INDEPENDENT TESTING OF BUOYANCY AIDS AND SURF HELMETS FOR SURF LIFE SAVING AUSTRALIA

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EXECUTIVE SUMMARY

Previous research has identified that 90% of surf beach drowning deaths in Australia over a four-year period (2002-2005) involved surf craft or the victims swimming or wading. Research from the United States identified that for boating activities, 49% of drowning deaths could be prevented if the victims had been wearing a personal floatation device (PFD), although of those victims that were wearing a PFD, 45% drowned. In surf lifesaving, participants are required to undertake numerous occupational lifesaving activities that comprise swimming, paddling or rowing a surf craft that are physiologically, highly demanding. To date, no research has explored the use of personal protective equipment (PPE) such as buoyancy aids and surf helmets within lifesaving activities.

Forty-five (N = 45; males = 27, females = 18) active, financial and proficient members of Surf Life Saving Australia (SLSA) affiliated surf lifesaving clubs in the Sydney region volunteered to take part in this study and were pre-screened for any contra-indications . Participants were randomly allocated to each of the seven (7) buoyancy aids (BA) and a control condition. Within each of the BA trials, surf helmet (BA-H) allocation was also randomised for each of the 13 submitted surf helmets. All trials were held in Sydney, New South Wales during October with each participant completing as many trials as possible within the allocated time, and ceased activities when physically unable to complete any further tasks due to fatigue or cold and/or upon their choice.

Participants completed standard and familiar lifesaving activities commensurate with their previous lifesaving training and in accordance with SLSA policies regarding surf craft. These activities included swimming (both in a salt-water pool and in the ocean), duck diving (both in the pool and in the ocean), board paddling of their specific board at a comfortable pace (e.g. nipper or Malibu racing boards), and surfboat rowing at a comfortable pace. All pool-based tasks where completed as quickly as was comfortable while the ocean-based activities were completed at a comfortable pace to ensure specific task requirements were completed. As per the research project design, all participants were randomly allocated to a BA only, BA-H combination and control condition for each of the tasks in accordance with participant's availability, testing session specifics or SLSA policies.

Firstly, a number of PPE did not fit participants when following the manufacturer's recommendations. Secondly, all tasks completed whilst wearing PPE were more *uncomfortable* and required more effort than the corresponding control conditions. For the ocean based lifesaving activities, participants found the BA only condition more *uncomfortable* and required more effort than the corresponding BA-H condition as a group. However, examination of individual buoyancy aids often identified BA was worse than the BA-H condition. These findings in conjunction with technical expertise should form the basis for modifications to current PPE to ensure correct PPE fit for users, reduce the effort required and increase comfort when completing lifesaving activities.

Participant feedback during PPE use identified a number of design shortcomings such as inappropriate distribution of buoyancy that impeded the technical ability of task completion, reduced paddler stability while paddling surfboards, reduced paddler confidence in negotiating waves and irritation such as rubbing or chaffing. Specific impediments of technical ability during task completion included the PPE riding up and remaining out of place, impaired hearing and vision as well as the PPE often becoming too restrictive due to its weight or movement. The PPE assessed in the current study appeared to be more *uncomfortable* and resulted in a substantial increase in the effort required to complete simple, standard lifesaving activities for active and proficient lifesavers.

As a result of the current project, a number of recommendations were made to SLSA including the potential revision of buoyancy requirements for lifesaving activities (currently governed by ISO 12402) and establish an expert advisory panel who, along with SLSA, work with manufacturers to modify PPE design as well as potentially identify appropriate and lifesaving task-specific PPE. Potential modifications should focus on buoyancy placement and flexibility; garment fit and limiting any hearing or sight impairments. Future research should also explore the physiological demands of lifesaving activity completion of different intensities, durations and environments with current or modified PPE.

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1.0 INTRODUCTION

Surf Life Saving Australia (SLSA) has proposed including compulsory personal protective equipment (PPE) in to surf lifesaving activities in direct response to the Coroner's report in to the tragic death of a competitor at the 2010 Australian Championships. The recommendation from the Coroner's report sought SLSA to collaborate with manufacturers of relevant PPE (such as buoyancy aids and surf helmets) with a view to mandate their use once the governing body had satisfactorily completed the relevant testing of such PPE.

In Australia, 16% (n = 20) of surf beach drowning deaths over a four year period (N = 129; 2001-2005) involved surf craft while 74% (n = 95) involved swimming or wading activities.[1] In a study of 625 vessels and 878 drowning deaths while boating in the United States (US), it was suggested that wearing a personal floatation device (PFD) would reduce drowning deaths by 49% (a risk ratio of 0.51).[2] Additionally, in the same cohort, 45% of those who were wearing a PFD drowned compared with 58% of those who did not wear any PFD.[2] The notion of floatation devices for surf craft users is not new [3] however, few studies have explored the concept.

One study that utilised a torpedo buoy as a rescue device investigated the physiological requirements to undertake a simulated rescue with and without the rescue device.[4] Although the torpedo buoy was not specifically categorised as PPE and was not worn by the rescuer, the simulated rescue parallels the purpose requirements for surf lifesaving activities to be undertaken during routine activities. This study highlighted the significant physiological demands of performing a simulated rescue in wave conditions and specifically identified delays in reaching the person being rescued as a result of towing the torpedo buoy although floatation advantages were observed when towing the victim back to shore with waves.[4]

In a study of 50 kayaking incidents in New Zealand between 1992 and 2005, 82% of victims were wearing a PFD with a more severe injury associated with not wearing a PFD (injury rating of 7 vs. 5 with a PFD) as subjectively rated (0 and 10 where 10 denotes fatal).[5] Additionally, eight of the 14 fatalities in the study were reported to have been wearing a PFD, while four were not wearing a PFD and two were unreported. More recently,[6] three white-water kayaking deaths were observed to have a distinct similarity in that all victims were wearing bicycle helmets, rather than rafting or white-water kayaking helmets. This similarity highlights the importance for PPE to be purpose specific for water-based activities that are unique in nature such as lifesaving activities. Additionally, whilst it is acknowledged that helmets reduce the risk of head injuries, they must be worn as designed (i.e. fit for purpose) and must not result in any secondary complications.[6]

1.1 AIM OF THE RESEARCH

The aim of this research project was to evaluate the *fit for purpose* suitability of identified personal protective equipment (PPE) for selected tasks within specific aquatic, non-powered lifesaving craft activities such as board paddling, surf ski paddling and surfboat rowing under simulated operational conditions.

2.0 METHODS

2.1 PARTICIPANTS

Forty-five participants (N = 45; males = 27, females = 18) volunteered to take part in this project with descriptive characteristics presented (Table 1). All participants were active, financial and proficient members of Surf Life Saving Australia affiliated surf lifesaving clubs in the Sydney region and were pre-screened for any contra-indications to participation in the study as per the James Cook University Human Research Ethics Sub-Committee approval of experimental protocols and procedures. Participants were actively recruited via SLSA project leaders using documentation provided by James Cook University and were provided with incentives for their participation in the form of generic shopping vouchers ($100) provided by SLSA.

Table 1: Mean (±SD) participant characteristics (N = 45)

Variable	Nippers	Juniors	Seniors	Masters
Number of participants (n)	11	7	18	9
Age (years)	12.2 ±1.4	15.3 ±1.3	22.4 ±5.0	43.7 ±12.9
Height (m)	1.52 ±0.10	1.72 ±0.11	1.81 ±0.07	1.81 ±0.09
Body mass (kg)	43.2 ±10.5	73.0 ±5.3	84.2 ±16.8	81.8 ±11.2

NB: Age classifications were as follows: Nippers (≤14yr); Juniors (14-18yr); Seniors (18-29yr); Masters (≥30yr)

2.2 EXPERIMENTAL PROCEDURES

All participants were randomly allocated to each of the seven (7) buoyancy aids (BA) and a control condition; within each of the BA trials, surf helmet (H) allocation was also randomised for each of the 13 offered surf helmets. All PPE was allocated a code for randomisation (Appendix A). All trials were held in Sydney, New South Wales during October with pool-based assessments conducted at the Andrew (Boy) Charlton Aquatic Centre, Woolloomooloo Bay; the ocean-based assessments were conducted at Green Hills, Wanda Beach. Each participant completed as many trials as possible within the allocated time, and ceased activities when physically unable to complete any further tasks due to fatigue or cold and/or upon their choice.

