew membership of the RNLI and having been issued with a RNLI medical certificate where RNLI members are required to be over 18 years old and under 55 years old (inshore lifeboat). Crew members also have previously passed a medical and eyesight test and are classed as physically fit.

Responses/data were anonymously recorded and only personal data such as demographic variables including age and sex were recorded. All participants provided written informed consent and were screened for underlying health conditions with a physical activity readiness questionnaire (PARQ) (Warburton, Jamnik, Bredin, Shephard, & Gledhill, 2019).

There were no exclusion criteria as all were active members of the RNLI, with no known absolute contraindication (e.g., angina, ischemia, heart failure). Only participants with a recent joint or muscle injury (within the prior two weeks) which resulted in impairing their ability to complete the testing were excluded from the test. Ethical Approval (1617 026) was granted by Kingston University Faculty Ethics Committee. All testing was conducted in accordance with the Declaration of Helsinki.

Experimental design

The study followed a cross-disciplinary design, drawing on three streams: the use of search patterns and the efficiency of the SAR crew; the role and impact of exertion on SAR performance, and impact on operational effects, to explore this complex and under-researched topic. Participants were part of a crew of four completing a riverine SAR operation (Scenario Based Training). The use of search patterns and the efficiency of the SAR crew was assessed using a protocol adapted from (Robe & Frost, 2002).

The scenarios took place over a two-week duration consisting of four possible trial scenarios (Table 1). During session one, participants received an introduction to the study and crew members were randomly allocated to one of four crews consisting of three people with an allocated experienced helm (12 crew in total). Two crews were put under ‘distracted’ conditions, and two crews were under ‘undistracted’ conditions as well as being either under a ‘physically and mentally exerted’ [exerted] state or not [non-exerted]. These formed the four conditions of (A) non-distracted, non-exerted [control]; (B) distracted, non-exerted, (C) non- distracted, exerted state and (D) distracted and exerted state (Table 1). The crews were reversed between week one and two trials to provide comparative data for each crew.

Table 1. Crew and condition allocations (N=No, Y=Yes), where (A) non-distracted, non-exerted [control]; (B) distracted, non-exerted, (C) non-distracted, exerted and (D) distracted and exerted.

	Week 1				Week 2			
Crew	1	2	3	4	1	2	3	4
Condition	A	B	C	D	D	C	B	A
Distracted	N	Y	N	Y	Y	N	Y	N
Exerted	N	N	Y	Y	Y	Y	N	N

Search and Rescue Targets

Search target locations and appearances were specifically designed for this study, using a protocol adapted from existing lowland search data (Greatbatch et al, 2015). Twelve targets were randomly placed along a river section. The locations were generated using a combination of Microsoft Excel (version 2010, Microsoft Corporation, USA) and geographic information system (GIS) software (ESRI ArcMap 10.4). Ordnance Survey (GB) VectorMap® Local (scale 1:10,000) raster data and OS VectorMap™ Local vector data were obtained using the EDINA Digimap Ordnance Survey Service (http://digimap.edina.ac.uk) and added to the maps to provide context, and river boundaries. The type (size) and visibility status of each target was randomised using the 'RAND' function in Excel. Twelve targets were randomly placed in the search corridor using the 'Create Random Points' tool in ESRI ArcMap (Figure 1), creating a maximum of two targets within each sub area. The visibility and size codes were then joined to the spatially randomised points and plotted.

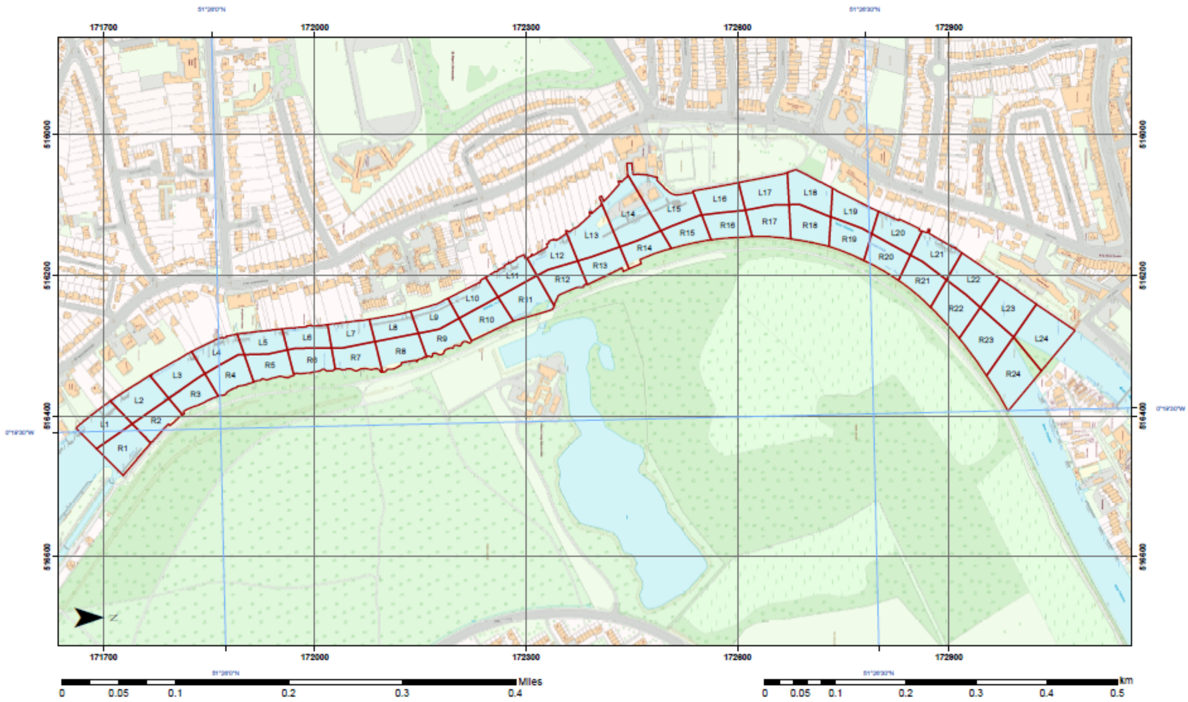

Figure 1: Gridded Exercise Area

These targets reflected four of the most commonly encountered body positions (Koester, Gordon, Wells, & Tucker, 2013), further divided by two levels of clothing visibility (high and low). ‘Low’ visibility consisted of drab and dark coloured clothing or colouring, with no white or reflective components and ‘High’ visibility incorporated reflective strips and bright colours.