2.2.1 Lifesaving tasks being assessed

Participants completed standard, familiar lifesaving activities commensurate with their previous lifesaving training and in accordance with SLSA policies regarding surf craft. An overview of those tasks included:

- Freeboard – participants were required to float vertically and horizontally in the salt-water filtered pool to assess buoyancy of the PPE being assessed;
- Swimming – participants were required to swim 25m in the salt-water filtered pool as quickly as possible as well as complete a number on “in’s and out’s” at the ocean venue;
- Duck diving – participants were required to duck dive in the salt-water filtered pool to retrieve 3 (if ≤18yr) or 5 (if ≥18yr) bottom fixed objects as quickly as possible as well as during a number on “in’s and out’s” at the ocean venue;
- Board paddling – participants were required to undertake a number of defined skills while paddling their specific board at a comfortable pace (e.g. nipper or Malibu racing boards);

- Surf ski paddling – participants were required to undertake a number of specific skills while paddling their surf ski at a comfortable pace;
- Surfboat rowing – participants were required to undertake a number of specific skills while rowing their surfboat at a comfortable pace.

As per the project design, all participants were randomly allocated to a BA only or BA-H combination or a control condition for each of the tasks the participant was able to complete due to equipment availability, testing session specifics or SLSA policies. A detailed matrix of the number of times each PPE were assessed per task is provided in Appendix B.

Please note that due to only one participant (n = 1) volunteering for the surf ski discipline, and the inexperience of this participant with this craft, this data was not included as it was insufficient for conclusions.

2.2.2 Experimental standardisation

Upon arrival at each of the testing venues, participants were provided with an overview of the protocols to be undertaken by the research team. More specific details of each task were conveyed to each participant at the commencement of those tasks to ensure the participant understood their requirements and that the tasks were satisfactorily completed.

Experimental conditions were standardised at the salt-water pool with the swimming distance being set as the 5m to 30m area of the deep end (i.e. to ensure that the pool walls or bottom were not used for pushing off); the duck diving zones remained constant for depth by remaining in the same designated area for all participants. At the ocean venue, testing sessions were separated into morning (0900-1200) and afternoon (1300-1600) testing sessions which equated to local tides of Saturday (Low tide: 0.56m at 0729; High tide: 1.58m at 1400) and Sunday (Low tide: 0.56m at 0845; High tide: 1.58m at 1514). Surf conditions remained relatively constant for the duration of each session although there were slight differences between morning and afternoon sessions but not dissimilar between days.

All PPE were assessed for a suitable fit by the researcher and the participant in accordance with manufacturer's guidelines and specifications. All buoyancy aids were assessed by weight category designated by the manufacturer. Additionally, where required and available, additional padding specific to the surf helmet brand and style were included or removed in order to attain an appropriate fit. The same researcher assessed fit for uniformity for all trials with the head "up-down-left-right" movement sequence conducted to assist with suitable fit for the surf helmets.

All participants were given the opportunity to provide feedback in relation to the PPE worn. Additionally, when participants provided further explanations, researchers documented these comments in their response (Appendices C and D). The number of occasions a surf helmet or buoyancy aid did not fit a participant are also documented in Appendices C and D.

2.3 - Experimental Protocols

2.3.1 - Anthropometric measures

Participant's heights (m) were recorded to the nearest 0.01 m using a portable stadiometer (Handy Height Scale, Mentone Educational Center, Australia) where possible or self-reported (e.g. beach testing). Body mass (kg) was recorded with participants in minimal clothing (their swimsuit) via electronic scales (Tanita TBF-521, Tanita Corporation, Tokyo) to the nearest 0.1 kg. This body mass measurement was then used to assist the fitting of PPE for testing. Mean results for the assessed population are provided in Table 1.

2.3.2 - BA Equipping and Freeboard assessments

The ease of donning and removing a wet BA was evaluated by observing participants donning/removing procedure with time for donning/removal recorded manually (Sports timer 898, Hart Sports, Australia) within a maximum limit of 1 minute (adults) and 1.5 minutes (children).

For freeboard assessments, participants entered the salt-water filtered pool and were requested to float vertically with their legs off the bottom of the pool or on their backs (horizontal) while measurements of clearance were taken. Clearance between water surface and the lowest point of respiration above the water were recorded in duplicate via the alignment of an opaque measuring stick. Where the two measurements were different by ±5%, a third trial was recorded with the average of the two closest values used for reporting purposes.

2.3.3 - 25m swim and duck diving

Participants completed two trials (BA only and BA-H) of swimming 25m and another two trials (BA only and BA-H) of duck dives for each BA and control condition with times (sec) manually recorded (Sports timer 898, Hart Sports, Australia). For the swimming task, participants commenced on the "Go" command with time recorded when the hand of the swimmer reached the 25m mark (i.e. flagged area at one end of the pool) or the 30m mark depicted by a marker cone. For the duck diving task, participants commenced on the "Go" command with time recorded when the final object was visible above the water (participants were required to hold up and show each retrieved item).

2.3.4 - Psychophysical measures

Psychophysical measures of perceived comfort and effort exerted were recorded from participants following the completion of each of the various tasks. Each measure was assessed using a question designed to elicit a subjective measure of their perceptions *at the time of that particular task*.

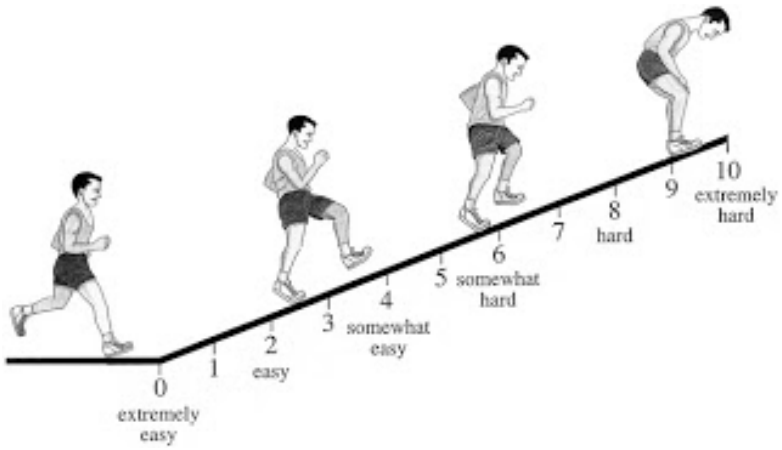
2.3.4.1 - Comfort scale

The comfort of completing a task while wearing the BA only or BA-H ensembles as well as the control condition were assessed via a modified 9-point scale (shown below) where participants were asked to quantify their response to the question "*How do you feel completing that task wearing what you are wearing*?" This scale was adapted from that previously used to assess a person's comfort under various environmental conditions.[7]

1.0 Comfortable
1.5
2.0 Slightly uncomfortable
2.5
3.0 Uncomfortable
3.5
4.0 Very uncomfortable
4.5
5.0 Extremely uncomfortable

2.3.4.2 - Rating of perceived effort scale

Participants were asked to rate their level of effort required to complete the various tasks while wearing the BA only or BA-H ensembles as well as the control condition via the OMNI scale (shown below).[8] The OMNI scale was preferred for its previous use with children as well as adult participants when performing progressively incremented laboratory-based exercise protocols.[8] Participants were asked to quantify their response to the question "*How much effort did that task take while wearing what you are wearing*?"



2.3.4.3 - Polar questions: board-paddling task

Participants were asked for their perception of whether the BA only or BA-H ensembles influenced their ability to complete a number of tasks. Participants were asked to quantify their response to the questions with a "Yes" or "No" response as well as provide any additional details for the following:

- *"Did you perceive any difference in the way you negotiated the waves (paddling out the back of the break as well as returning to the beach) while wearing what you were wearing?"*
- *"Did you perceive any difference in your stability while paddling wearing what you were wearing?"*

2.4 Statistical Analyses

Data analysis was conducted using the IBM Statistical Package for Social Sciences (IBM SPSS Statistics v.19, SPSS, Chicago, USA). Differences between BA and BA-H for the time to complete the 25m swim, the duck diving tasks, and the perceived ratings for comfort and effort for each of the tasks assessed were examined using paired-samples T-test or Wilcoxon signed-rank test where appropriate. The level of significance to identify differences was set at 0.05 and all values are presented as mean $\pm$ SD.

3. Results and Discussion

3.1 Freeboard and equipping BA

Mean freeboard assessments were similar (Table 2) amongst the various BA with a group average horizontal freeboard of 9.2 ±2.6cm (range: 3-14cm) and vertical freeboard of 11.0 ±2.1cm (range: 6-16cm) suggesting adequate clearance between the water's surface and lowest point of a participant's respiration above the water.

A number of participants were unsuccessful in putting on or removing their BA (8.3% of all assessments) with participants having difficulties donning or removing BA1 (26.7%), BA2 (12.5%), BA6 (11.8%) and BA4 (8.0%). Additionally, researchers were unable to equip participants with a BA on 12 occasions (Appendix B) due to failure of the BA to satisfactorily fit participants as per manufacturer's guidelines and body weight stipulation.

Table 2: Mean (±SD) measurements for participants performing the freeboard tasks

	Freeboard			Donning BA				Removing BA			
	N	Horizontal (cm)	Vertical (cm)	**N**	Time (sec)	RPE	**X**	**N**	Time (sec)	RPE	**X**
BA1	*18*	8.1 ±2.3	11.3 ±2.0	*6*	14.3 ±2.5	6.1 ±2.7	**3**	*9*	6.5 ±4.1	3.1 ±3.1	**1**
BA2	*21*	8.2 ±2.3	11.1 ±1.7	*12*	22.6 ±13.9	6.2 ±2.7	**1**	*12*	22.6 ±18.1	6.8 ±2.8	**2**
BA3	*17*	7.6 ±2.1	11.2 ±2.0	*6*	20.1 ±15.3	5.0 ±3.0	**0**	*7*	3.5 ±1.4	1.9 ±0.9	**0**
BA4	*17*	9.9 ±2.1	11.1 ±2.0	*12*	11.8 ±3.9	3.6 ±1.6	**2**	*13*	12.3 ±8.1	4.2 ±2.2	**0**
BA6	*17*	8.4 ±2.3	10.7 ±2.6	*9*	22.1 ±14.5	6.0 ±1.9	**0**	*8*	29.7 ±18.2	8.3 ±1.7	**2**
BA7	*21*	7.9 ±2.6	10.7 ±2.2	*10*	8.3 ±2.7	1.8 ±1.5	**0**	*10*	5.6 ±3.1	1.3 ±1.4	**0**
BA8	*17*	8.2 ±2.2	11.0 ±1.9	*9*	24.8 ±10.1	4.1 ±1.7	**0**	*9*	8.1 ±2.0	2.7 ±1.7	**0**

N = number of times that BA was assessed for that task; X = number of participants unable to complete the task

3.2 - The closed, flat-water environment

3.2.1 - 25m swimming task

The mean time to swim 25m in a flat-water environment was longer while wearing only a BA or BA-H ensemble when compared to the control condition for most BA assessed ($p<0.05$; Figure 1). There was no significant differences between BA-H ensemble or BA only for time taken to complete the 25m swim ($p>0.05$; Figure 1). When all BA and all BA-H were compared to each other, there was a significant difference in the time taken to swim 25m (21.7 ±4.0 sec vs. 22.0 ±2.9 sec; $p>0.05$). However BA-H was both significantly more *uncomfortable* (3.3 ±1.0) and required more effort (5.0 ±1.8) than a BA only (2.9 ±1.0 and 4.2 ±1.8, respectively; $p<0.05$). On average, the control condition was faster (19.9 ±2.1 sec), more *comfortable* (1.0 ±0.0) and required less effort (1.0 ±0.8) than both the BA and BA-H conditions for the 25m swimming task.

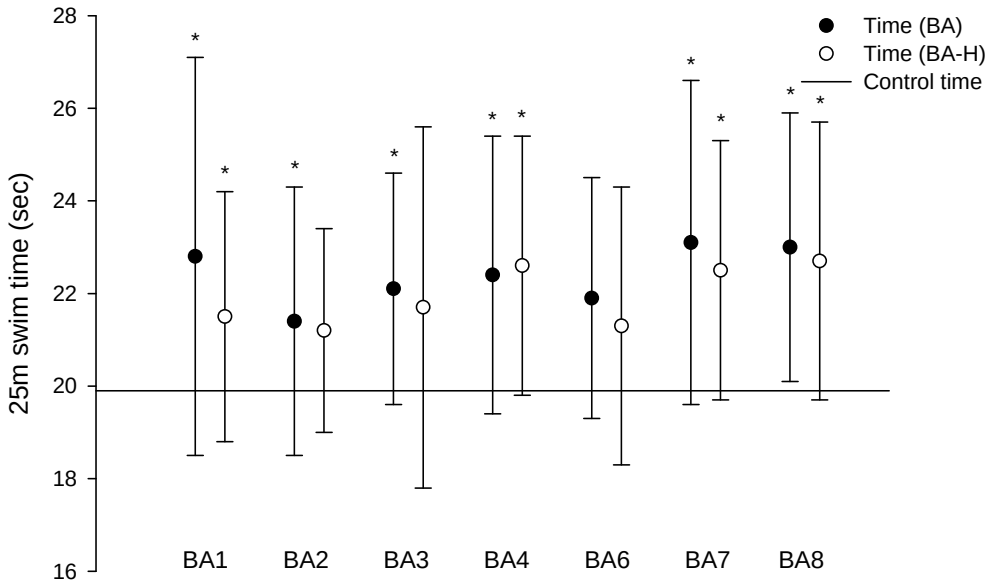


Figure 1. Mean (± SD) time to complete a 25m swim in a flat-water environment for BA only and BA-H. *p<0.05, slower than the control condition.

Table 3 illustrates that participants felt it was significantly more *comfortable* and an easier effort with the BA only condition compared to the BA-H (BA4; p<0.05) or just significantly easier (BA2, BA3 and BA6; p<0.05) when swimming 25m in a closed, flat-water environment. Interestingly, despite feeling more *comfortable* in BA only (BA4), this did not translate to participants perceiving their effort to be any easier than that of the BA-H condition (p>0.05). Conversely, those BA that were perceived to require less effort for the swimming task (BA2, BA3 and BA6) did not appear more *comfortable* with or without the surf helmet suggesting the influence of the surf helmet to be minimal in relation to comfort and the effort required to complete the task.

In regards to the surf helmet, the "peak" of a surf helmet has been anecdotally suggested to defer water from the face once the head becomes elevated. However, numerous comments were provided by participants (Appendix D) who collectively suggest a "peak" may negatively influence a swimming task due to restricted vision, dragging the head down and feeling that the water was more turbulent over their face whilst swimming.

3.2.2 - Duck diving task

The time taken to complete the duck diving tasks were significantly slower for three BA-H conditions (BA1, BA2 and BA7) and one BA only condition (BA7) than the control condition (Figure 2). However, there were no differences between the BA only condition and the BA-H condition when grouped together for any of the buoyancy aids (p>0.05; Figure 2).