The target body positions were: (1) swim failure - top of head visible, (2) floating - head above water (secured with weights / anchor), (3) prone on shore and (4) standing on shore/pathway. University members (students and staff) were voluntarily recruited as live human shore/pathway targets with co-supervisors (for safety) placed along the route. Targets were assigned using a random number generator for each test run with their number, distance along the route, and position to the left or the right of the route randomly determined (Figure 2). Each target was identified by a unique four-character alphanumeric code. Crews were required to identify all targets in the predetermined search area by transmitting and reporting the code from the target to the exercise control station via a marine VHF radio and the time of report logged.

Figure 2: random target placement

During the operation, the crew were distracted by interruptions in the search at predetermined intervals by asking crewmembers to perform a distracting task such as locating and reporting extraneous data. The speed and length of journey was recorded through a global positioning system (GPS) tracker (Garmin etrex, Garmin Ltd., Olathe KS), and, in combination with the number of targets correctly, to calculate a value for the 'success' of the crew. This value formed the basis of the comparative evaluation between distracted and 'exerted' crews.

Distracting Protocol

Search and rescue can often require complex organisation, communication and navigation with the RNLI increasingly working in multi-agency response that requires coordination with groups external to the immediate team such as Her Majesty's Coastguard, Port of London Authority, Metropolitan Police, London Ambulance Service, and members of the public. To recreate this sort of possible environment, a distracting protocol was used during the Scenario Based Training. During the SAR, distraction of the crews was achieved by interrupting the SAR routine at predetermined intervals and asking crewmembers to perform a distracting task such as locating and reporting extraneous data. This took the form of a three-way radio transmission exercise, in which a pair of words (Table 2) were transmitted to the crew via the VHF radio, where each word required looking up in a laminated booklet, which gave a corresponding output word or colour for each input word or colour. This required both non-helming crew members to be distracted for the period required to look up the corresponding translation, inform the helm, who then translated the responding coded message. The requirement to helm the boat safely, as well as receive and transmit information of this kind, also served to distract the helms. Examples of the structure of the outward / return messages can be seen in Table 2.

Table 2. Examples of outward / inward code transmissions used in the distracting tool.

Outward transmission	Colour Look-up	Object Look-up	Return Transmission
RED FOX	(RED = BLUE)	(FOX=LEMUR)	BLUE LEMUR
YELLOW FISH	(YELLOW = RED)	(FISH = EMU)	RED EMU

Physical and Mental Exertion Protocol

In addition to the Scenario Based Training and the distracted condition, two of the four crews were also 'exerted' with both physical and cognitive (mental) stressors (i.e., change blindness, gradual change, and movie perception tests as developed by Simons and Levin (1998)). For physical exertion, an exercise protocol developed by the authors, specifically for this study based on existing research (Duncan, Smith, & Lyons, 2013; Welford, 1980) consisted of submaximal exercise of continuous Harvard stepping (stepping up and down a step-up box) for a maximum of 30 minutes between a target of 70-90% of age-predicted heart rate maximum (220-age; 171.1±6.6 bpm), in time to a metronomic beat. The exertion was conducted immediately prior to the initiation of the Scenario Based Training and all crew members performed the activity wearing inshore lifeboat dry suits. During the physical exercise, heart rate was continuously monitored using telemetric polar heart rate monitors with chest strap (Polar Electro Oy, Kempele, Finland). For mental exertion, cognitive measures of change blindness, visual perception, memory recall and reaction time were monitored every 5-10 minutes during the 30 minute exercise protocol. During the SAR Scenario Based Training, heart rate was also continuously monitored using a portable Global Positioning System (GPS) with integrated HR receiver (GPSport, SPI-Pro, Canberra, Australia) device.

Reaction time tests

Reaction time was measured before and on completion of the physical and cognitive exertion bout. Participants first performed a practice (five attempts) using the Deary-Liewald (Deary, Liewald, & Nissan, 2011) reaction time software (V3.10; CCACE software, The University of Edinburgh, Scotland), followed by five recorded reaction time responses. From the results, an average 'time taken' was generated.

Safety Precautions

To ensure that the public were not alarmed by field study design, precautions were taken which included the study being conducted as part of typical weekly RNLI training practice and conducted in accordance to their policies and procedures. This was therefore a registered event, where Her Majesty's Coast Guard (HMCG), who are the coordinating authority on tidal and coastal waters, was made aware of the training session, identifying exact location and exact timings taking place, so that any calls raised by the public were identified against the training event. In addition, the project was coordinated by 'supervisors' patrolling the area to ensure the safety of targets and the general public.

Performance success of SAR

Success in the SAR element of the experiment was defined as the location and transmission of the identifying code of each of the placed targets. Therefore, the quantification of success can be described as the percentage of targets correctly found calculated as [Hits / potential targets] (Greatbatch et al., 2015). In other works, (for example Koester, Cooper, Frost, and Robe (2004)) other elements, such as speed over ground or sweep width were calculated. In Greatbatch et al. (2015), an additional effectiveness statistic was calculated, by incorporating false positives, but in this experiment, a simple success statistic was deemed sufficient.

Statistical analysis

Data are presented as mean ± standard deviation (SD). Data was pooled before analysis, and from these data values for both success and effectiveness were calculated. Success is defined as the accomplishment of the purpose, this being to find the target. Therefore, success was classified as the number of targets correctly found, calculated as [Hits/Potential Targets]. Differences in reaction time (msec) between conditions (baseline and post-exertion stressors) were analysed by an independent sample t-test. Cross conditions [(A) control, (B) distracted only, (C) exerted only, (D) distracted and exerted] x time [mins] were analysed using a two-way repeated measures analysis of variance (ANOVA) with Bonferroni post-hoc analysis. Effect sizes were calculated using Cohen's d (d) or using eta2 (η^2). All statistical analyses were conducted as two-tailed with IBM SPSS Statistics 23 (IBM Corp., New York, USA) and significance set at $P<0.05$.

Results

The results are presented in two stages; firstly the pre-exercise stressors, and secondly the effects on search performance of the various crews.

Physical and mental exertion protocol

During the physical and mental 'exertion' protocol, crew members were analysed on their recall of a number of cognitive perceptual tests to induce cognitive (mental) stress. Exerted crew members (n = 12) were able to recall 52±35% of all correct information, 27.5% significantly less accurate recall ($P=0.007$) compared to 79±29% of the control crew (n= 10) performed at rest.
Heart rate at rest was 78.9±5.0 bpm. During the physical exertion protocol, participant's average heart rate reached 146.1±5.5 bpm, which was 86±1% of age-predicted heart rate max. Heart rate response varied between 120 (70%THR) and 160 bpm (90-100% THR) during the protocol (Figure 3), however there was no significance difference in heart rate response to the protocol between crews ($P=0.143$; $2.407(3,8)=F$; $\eta^2=0.464$).

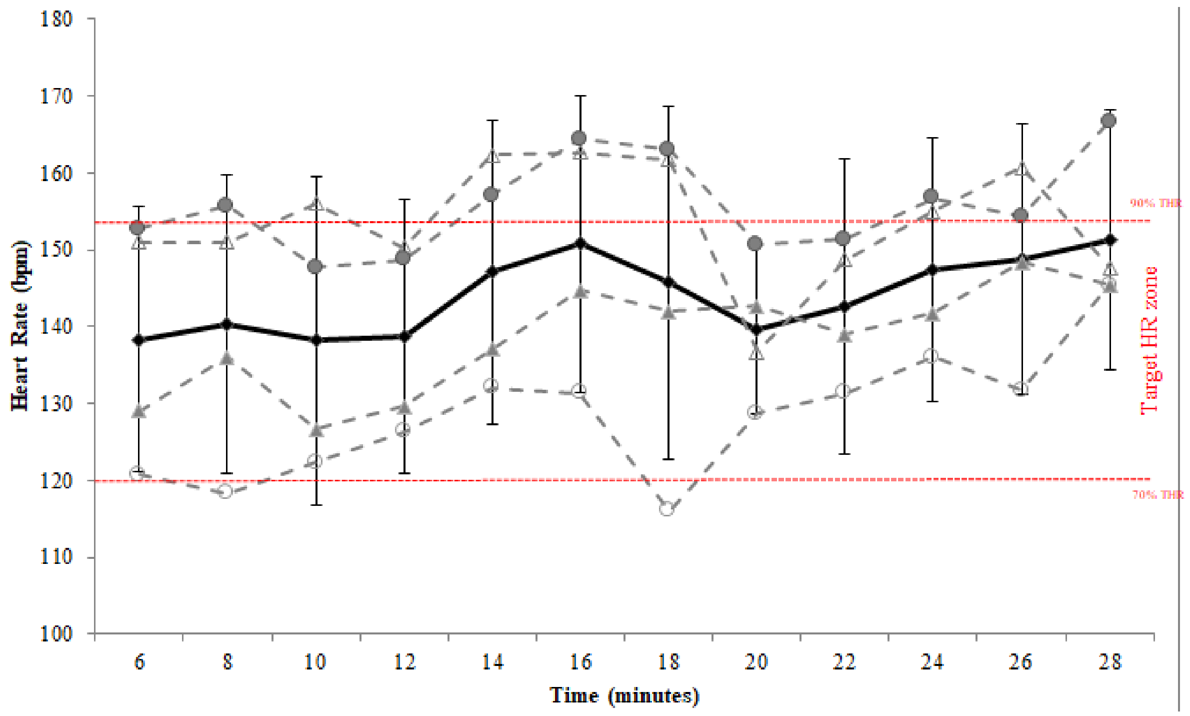

Figure 3: Heart rate response of crews during physical and mental exertion protocol (black solid line represents average±SD bpm; dashed lines represent the four crews average±SD bpm, where solid triangle are (A) control crew, open circle was the (B) distracted only crew, solid circle was (C) exerted only crew and open triangle were(D) distracted and exerted state crew.

Reaction time response

Comparing baseline, reaction time was 286±41 msec vs. 311±41 msec post stressor. Mean reaction time (ms) between baseline compared to post-exercise and cognitive stressors significantly differed by 24.6msecs (Figure 4; p=0.012, d=0.6).