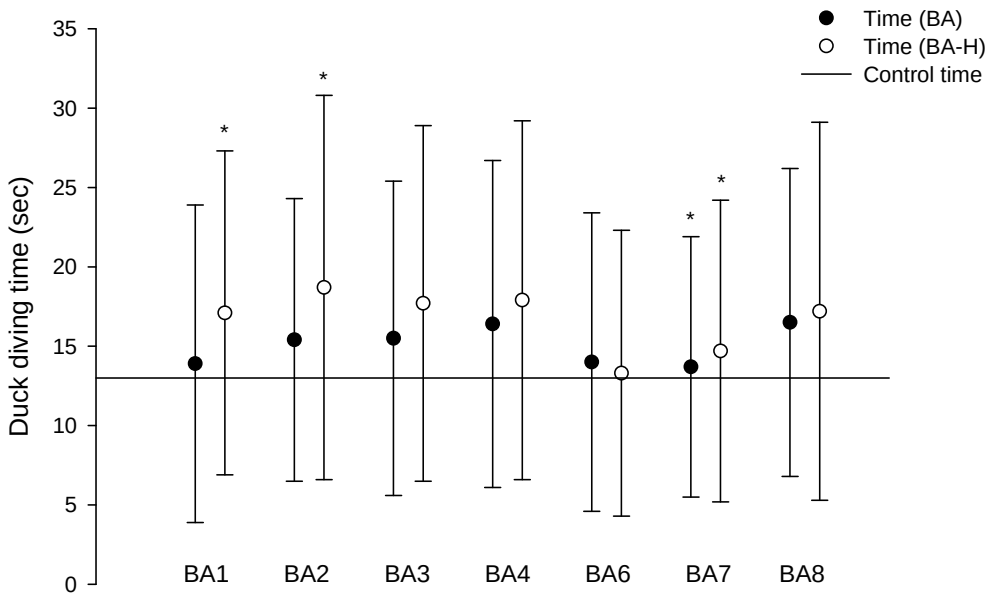


Figure 2. Mean (± SD) time to complete the duck diving tasks in the flat-water environment for the two trials: BA only and BA-H. *p<0.05, slower than the control condition.

Table 3: Mean (±SD) ratings of perceived comfort and effort (RPE) of the participants performing the pool-based tasks

		Swimming 25m				Duck diving			
		Comfort		RPE		Comfort		RPE	
	N	BA-H	BA only	BA-H	BA only	BA-H	BA only	BA-H	BA only
BA1	*32*	2.9 ±1.1	2.8 ±1.1	4.7 ±2.4	3.8 ±1.7	2.8 ±1.1	2.5 ±0.6	4.8 ±2.3	4.2 ±1.3
BA2	*39*	3.2 ±0.9	2.8 ±0.9	5.2 ±1.6	4.3 ±1.6*	3.4 ±1.1	2.5 ±0.9*	5.5 ±2.3	4.3 ±1.8
BA3	*30*	3.4 ±0.9	2.7 ±0.8	5.1 ±2.0	4.3 ±2.1*	3.2 ±0.7	2.5 ±0.9	4.7 ±2.0	3.6 ±2.0
BA4	*38*	3.4 ±1.1	3.0 ±1.1*	4.6 ±1.9	4.1 ±1.9	3.3 ±1.0	2.8 ±1.1*	5.1 ±2.3	4.4 ±2.3*
CONTROL	*22*	1.0 ±0.0		1.0 ±0.8		1.1 ±0.3		1.2 ±1.2	
BA6	*32*	3.1 ±0.7	2.8 ±0.6	4.5 ±1.2	3.9 ±1.3*	2.9 ±0.6	2.4 ±0.6*	4.6 ±1.6	3.4 ±1.5*
BA7	*38*	3.7 ±1.1	3.5 ±1.0	5.4 ±1.7	5.1 ±1.9	3.0 ±0.7	2.8 ±0.7	4.2 ±1.2	4.2 ±1.3
BA8	*35*	3.5 ±1.1	3.5 ±1.0	5.3 ±1.8	5.1 ±1.6	3.5 ±0.9	3.1 ±1.0*	5.4 ±1.7	4.5 ±1.7*

Comfort: 1 = Comfortable, 5 = Extremely uncomfortable; RPE: 0 = Extremely easy, 10 = Extremely hard; * p <0.05, less than BA-H condition; N = number of times that BA was assessed for that task

Participants reported the duck diving task as being more *comfortable* during the BA only conditions for half of those assessed (BA2, BA4, BA6 and BA8; Table 3) as well as an easier effort for BA4, BA6 and BA8

(p<0.05; Table 3). On average however, it took longer to duck dive for the BA-H condition (16.6 ±10.3 vs. 15.7 ±9.6 sec; p<0.05) suggesting that the BA-H condition was more arduous when retrieving the items from the bottom of the pool at a depth of 1m (<18 yr) or 2m (>18yr). Additionally, participants felt significantly more *uncomfortable* for the BA-H condition (3.2 ±0.9) than BA (2.6 ±0.9; p<0.05) although there was no difference in the participant's perceived effort during the task (BA: 3.9 ±1.9 vs. BA-H: 3.8 ±2.7 sec; p>0.05). On average, the control condition was faster (13.0 ±7.4 sec), more *comfortable* (1.1 ±0.3) and required less effort (1.2 ±1.2) for the duck diving task compared with the BA and BA-H conditions.

3.3 - THE OPEN WATER ENVIRONMENT

3.2.1 - Ocean swimming

Participants perceived their effort to be greater during entering (4.7 ±2.1 vs. 3.9 ±3.2; p<0.05) and exiting (4.9 ±2.1 vs. 3.8 ±3.3; p<0.05) the ocean for their ocean swim when wearing only a BA as well as finding the BA condition more *uncomfortable* when exiting the water (2.9 ±1.1 vs. 2.4 ±2.0; p<0.05) compared to the BA-H condition. For the control condition, participants were more *comfortable* and required less effort when entering and exiting the water compared with the BA and BA-H conditions (Table 4). There were no differences between BA and BA-H conditions for the ocean swimming tasks.

Table 4: Mean (±SD) ratings of perceived comfort and effort (RPE) of the participants entering and exiting the water during the ocean swim task

		Entering the water				Exiting the water			
		Comfort		RPE		Comfort		RPE	
	N	BA-H	BA only	BA-H	BA only	BA-H	BA only	BA-H	BA only
BA1	*31*	3.8 ±1.2	2.7 ±0.8	6.2 ±2.2	4.5 ±1.5	3.8 ±1.3	2.7 ±1.0	6.5 ±2.4	4.6 ±2.0
BA2	*33*	3.0 ±1.1	2.8 ±1.1	4.9 ±2.2	4.8 ±1.8	3.1 ±1.1	2.7 ±1.2	5.0 ±2.5	4.9 ±2.0
BA3	*34*	3.6 ±1.2	2.6 ±1.1	5.7 ±1.6	4.2 ±2.0	3.3 ±1.2	2.7 ±1.1	5.1 ±1.5	4.2 ±1.8
BA4	*32*	4.0 ±1.1	3.5 ±1.1	6.5 ±2.2	5.3 ±2.1	4.0 ±1.1	3.4 ±1.2	6.9 ±2.0	5.3 ±2.4
CONTROL	*25*	1.0 ±0.0		1.4 ±1.8		1.0 ±0.0		1.5 ±2.0	
BA6	*30*	3.7 ±1.0	2.5 ±1.1	5.3 ±2.1	4.2 ±1.8	3.5 ±1.1	2.4 ±1.1	5.6 ±2.4	4.2 ±1.9
BA7	*27*	4.0 ±0.9	3.2 ±1.0	6.1 ±1.4	5.4 ±2.5	3.9 ±0.9	3.4 ±0.9	6.2 ±1.8	5.5 ±2.3
BA8	*32*	3.9 ±1.1	3.7 ±1.0	5.8 ±2.2	5.7 ±2.0	4.0 ±1.2	3.7 ±1.0	5.9 ±2.3	6.0 ±2.1

N = number of times that BA was assessed for that task; Comfort: 1 = Comfortable, 5 = Extremely uncomfortable; RPE: 0 = Extremely easy, 10 = Extremely hard;

The results from the open-water swimming tasks contradict those of the 25m swim where the BA only condition was favoured over that of BA-H despite having similar ratings of perceived efforts. The open-water environment was more dynamic than that of the pool which may have contributed to participants being more focused on the task at hand including negotiating the waves going in and coming out of the ocean. Three (3) participants did not wish to continue with their board paddling tasks once they had completed the ocean swimming tasks with another uncomfortable with their helmet (H10).