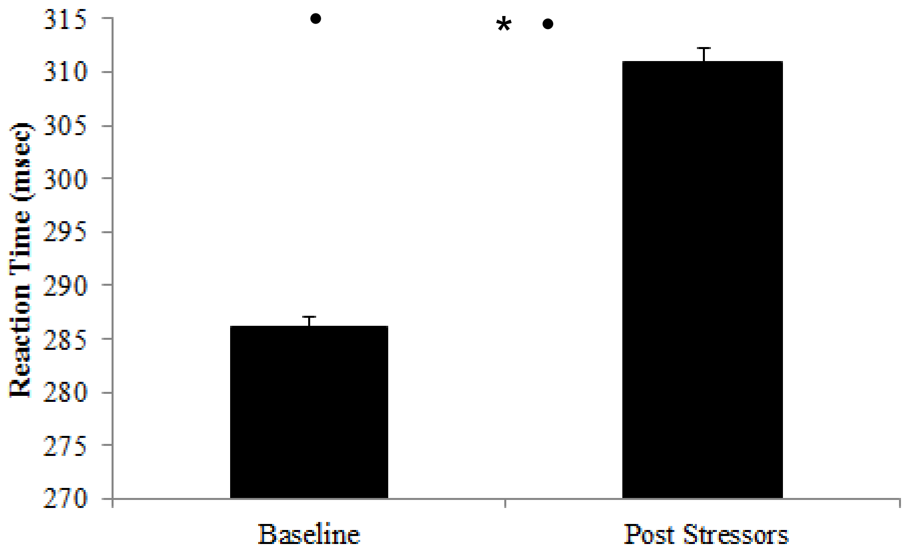

Figure 4: Mean ± SD reaction time (msecs) at baseline and post physical and mental stressors (denotes a significant difference (p<0.05) from baseline).*

Heart Rate response during SAR

During the Scenario Based Training, the average heart rate of all crews was 112.3±20.5bpm, which was 66±12% of predicted heart rate max, and average maximal heart rate reached 123.9±22.7bpm which was just 72±12% of predicted heart rate max. As can be seen in Figure 3, the average heart rate response was significantly higher in the (D) distracted and exerted crew (P=0.005, 3.267(11.4,31)=F; η2=0.551) with average heart rate being 131.5±7.8bpm compared to (A) control average heart rate of 108.3±11.1 bpm. Distracted only crew (B) versus the exerted only crew (C) were also higher than control (A) but not significantly different between crews (P>0.05) apart from distracted (B) being at times more significant than control (A) (P<0.05; Figure 5).

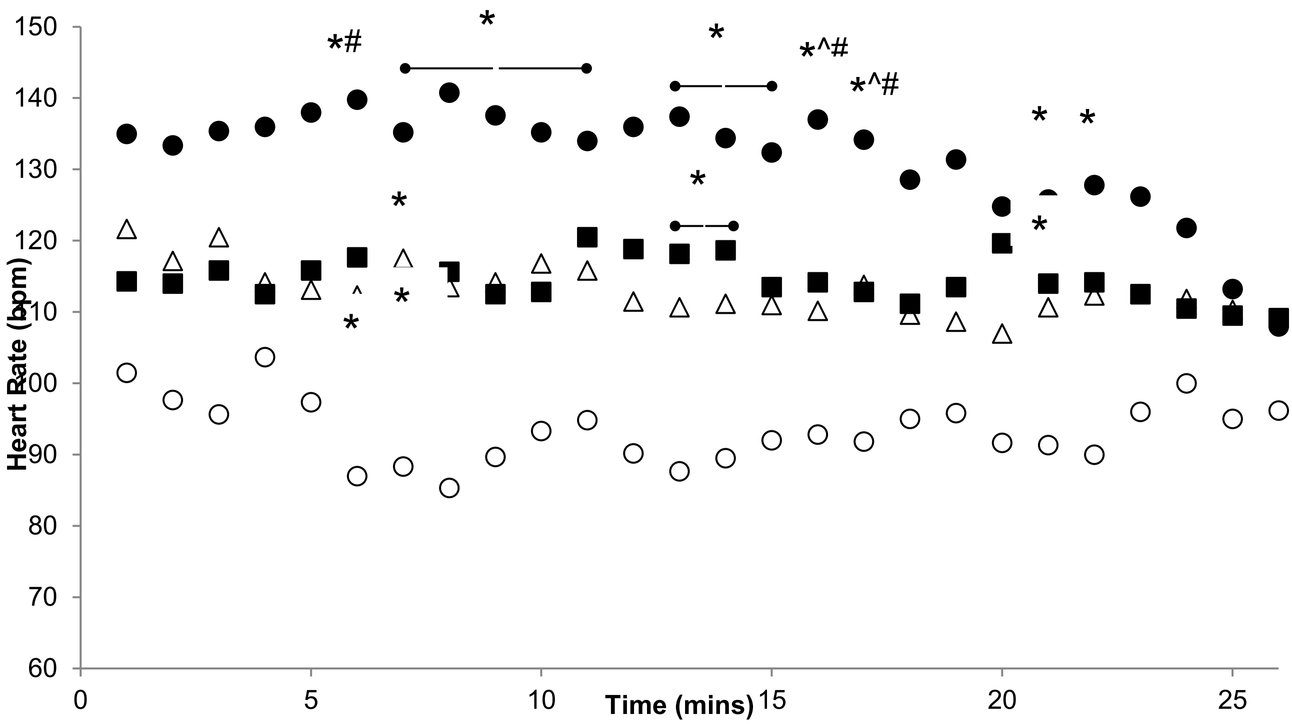

*Figure 5: Average heart rates (bpm) during Scenario Based Training (*denotes a significant difference from (A) control crew, ^denotes significant difference from (B) distracted crew, #denotes significant difference from (C) exerted crew), n=60, open circle represents (A) control, solid square represents (B) distracted, open triangle represents (C) exerted and solid circle represents (D) distracted and exerted)).*

As shown in Figure 6, maximal heart rate was significantly higher in the distracted and 'exerted' crew (D) (P=0.014, 4.529(3,20)=F; η2=0.405), with the average maximal heart rate reaching 140.3±8.7bpm compared to 108.3±11.1bpm for control (A). Distracted crew (B) versus the exerted only crew (C) were also higher than control but not significantly different between crews (P>0.05) apart from being at times more significant than control (P<0.05; Figure 6).

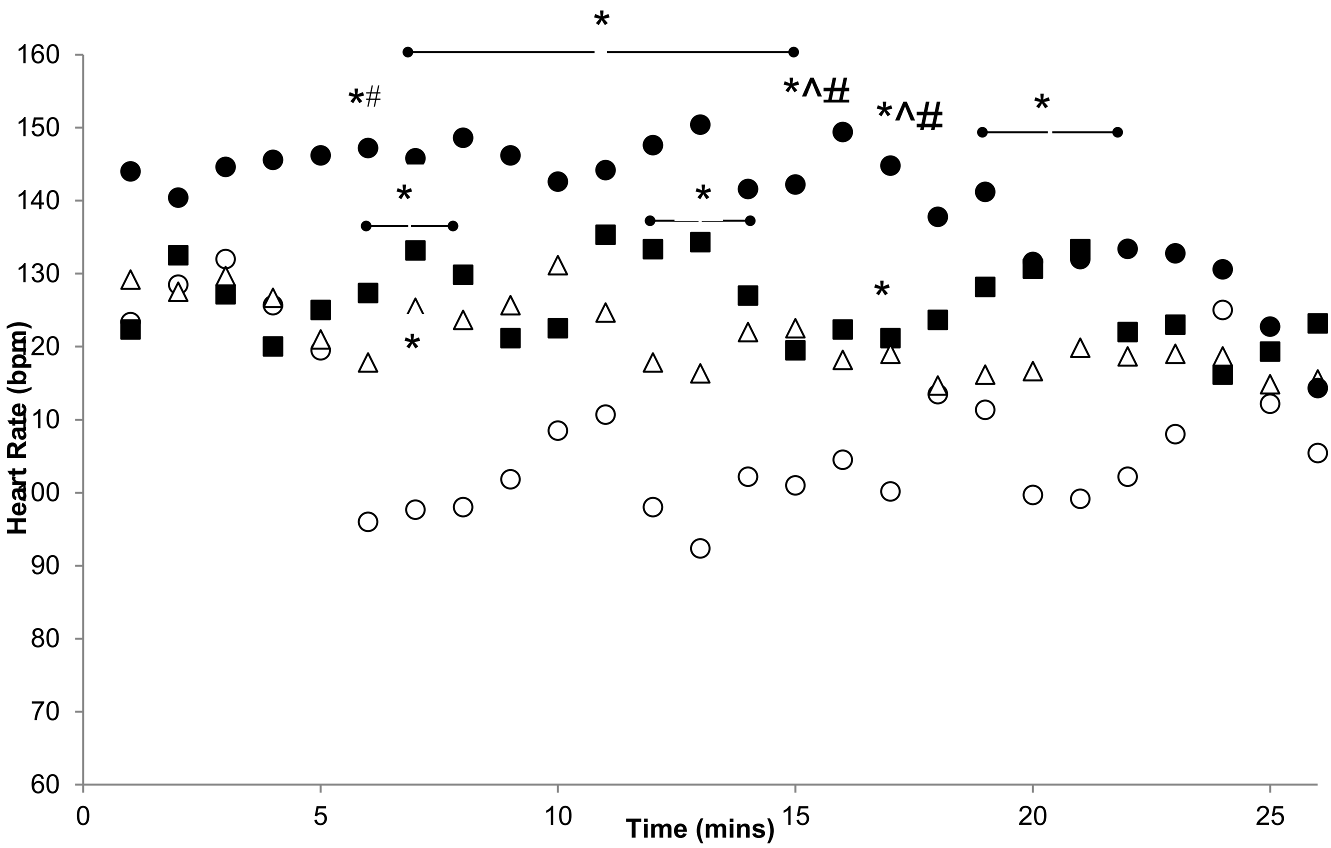

Figure 6: Maximal heart rates (bpm) during Scenario Based Training (denotes a significant difference from control crew (A), ^denotes significant difference from distracted crew (B), #denotes significant difference from exerted only crew (C), n=60, open circle represents control (A), solid square represents distracted (B), open triangle represents exerted (C) and solid circle represents distracted and exerted (D)).*

Impacts of stressors and distraction on searches.

The following data presents the disaggregated data by target type, stressor/distraction, and boat crew to enable cross-comparisons.

Performance success of SAR

Success in the SAR element of the experiment was defined as the location and transmission of the identifying code of each of the placed targets. Table 3 gives comparative success statistics across target types, and fatigue / distracted group types. The 'control' group (A) i.e. non- distracted and non-exerted crew were the most successful at locating the targets (78%), whereas the 'distracted and exerted' crew (D) were least successful only locating 57% of targets, as well as the 'distracted only' crew (B). The 'exerted only' (C) crew were able to locate 70% or targets.

Table 3: Comparative success values (located/total) for each set of stressors and distractions, with targets grouped and disaggregated by visibility and size (where HH= high head, LH= low head, HB= high body, LB= low body). Despite extensive pre-test preparation, one high-visibility whole-body target was recovered and returned to the RNLI station by a member of the public. This target was therefore excluded from the calculations of success values.

	Total (n=23)	**Heads** (n=12)	**Bodies** (n=11)	**High-Vis** (n=11)[1]	**Low-vis** (n=12)	**HH** (n=6)	**LH** (n=6)	**HB** (n=5)	**LB** (n=6)
(A) Control [Non-distracted, non-exerted]	0.78	0.75	0.82	0.73	0.83	0.67	0.83	0.80	0.83
B) Distracted only	0.57	0.50	0.64	0.55	0.58	0.50	0.50	0.60	0.67
(C) Exerted only	0.70	0.58	0.82	0.82	0.58	0.83	0.33	0.80	0.83
(D) Distracted & exerted	0.57	0.67	0.45	0.64	0.50	0.67	0.67	0.60	0.33

To establish comparison between conditions and their corresponding levels of success, a ranking system was implemented to compare conditions (Table 4). In this system, the conditions were compared based on the crews' average percentage of maximum heart rate, with the lowest average value indicating less physical exertion during the SAR operation, and higher values indicating greater success in locating targets. The control crew (A), which underwent typical Scenario Based Training, demonstrated the most effective SAR response. On the other hand, the distracted and exerted crew (D), had the least successful SAR outcome, and they also exhibited the highest percentage of maximum heart rate during the trial.