Participant comments regarding the BA designs in relation to surf swimming identified complications with negotiating waves, BA riding up as a result of the turbulent water and providing too much buoyancy, as well as design imperfections such as BA rubbing under the arms and being firm about the body but riding up at the shoulders (Appendix C).

3.2.2 - Board paddling

When paddling their surfboards, participants perceived their effort to be greater in the prone (4.6 ±2.1 vs. 3.0 ±2.9; $p<0.05$) and kneeling positions (4.3 ±2.4 vs. 2.9 ±2.9; $p<0.05$) when wearing only a BA. Additionally, participants felt more *uncomfortable* in the BA only condition for the prone (3.0 ±1.2 vs. 2.1 ±1.9; $p<0.05$) and kneeling positions (2.8 ±1.4 vs. 2.0 ±1.9; $p<0.05$) compared to the BA-H. Further differences between BA and BA-H for comfort and effort are shown in Table 5. When transitioning between the kneeling and prone positions, participants felt more *uncomfortable* (2.7 ±1.4 vs. 1.8 ±1.8; $p<0.05$) and that it required more effort (4.1 ±2.3 vs. 2.8 ±2.6; $p<0.05$) in the BA only condition. Additionally, participants were more *comfortable* and required less effort during the control condition of board paddling tasks compared with both the BA and BA-H conditions.

Table 5: Mean (±SD) ratings of perceived comfort and effort (RPE) of the participants when paddling their surfboard in the prone (all boards) and kneeling (Malibu and rescue boards only) position during the board paddling task

		Prone paddling				Paddling on knees†			
		Comfort		RPE		Comfort		RPE	
	N	BA-H	BA only	BA-H	BA only	BA-H	BA only	BA-H	BA only
BA1	*29*	3.5 ±1.1	2.6 ±1.0	4.9 ±1.6	3.7 ±1.3	3.3 ±1.1	2.9 ±0.9	5.0 ±2.0	4.5 ±1.7
BA2	*35*	2.9 ±1.1	2.7 ±0.8	4.5 ±1.6	4.4 ±1.2*	3.0 ±1.1	2.9 ±1.0	4.6 ±2.1	4.7 ±1.7*
BA3	*27*	3.4 ±1.1	2.6 ±1.0*	5.4 ±2.1	4.0 ±1.9	3.4 ±1.1	2.7 ±0.9	5.7 ±2.3	3.7 ±1.7
BA4	*30*	3.8 ±1.3	3.4 ±1.3	5.8 ±2.8	5.1 ±2.2	3.7 ±1.3	3.2 ±1.3	5.6 ±2.9	4.8 ±2.1
CONTROL	*27*	1.0 ±0.1		1.7 ±2.0		1.0 ±0.0		1.3 ±1.3	
BA6	*28*	3.5 ±1.0	2.7 ±1.1	5.0 ±1.7	3.6 ±1.8	3.7 ±1.2	3.0 ±1.0	5.2 ±1.9	4.1 ±1.9
BA7	*27*	3.9 ±0.9	3.6 ±0.9	5.1 ±1.8	5.4 ±2.2	3.8 ±0.9	3.7 ±1.0	5.3 ±2.1	5.5 ±1.9
BA8	*29*	3.9 ±0.7	4.0 ±0.7	5.6 ±1.6	6.4 ±1.6*	3.6 ±0.7	3.7 ±0.7	5.5 ±1.7	6.1 ±1.8

† Nipper boards (no kneeling): BA1 (n=3); BA2 (n=3); BA3 (n=4); BA4 (n=2); Control (n=4); BA6 (n=3); BA7 (n=2); and BA8 (n=1). Comfort: 1 = Comfortable, 5 = Extremely uncomfortable; RPE: 0 = Extremely easy, 10 = Extremely hard; * $p<0.05$, significantly different to the same BA-H for that task

During the BA-H condition, participants felt more unstable (1.7 ±0.5 vs. 0.9 ±0.8; $p<0.05$; Figure 3) and had greater difficulties negotiating the waves both entering and exiting the water (1.7 ±0.4 vs. 1.5 ±1.9; $p<0.05$; Figure 4) compared to when wearing BA only. When comparing individual BA, the opposite appears to be more common with the BA-H condition influencing the participants ability to negotiate waves for five of the seven assessed BA (i.e. BA1, BA2, BA3, BA4 and BA6; Figure 4).

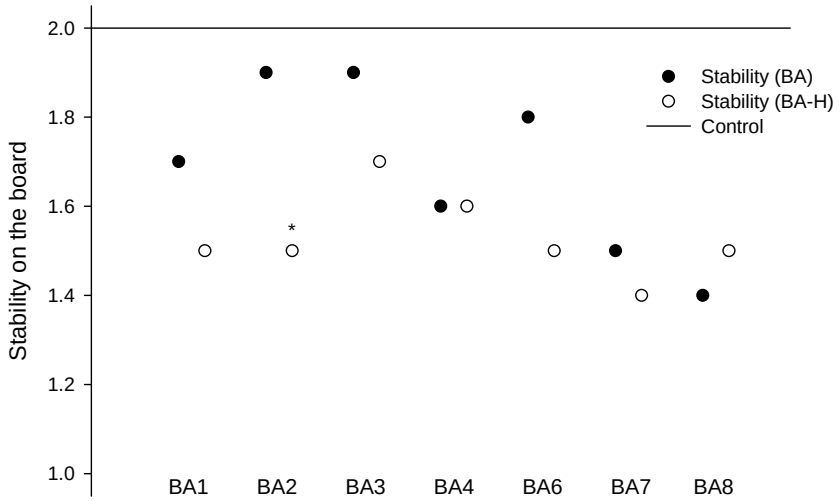


Figure 3. Mean perceptions of stability during the open-water environment, board-paddling task for the two trials: BA only and BA-H. 1 = the participant had issues with stability which they perceive were related to what they were wearing; 2 = they did not have any issues with stability. *p<0.05 significantly less stable than with BA only

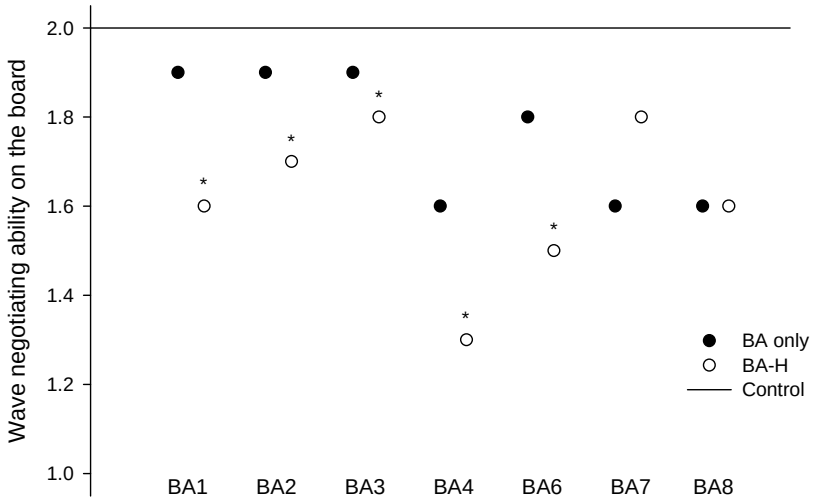


Figure 4. Mean perceptions of the participant's ability to negotiate the waves (in and out) during the open-water environment, board-paddling task for the two trials: BA only and BA-H. 1 = the participant had issues with negotiating the waves which they perceive were related to what they were wearing; 2 = they did not have any issues with negotiating the waves. *p<0.05 significantly less confident than BA only

When participants were required to roll their board (under a wave or in flat conditions), they felt more *uncomfortable* (2.7 ±1.1 vs. 1.8 ±1.7; p<0.05; Table 6) and perceived that it required more effort (4.1 ±2.1 vs. 2.7 ±2.7; p<0.05; Table 6) in the BA only condition compared to the BA-H condition. Similarly, when required to remount the board following the roll, participants felt more *uncomfortable* (2.7 ±1.1 vs. 1.8

±1.6; $p<0.05$) and that it required more effort (4.2 ±2.0 vs. 2.8 ±2.6; $p<0.05$) in the BA only condition compared to the BA-H condition.

Table 6: Mean (±SD) ratings of perceived comfort and effort (RPE) of the participants when negotiating waves and in reference to their stability during the board paddling task

		Rolling under a wave				Remount the surfboard			
		Comfort		RPE		Comfort		RPE	
	N	BA-H	BA only	BA-H	BA only	BA-H	BA only	BA-H	BA only
BA1	*29*	3.0 ±1.2	2.7 ±0.9*	4.3 ±1.7	3.7 ±1.4	2.8 ±1.1	2.6 ±0.9*	4.3 ±1.6	3.7 ±1.4*
BA2	*35*	2.7 ±0.9	2.7 ±1.0*	4.2 ±1.9	4.4 ±1.2*	2.7 ±1.0	2.6 ±0.9	4.1 ±1.7	4.2 ±1.5*
BA3	*27*	3.3 ±1.3	2.3 ±0.9	5.0 ±2.6	3.5 ±2.0	3.2 ±1.2	2.6 ±1.0	4.4 ±2.4	4.1 ±2.2*
BA4	*30*	3.3 ±1.1	3.0 ±1.1	5.2 ±2.3	5.1 ±2.2	3.2 ±1.2	3.2 ±1.3	4.7 ±2.5	4.8 ±2.1
CONTROL	*27*	1.1 ±0.3		1.6 ±1.5		1.1 ±0.2		1.6 ±1.6	
BA6	*28*	3.2 ±0.7	2.4 ±1.2*	4.6 ±1.9	3.3 ±1.8	3.0 ±1.0	2.6 ±1.2*	3.4 ±1.7	3.6 ±2.1*
BA7	*27*	3.2 ±0.9	2.9 ±0.9	4.6 ±2.2	4.5 ±1.8*	3.0 ±0.7	2.6 ±0.7	4.8 ±1.5	4.4 ±2.0
BA8	*29*	3.1 ±1.0	3.3 ±1.1	4.7 ±1.8	5.3 ±2.1	3.2 ±0.9	3.4 ±1.1	5.0 ±2.2	5.3 ±2.0

Note: nipper boards: BA1 (n=3); BA2 (n=3); BA3 (n=4); BA4 (n=2); Control (n=4); BA6 (n=3); BA7 (n=2); and BA8 (n=1); Comfort: 1 = Comfortable, 5 = Extremely uncomfortable; RPE: 0 = Extremely easy, 10 = Extremely hard; * $p<0.05$, significantly different to the BA-H for the same task

Collectively, the results from the board paddling tasks suggest that participants did not perceive the helmet to complicate their prone, kneeling or transition between the two paddling positions. Additionally, participants did not perceive the surf helmets to complicate their rolling of the surfboards of their board remounting. However, the surf helmets did complicate the participant's stability whilst paddling (prone and kneeling positions) as well as their confidence in negotiating waves both entering and exiting the water, core skills required by all active lifesavers in the event of a rescue, training or competition. Furthermore, when comparing individual BA and BA-H, participants found particular BA more *uncomfortable* and required greater effort to complete the tasks (Tables 5 and 6; Figures 3 and 4).

When considering participant ratings in conjunction with comments bulkiness of the PPE, riding up of the BA, inconvenient location of zippers as well as the PPE gripping on their knee pads (Malibu board paddlers) appeared to be common design faults with the PPE assessed. Additionally, in relation to the surf helmets, those with a peak or visor appeared to impact participants' proprioception, resulting in reduced stability and confidence when paddling and negotiating the waves.

3.2.3 - Surfboat rowing

There were no differences in perceived effort or comfort for participants during the surfboat rowing tasks except for a greater effort perceived when actually rowing the surfboat while wearing BA only (Table 7). Although no differences existed between the conditions for most activities, both conditions were more *uncomfortable* and required more effort than the control condition (Table 7). It is also important to note that the rowing components of the tasks (such as ability to row, 'hands away' and 'trail oars') were rated as a minimum of *uncomfortable* (comfort = 3.0) as well as 'trail oars' as *somewhat hard* (RPE = 6) for the BA-H condition.

Table 7: Mean (±SD) ratings of perceived comfort and effort (RPE) of the surfboat participants completing a number of typical tasks during the surfboat rowing task

Task		BA-H	BA only	Control
Getting in to the boat	Comfort	2.6 ±1.0	2.8 ±1.2	1.0 ±0.2
	RPE	4.2 ±2.1	4.3 ±2.3	0.4 ±0.5
Ability to row	Comfort	3.1 ±1.2	3.1 ±1.1	1.0 ±0.0
	RPE	5.0 ±2.7	5.3 ±1.8*	0.6 ±0.5
'Hands away'	Comfort	3.1 ±1.1	2.7 ±1.5	1.0 ±0.2
	RPE	4.9 ±2.6	4.7 ±2.3	0.6 ±0.5
'Trail oars'	Comfort	3.8 ±0.9	2.7 ±1.1	1.0 ±0.2
	RPE	6.8 ±2.5	4.6 ±2.2	0.5 ±0.6

Comfort: 1 = Comfortable, 5 = Extremely uncomfortable; RPE: 0 = Extremely easy, 10 = Extremely hard; * $p<0.05$, significantly greater than BA-H for that task

Note: Due to the small number of participants in the surfboat rowing task (n = 10, 2 complete crews), all data are presented as the group averages. Appendix B indicates the matrix for which buoyancy aids and surf helmets were assessed during this task.

Comments by the surfboat participants with respect to the designs of the BA assessed suggest that manufacturers need to consider the actual technique of the surfboat rowing stroke with many (BA2, BA3, BA6, BA7 and BA8) riding up during the stroke and then remaining in that position. Additionally, the bulk of the aid needs to be considered with the participant's oar getting caught up with the BA (BA2, BA7, BA8) causing complications with breathing, feeling restricted, as well as significantly impacting their ability to successfully complete the stroke. With regards to surf helmets, reduced hearing was the most common complaint followed by weight of the surf helmet causing additional head movements.

3.3 Design comments

Feedback provided by participants on the suitability of the PPE worn is presented in Appendices C and D and should form the basis for modifications by manufacturers to meet the occupational demands of the lifesaving tasks assessed. Additionally, as many of the PPE assessed impeded the lifesaving activities, skilled coaches and exponents of each of the lifesaving tasks should be included in future discussions for potential modifications to the PPE assessed in the current study.

For example, the type of material for the BA should be considered as the interaction with kneepads on a Malibu surfboard resulted in additional grip that was limiting paddler's movements (e.g. sliding back on the board when catching a wave). Additionally, design implications for board paddling and surfboat rowing should include positioning of the buoyancy (chest are in particular) to limit impediment to the stroke of each distinctly, different disciplines.

It is envisaged that the comments provided by participants in the current study will form the foundation for further research and development into the design and manufacture of PPE for lifesaving activities. Alignment of specific PPE with specific lifesaving activities should also be considered for future implementation.