Those crews (i.e. control [A]) with the lowest heart rate (indicated as % of heart rate max), had the higher SAR success (indicated as % effectiveness of SAR), compared to those crews (i.e. exerted and distracted [D]) with the highest heart rate had the lowest success rate (Figure 7). 'Exerted' or 'distracted' only conditions had some impact on SAR success with 'distracted' being slightly more impactful over 'exerted'. This is supported by ranking the crews (Table 4) based on lower heart rate being better than higher (scored one for lowest and four for highest) and SAR effectiveness (scored one for best success, scored four for worst success).

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Table 4. Ranking of SAR performance according to comparative success versus stressors and distractions

Condition (ranked best to worst)	**Heart rate response** (%HRmax)	**Search and Rescue effectiveness** (%Success)	**Outcome** (Scoring out of 8; Ranked 1- best, 4- worst)
(A) Control	55	78	1+1=2
(C) Exerted only	66	70	2+2=4
(B) Distracted	67	57	3+3.5=6.5
(D) Distracted & Exerted	77	57	4+3.5=7.5

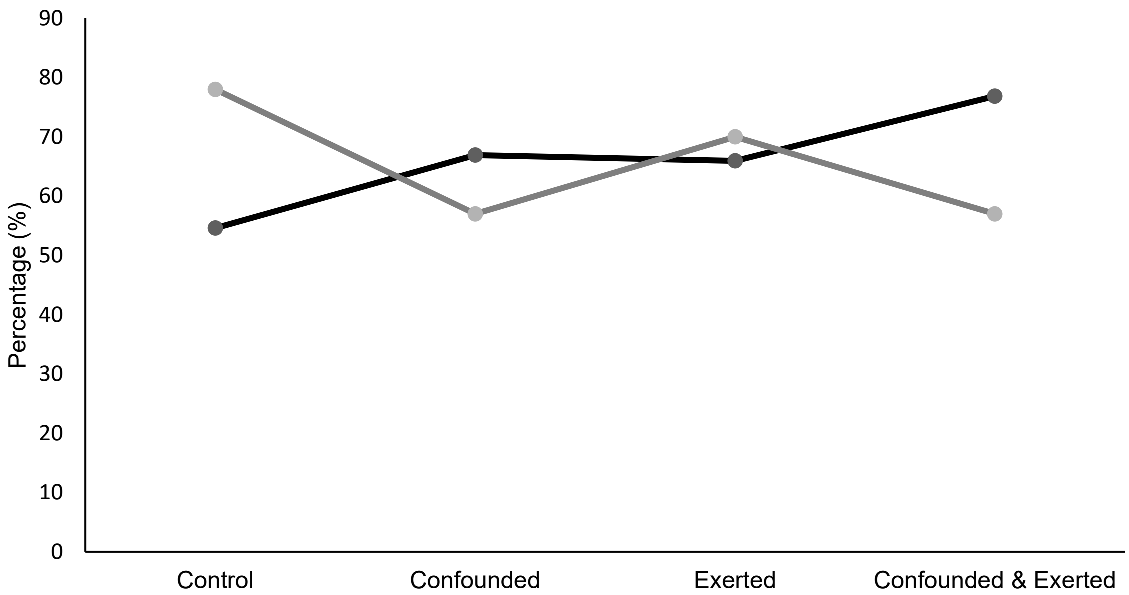

Figure 7: A graphical representation of heart rate response (%HRmax; black line) against search and rescue effectiveness (% success; grey line).

Discussion

This study sought to examine the impact of physical exercise and mental exertion, prior to the launch of a lifeboat, on the crew's performance. The experiment was undertaken during Scenario Based Training and the impact of 'during SAR distractions' was measured to determine the search effectiveness of the crew. The study established the impact of human contributors and distractors to search effectiveness, specifically physical and mental exertion and distractions. This is one of the few published studies to consider distracting and exertional approaches in a 'live' SAR riverine rescue of the RNLI.

As discussed earlier, the work of water SAR crews can often be complicated by both operational and personnel-related factors, such as limited information about location, behaviour and appearance of the victim, and the use of maritime search techniques that were developed for open water in the 1940s (Koopman, 1979). Limited research has been conducted on the influence of these factors. The appropriateness, or levels, of training of searchers and the status (physical fitness and mental alertness) of a search team may limit the chances of a successful search. This study identified that such variables may significantly impact the effectiveness of the SAR.

Impact of Physical and Mental Exertion Protocol

The study aimed to recreate the stressors of everyday life, overworking and levels of fatigue to establish the impact on SAR performance. To do this the authors established a physical and mental exertion protocol to complete during the Scenario Based Training. Thirty minutes prior to the Scenario Based Training, crews completed an exercise protocol at 86±1% of age-predicted heart rate max. Such an exercise intensity resulted in a 27.5% decline in perceptual recall and significantly slowed reaction time by 24.6msecs (Figure 4; $p=0.012$) compared to control crews. This indicated that the protocol induced both physical and mental exertion, aiming to recreate the stress experienced by the volunteer crew members upon receiving an emergency SAR call and arriving at the RNLI station.