4. CONCLUSIONS

This research project was conducted by the Institute of Sport and Exercise Science at James Cook University to assess the suitability of submitted PPE within specific aquatic, non-powered lifesaving craft activities such as board paddling, surf ski paddling and surfboat rowing under simulated operational conditions. The current study sought to evaluate the suitability of wearing a BA only or a BA with a surf helmet when completing the selected lifesaving activities and not to compare individual PPE. Although the current study only assessed a few of the typical tasks associated with each of the lifesaving activities included, an initial critical assessment of whether these simple tasks can successfully completed must precede further analysis. Additionally, identification of suitable PPE to progress to more rigorous testing protocols should be substantiated.

All of the PPE assessed in the current study resulted in the lifesaving tasks feeling more *uncomfortable* and requiring a greater effort than the same tasks completed without wearing any PPE. The identification of differences between the BA only and BA-H conditions should be noted although the dynamic open-ocean environment did appear to influence participants' perceptions of effort and comfortability. However, the level of comfort and effort reported by participants while undertaking the simple, low intensity, short-duration lifesaving tasks suggested that PPE design and material shortcomings need to be addressed prior to any further investigation. With increased intensity and duration of the assessed activities (e.g. during rough ocean conditions), it would be expected that the physiological demand of the activity would increase considerably with the use of PPE and may potential exceed the physical capabilities of the average active lifesaving member.

Feedback regarding design shortcomings were also noted with those about too much buoyancy resulting in unwarranted movement of the BA, and reduced comfort (i.e. rubbing, tightness, too much movement etc) suggesting the need for review and/or design modifications. Factors such as buoyancy distribution, appropriate fit and design specifics that are lifesaving activity specific should be considered to optimise PPE usage with individual lifesaving tasks such as swimming, board paddling and surfboat rowing.

5. RECOMMENDATIONS

The following recommendations for the *fit for purpose* use of the assessed PPE are based on the findings of the current research project:

- Potential revision of buoyancy requirements for lifesaving activities which is currently governed under ISO Standard (ISO 12402) for a Level 50 PFD (35 to 50N);
- Surf Life Saving Australia to liaise with manufacturers regarding design shortcomings identified for the lifesaving activities assessed, particularly those influencing technique;
- Establishment of a panel of accredited, experienced coaches or technical experts to liaise directly with Surf Life Saving Australia to optimise PPE design for successful and safe completion of standard lifesaving tasks including the possible development of task or craft specific buoyancy aids;
- Future reviews and potential modifications of PPE style should focus on:
  - buoyancy placement and flexibility;
  - reducing repetitive motion infringement (e.g. include a lower cut under the armpits for board paddling, swimming and rowing); and
  - reducing hearing and vision impairment.
- Future research should also investigate the physiological demands of wearing PPE whilst completing standard lifesaving tasks of a variety of intensities, durations and environments.

6. REFERENCES

1. Morgan D, Ozanne-Smith J, Triggs T. Descriptive epidemiology of drowning deaths in a surf beach swimmer and surfer population. *Injury Prevention* 2008;14(1):62-65.
2. Cummings P, Mueller BA, Quan L. Association between wearing a personal floatation device and death by drowning among recreational boaters: a matched cohort analysis of United States Coast Guard data. *Injury Prevention* 2011;17:156-59.
3. Morgan D, Ozanne-Smith J, Triggs T. Self-reported water and drowning risk exposure at surf beaches. *Australian and New Zealand Journal of Public Health* 2009;33(2):180-88.
4. Prieto Saborit JA, del Valle Soto M, Ďez VG, Sanclement MAM, Hernández PN, Rodŕguez JE, et al. Physiological response of beach lifeguards in a rescue simulation with surf. *Ergonomics* 2010;53(9):1140-50.
5. Bailey IMFP. An Analysis of Sea Kayaking Incidents in New Zealand 1992-2005. *Wilderness & Environmental Medicine* 2010;21(3):208-18.
6. Stemberga V, Cuculic D, Petaros A, Sosa I. Kayaking fatalities: could more appropriate helmets prevent fatal consequences? *Sports Medicine* 2013;43:1201-02.
7. Gagge AP, Stolwijk AJ, Hardy JD. Comfort and thermal sensations and associated physiological responses at various ambient temperatures. *Environmental Research* 1967;1:1-20.
8. Utter AC, Robertson RJ, Green JM, Suminski RR, McNaulty SR, Nieman DC. Validation of the adult OMNI scale of perceived exertion for walking/running exercise. *Medicine and Science in Sports and Exercise* 2004;36(10):1776-90.

7.0 Appendices

Appendices A and E – removed during de-identification process

Appendix B

Number of trials for each item of PPE for the closed (sat-water pool) and open (ocean) testing environments.

	Freeboard	25m swim	Duck diving	Ocean swimming	Board paddling	Surf boat	***Totals***
Buoyancy aids							
BA1	18	19	15	15	16	1	**84**
BA2	21	20	19	17	19	3	**99**
BA3	17	15	15	17	14	2	**80**
BA4	17	19	18	16	18	2	**90**
BA6	17	17	13	14	15	2	**78**
BA7	21	18	16	14	13	2	**84**
BA8	17	17	14	17	15	4	**84**
Totals	**128**	**125**	**110**	**110**	**110**	**16**	**599**
Surf helmets							
H1		9	9	10	11	2	**41**
H2		6	3	8	8	2	**27**
H3		11	10	7	8	2	**38**
H4		10	9	9	9	0	**37**
H5		9	8	11	9	3	**40**
H6		9	8	10	11	1	**39**
H7		11	9	6	6	0	**32**
H8		11	9	11	11	0	**42**
H9		10	10	4	5	1	**30**
H10		7	7	8	6	1	**29**
H11		11	11	14	13	3	**52**
H12		12	10	6	8	1	**37**
H13		9	7	6	5	0	**27**
Totals		**125**	**110**	**110**	**110**	**16**	**471**

Appendix C

Comments specifically relating to the buoyancy aid (BA) as provided by participants during each of the lifesaving activities:

Buoyancy Aid	Task	Participant comments
BA1	Pool tasks	– dragging weight – rode up during task
	Ocean swimming	– did not feel comfortable to continue (H5 & BA1) – good combination (H3/BA3) – rode up, fell of wave, felt drag from BA – range of motion restricted when popping, rode up under armpits causing rubbing, BA collided with H6 – slowed on wave; zipper rubs under the arms
	Board paddling	– did not feel comfortable to continue (H5 & BA1) – starts and finishes board slips on hips, unzipped when sliding back on wave, rubbed armpits, thick - decreased depth of chest on knees – armpit catches and prevents/limits movement when paddling and catching a wave – bit loose and moves around at the top – rode up when paddling on knees – rode up with waves – rubbing under the arms when paddling – weight impacts stability
	Surfboats	– rubs under the arms
Number of times PPE did not fit		***2***
BA2	Pool tasks	– No additional comments were made by participants during the pool-based assessments
	Ocean swimming	– couldn't dive under or catch a wave – filling up with sand, high cut under arms, felt more buoyant, felt almost normal just needs to be higher – more effort required to swim, fell off wave, rode up – riding up when resurfacing, doesn't stay light – rode up restricting movement and limiting ability to swim correctly – rose up with bobbing in water
	Board paddling	– caused chaffing – high cut under the arms, BA was gripping on the knee pads/hard to slip back on wave, not as bulky as similar style previously trialled – high under armpits, chaffing/rash – rode up when on knees – rode up during transition, got caught sliding back on wave in prone position, pushing board away when rolling, issues in changing direction – reduced ROM on knees, got caught when remounting, bundled at the bottom reducing ROM, impacted on stability – kept too close to board when rolling under a wave
	Surfboats	– caught during trailing oars – tight around armpits and neck - rubbing, felt heavy
Number of times PPE did not fit		***NIL***