Although both distracted (B) and exerted (C) crews experienced declines in search success compared to the control, the subsequent performance in the Scenario Based Training was only slightly impacted in the exerted crews (C). This was less so than hypothesised, where it had been presumed that the physical and mental exertion would degrade the performance when compared to control (A) and distracted alone (B). What the current study indicates is that, despite experiencing physical and mental exertion through the pre-SAR exercise, the crews still performed well cognitively prior to initiating the boat launch (as indicated by reaction time, Figure 4), but physiologically they were more stressed (as indicated by heart rate, Figure 3). This could indicate that the condition of the exertion protocol heightened their alertness (such as due to hypothalamic–anterior pituitary–adrenocortical axis (HPA) activation and the subsequent release of epinephrine) and therefore cognitively performed better as a result (Sünram-Lea, Owen-Lynch, Robinson, Jones, & Hu, 2012).

Performance success of SAR

During the Scenario Based Training, the average heart rate of all crews were between 66-72% of maximal heart rate which corresponded with the pre-SAR exertion protocol that required participants to exercise between a target heart rate of 70-90% maximal heart rate. This indicates that crews experience a moderate to high-intensity of physiological stress during the Scenario Based Training, but that all crew members were fairly well adapted to these conditions and that additional physical or mental exertion prior to the SAR did not significantly impact on their performance (Table 4). However, the highest physiological stress, as indicated by heart rate (Figure 3 and Figure 6), was seen in the 'distracted and exerted' crew (D) which was significantly different to all other conditions ($P<0.05$). This demonstrates that SAR success can be significantly impacted by the amalgamation of operational and personnel-related factors such as distraction, fatigue and over-working. This is especially important for those in voluntary SAR roles who may be on shifts following long working days, who are impacted by lack of sleep, personal life stress and stress linked to sudden alerts to an emergency call. This may also apply to those in retained (on-call) firefighter roles, or even wholetime firefighters responding towards the end of a busy set of shifts.

This finding was reiterated by the ranking (Table 4); when crews experienced both physical and mental exertion as well as distraction during the Scenario Based Training, there was a significant decline in search success. The 'distracted and exerted' crews (D) were least successful and only located 57% of targets (with 77% maximal heart rate) compared to 78% of the control crews (A, Table 4). The second least successful condition was the 'distracted' only crew (B) which also only located 57% of targets but were physiologically less stressed (as indicated by heart rate of 67% maximal heart rate). This was comparable to the 'exerted' only crew (C) but they were more successful in locating 70% of targets. This indicates that distraction is more impactful on search success over physiological exertion, but that both have implications, and that individuals experiencing a combination of both have a significant impact on success rates (Figure 7).

As may be expected, crews that were 'distracted', either by distraction alone (B), or exacerbated by physical and mental exertion (C) prior to the SAR (Tables 3 & 4), were less successful in the SAR response in comparison to the 'control' crew. However, the physical and mentally 'exerted' crew (C), were the *least* adversely impacted in their SAR success (7%).

This contradicts the initial hypothesis and may reflect a heightened alertness (e.g. released epinephrine) rather than inducing sufficient levels of fatigue. However, this is consistent with Fernández-Castillo and Gutiérrez Rojas (2009) who demonstrated individual-level stress and performance can improve attention. The findings of the main Scenario Based Training demonstrate a combination or increase in number of demands, such as the influence of teamwork and communication (Sonoda et al., 2018) can inhibit task attention (Robinson et al., 2013). Findings by McMorris et al.,(2011) have demonstrated that moderate-intensity activity (as seen in the current study) impacts the speed of response in working memory tasks and reduces accuracy in performance due to the increase in arousal levels. The increased release of glucocorticoids (specifically cortisol) in response to stressors, such as the physical and psychological demands experienced during 'live' SAR situations (Kaddoura, 2010), along with the aims of the current study design, may have resulted in increased circulating catecholamines (epinephrine and norepinephrine). These catecholamines can enhance the speed of neural transmission but may also have led to errors in judgement, either through omission or commission (Sandi, 2013).

Typically, physical and cognitive stress, and thus psychological stress, tends to also cause changes in heart rate and heart rate variability, where acute stress results in elevated heart rate response. Of additional interest was the decline in control group maximal heart rate (Figure 6) during the initial five minutes of the Scenario Based Training. This decrease, we hypothesise, may reflect the physical exertion of the SAR crew while manoeuvring their D-class lifeboat and subsequently entering the water. However, it is noteworthy that the crew managed to maintain a relatively calm state throughout the Scenario Based Training, as indicated by an average heart rate of 93.4±4.5 bpm (55% maximal heart rate).

Heart rate monitoring demonstrated that psychological stress and the physical challenges presented to the crews heightened physiological parameters. The heart rate of the crews showed that the exercise and distracted elements of the experiment had a measurable effect on the participants, and higher heart rates corresponded to poorer success in searching (Figure 7). Overall, the results showed that exercise and mental activity generally improved the perceptual performance of the crew, whilst the distracting element diminished performance.

This is the first study that indicates such implications on rescue crew team performance in high-pressure situations of a riverine SAR and provides knowledge and awareness of the importance of training to target managing both physical and cognitive stressors to improve skill and knowledge, although other studies have explored the role of simulation (Maran & Glavin, 2003). The implication is that emergency response organisations may consider the crewing levels, and role distribution within craft. It may be that the traditional role of "helm", where one individual is responsible for manoeuvring the vessel, all communications, as well as having overall command of the incident may need to be reconsidered. The National Operational Guidance for Incident Command (NOG, 2020) recognises that exceeding spans of control can lead to poor situational awareness and decision-making, and can contribute to a loss of control of an incident. This work provides additional evidence that excessive tasking ('distracting') on rescue craft may contribute to reduced incident command, and as such consideration should be given to roles and tasks within crews. Consideration may also be given to establishing additional levels of incident command away from the vessel itself, in order to provide a more holistic view of the incident, and reduce the task loading on the vessel commander.

Limitations

One factor that was not screened for, or taken into account, was the experience or skill level of the crews. Therefore, it is possible that crews that performed better on the runs may have been doing so as a result of factors other than exertion or distraction. There may also have been external environmental factors, such as light conditions, tidal conditions or river traffic – that may have had an impact on the search success. These factors would be difficult to eradicate but must be acknowledged between crews. Scenario Based Training was conducted in a randomised order for both conditions and crew order in order to mitigate the variables.

Additionally, the fitness level of participants was not assessed. Chang et. al, 2012 argue that cognitive function can be affected by physical fitness level, with higher fitness associated with improved cognitive function such as information processing and reaction time. However, all RNLI crew are routinely tested and classed as physically fit to be an active member.

Furthermore, cognitive disorders such as depression, and chronic personal levels of stress and mood were not established in the crews which may have impacted individual performance (Yaribeygi, Panahi, Sahraei, Johnston, & Sahebkar, 2017). Physiological measures of stress and arousal level were also not monitored during the study, therefore future studies should look to monitor both cognitive levels of stress and hormonal responses such as catecholamine response during Scenario Based Training, where glucocorticoid levels can impair attentional processes (Bohnen et al.,1990).

For this study, only a predetermined Scenario Based Training of 30 minutes in duration was utilised. However, it is important for further studies to investigate the long-term implications of SAR performance with longer searches. Typical callouts can include events that last beyond 4.5hours where additional fatigue, loss of concentration and focus may occur. Regarding the Teddington Lifeboat specifically, RNLI records show that the average response duration between 2007 and 2012 was 57.4 minutes with the maximum duration of 9.5 hours for one incident, with 282 incidents in total.

For the 'distracted' condition, a model that stressed external-intra-team forms of communication was utilised. However, with large multi-agency responses, individuals may require more mental bandwidth, and the need to retain information for longer and integrate it over a broader remit. The timely and accurate communication of individual, group, and environmental inputs are vital for collective success, with authors noting of aircraft crews "communication processes are of central importance to the group activities that rely on verbal exchanges and information transfer" (Kanki, 2019, p.120). As group complexity increases, so does the need to process and act on diverse sources of information and resources within, and outside, of the immediate team. The authors of the current study suggest the distraction model is appropriate for small-team use, but a more appropriate model should be developed to reflect the complexities of larger SAR operations.

Finally, it is also worth noting, that the participants of the RNLI crews are voluntary and aspects such as diet and pre-SAR conditions were not monitored or controlled, and findings may have been affected by underlying aspects beyond the scope of the study design. For example, caffeine and carbohydrates have been known to enhance cognitive performance (Lieberman, 2003). However, it was deemed appropriate to maintain the ecological validity of the study to replicate real-world conditions the RNLI crew members face at the time of a SAR call to simulate the typical demands put upon the attention of the crew.

These findings provide support for the efforts of the emergency services and emphasise the importance of considering confounding factors, such as physical and mental exertion, as well as distractions, when assessing search effectiveness. This is particularly relevant for responders who have to rapidly respond from their home or work environments. Furthermore, the findings underscore the significance of the appropriateness and levels of training of searchers, taking into consideration factors such as fatigue, and potential for overworking a search team, in order to improve the likelihood of a successful search (Covassin et al., 2007; Hancock & McNaughton, 1986). This may however, be difficult in a voluntary setting such as for the RNLI crew who are also managing personal and work commitments, and as such, approaches to mitigate such consequences should be investigated further.

Conclusion

The findings from this study indicate that increases in alertness and search performance have significant implications for those involved in SAR. The data overview suggests that distractions may have a greater influence on operational search success than exertion but that both conditions have significant implications for those involved in Search and Rescue. This study recommends the need to review emergency response organisation at crewing levels, and role distribution within craft. Consideration should include additional levels of incident command away from the vessel itself, in order to provide a more holistic view of the incident, and reduce the task loading on the vessel commander. This should be set against observations that individual crew performance may also be a significant contributing factor to the success of a mission that warrants further evaluation.

Future studies in the domain of riverine search and rescue performance could look at the effects of additional factors, such as dietary supplements, and mental training techniques such as mindfulness. Examining the effects of dietary supplements could demonstrate how specific nutrients or supplements may enhance cognitive abilities, endurance, or overall physical wellbeing, thus potentially influencing search and rescue operations. Furthermore, exploring the application of mental training techniques like mindfulness, could reveal their potential in improving focus, decision-making abilities, stress management, and overall mental resilience, all of which are crucial in the demanding and high-pressure situations encountered during riverine search and rescue operations.

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Author Biographies

Dr Hannah Jayne Moir is an Honorary Senior Fellow (Associate Professor in Health and Prescription) in the Department of Applied and Human Sciences, Faculty of Health, Science, Social Care & Education, at Kingston University London. Her expertise is in exercise physiology with an interest in occupational physiology. Her research examines the physiological, pathophysiological and psychological responses and recovery patterns to extreme physical challenges. She is also a Senior Medical Writer and Moderator for EMJ, London, a European medical journal.

Dr Alex Tasker is a Lecturer (Teaching) in Human Ecology in the Department of Anthropology at University College London. His expertise is in the combined influence of social, cultural, ecological, and biological drivers of health and performance, with a specific interest in marginalised and extreme populations. His biosocial research currently examines multi-dimensional drivers of health and disease linked to human-animal contact in forced migration settlements.

Christopher C.F. Howe is Research and Innovation Lead for ai.io, a technology company providing solutions to generate and analyse amateur and professional sport data, and also Researcher in Sport and Exercise Physiology in the Faculty of Health, Science, Social Care and Education, at Kingston University London. His expertise is in psycho-physiology of extreme environments and endurance performance.

Dr Ian Greatbatch is a fire officer, Visiting Researcher at the University of Portsmouth and formerly Associate Professor at Kingston University London. His research concerns the operational effectiveness of Search and Rescue and Fire and Rescue Operations.

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