Buoyancy Aid	Task	Participant comments
BA3	Pool tasks	– rode up during duck dives
	Ocean swimming	– gets loose and fills up with water – great fit – rode up for ins and outs, helped float
	Board paddling	– bulky at belly, rode up, gripped on knee pads – couldn't get under wave (swim), couldn't move well on the board – easier to catch waves with BA, rode up, chaffing under arm – felt restrictive like couldn't move head – restricted movement when kneeling – rubs at armpit – lateral movement on board causing instability
	Surfboats	– felt a bigger BA would pull them under – rode up and stayed up, restricted breathing, distracting, rubs under arms
Number of times PPE did not fit		***2***
BA4	Pool tasks	– loose fitting – rode up – rode up – rode up (BA & BA/H) – rode up
	Ocean swimming	– back rides up, ROM is good; drowning (combination) – rode up over face – rode up over face; happy to board but not swim
	Board paddling	– already uses previous style, chest was bulky, can use hips for starts as lycra not rubbing – BA altered technique – back pad gets in the way when paddling on knees – back plate too long, digs in to neck/lower back, uncomfortable on approach, issues due to back piece negotiating waves going out, stability issues – stability issues due to tippy because lack of depth on stroke, couldn't get chest down or shoulders in – too big in the chest/can't lie down – too much buoyancy length causing issues with stability – H12 hits back of BA which reduced ROM, felt like you were
	Surfboats	– felt restrictive – already uses previous style, previous style preferred
Number of times PPE did not fit		***2***
BA6	Pool tasks	– loose fitting
	Ocean swimming	– bundles up, got heavy with waves – filled with water/hard to swim/exhausting, chaffing under armpits – hard to swim in – impacted on hearing/covered ears – needs to be tighter at shoulder area – pulling up when in the water, didn't restrict head movement, hard to go deep – rubbing under arm pits

Buoyancy Aid	Task	Participant comments
BA6 ***(cont.)***		– too buoyant and couldn't get on wave, rode up under armpits, did not feel comfortable enough to continue BA only
	Board paddling	– better fit than previous of similar style; catches on the knee pads; bulky – hard to bend for stroke, floats up swimming – rode up when on knees, rode up a lot (wide sides), issues catching waves and with balance on knees – resulted in staying close to board during roll, rode up around neck, sliding on board (gripping pads?), loose at front, – too loose, rode up around arm pit, lower cut needed – rubbing armpits caused difficulties negotiating waves and stability
	Surfboats	– rode up and stayed up – rubbing under the arms, restrictive on back
Number of times PPE did not fit		***NIL***
BA7	Pool tasks	– loose fit – restrictive for breathing – rode up – side straps rise and water in mouth – way too big – pulling back
	Ocean swimming	– brings him up in the waves (floats upward) – pulling up when in the water more than BA6 – rode up (undersized BA used compared to manufacturer's recommendation) – rode up; straps needed to be tighter but perfect fit at belly – struggled to catch a wave, material feels sticky inside and it sits wide – tough swim, way too buoyant - opted not to complete the BA only trial
	Board paddling	– always moving, changes stroke – bulkiness impacted on stability/negotiating waves – impact on stability and catching waves due to BA moving, rode up a lot on knees, felt was dragged in the rip easier (bulkier?), unzipped when sliding forward on knee pads after coming down face of wave, pads split/rolled edges – impact on stability and negotiating waves, BA too loose when prone paddling/slipping, – too much padding at front leading to poor stability in prone, getting caught in mouth/rode up – too much paddling on front, too far off board, float to the surface quickly, loose – zipper scratched the board, prevents a deep stroke resulting in instability, rolls in on the edges particularly favoured side, uncomfortable – rode up during transition, gets caught when rolling board, impacts when going through waves – sliding about in the BA; gripped on the board/knee pads and unable to slide – sat high when on knees, unstable – too much padding, couldn't stay on board, restricted paddling motion (not as fast, to catch waves), stability issues, rode up

Buoyancy Aid	Task	Participant comments
BA7 ***(cont.)***	Surfboats	– greater ROM for arms but still rode up, once it rode up it stayed up, neckline sitting away, *lycra rides up too* – oar hit paddling at the end of the stroke, rode up and was restrictive, rode up and stayed up – rode up/stayed up and felt couldn't breath as easily, thumb rubbing on zipper – tight around armpits and neck - rubbing, felt heavy
Number of times PPE did not fit		***3***
BA8	Pool tasks	– comments that the BA rode up by 7 different participants during these tasks
	Ocean swimming	– BA pulls back – restrictive and hugging on sides, too buoyant/restrictive – rode up at the top although bottom was fixed - loose straps? – thickness/floats creating drag upwards, rode up significantly at back – felt too uncomfortable with H10 to proceed, felt too buoyant and couldn't get under waves – fills up with water, reduced ROM
	Board paddling	– bulky - thick and hard to paddle and float – felt bulky when kneeling and remounting the board, rubbing neck, fits at belly but loose chest (breasts), chaffing neck – rode up very high, participant slipping in the BA – too big, restricting movement – bulky caused issues with balance – pulled up on rolling, was moving/rolling while paddling resulting in stability issues, less confident negotiating waves, chest pushed up in kneeling and prone position (instability) – uncomfortable, loose, rode up, moving to the side when mounting board – loose fit, thick BA, when paddling you are higher out of the water – unable to slide back when on a wave – rolling and sliding in prone position, issues with stability as a result – thickness makes it hard on stomach/moving around, uncomfortable – catches water, harder to remount board
	Surfboats	– felt bulky and therefore limited movement, rode up during stroke and stayed there, better than with helmet – oar got caught underneath BA when trailing and felt choked
Number of times PPE did not fit		***3***

NB: There was no buoyancy aid given the allocation BA5 – this was instead the control condition, which was also randomised amongst the seven buoyancy aids submitted for assessment.

Appendix D

Comments specifically relating to the surf helmet (H) as provided by participants during each of the lifesaving activities:

Surf helmet	Task	Participant comments
H1	Pool tasks	No additional comments were made by participants during the pool-based assessments
	Ocean swimming	– lowered vision; – impacts vision by rolling forward – impacted vision with helmet falling forward, additional head movement – impacted hearing and slightly with peripheral vision – feels normal – dragged
	Board paddling	– vision obscured, interfered with stability – pulled head up when rolling – impacted vision (slightly) and hearing resulting in stability issues (slight) – additional head movement was required, H1 hit board
	Surfboats	No additional comments were made by participants during the surfboat assessments
Number of times PPE did not fit		***2***
H2	Pool tasks	No additional comments were made by participants during the pool-based assessments
	Ocean swimming	– heavy and difficult to breathe – hit visor – impacted hearing a little, pulls head up and bulky – impacted vision, tight fit but still moves a lot, fills with water and chokes neck
	Board paddling	– impacted vision and hearing, moving during paddle – heavy and difficult to breathe – chose not to complete the board paddle with helmet due to H2 pulling up and being too bulky
	Surfboats	No additional comments were made by participants during the surfboat assessments
Number of times PPE did not fit		***6***
H3	Pool tasks	– forms a wake over face when swimming
	Ocean swimming	– good combination (H3/BA3), visor issues, impacted hearing – impacted vision and hearing (OS & B) – slid down, couldn't hear anything – swim with head tilted back to be able to see under brim, impacted vision – visor made waves difficult
	Board paddling	– Hard to hear – required additional head movement, issues negotiating waves – impacted (very poor) vision, hearing and head movement, visor dragged causing eddy around face – changes technique - bouncing to see under brim creating resistance, impacts vision and hearing and requires additional head movement,

Surf helmet	Task	Participant comments
H3 ***(cont.)***		– impacts on negotiating waves and stability – impacted hearing – hard to transition, bad fit/always moved
	Surfboats	– slight impact to hearing
Number of times PPE did not fit		***2***
H4	Pool tasks	– can't hear – obstructive, muffled hearing
	Ocean swimming	– couldn't hear, felt like they were still underwater after resurfacing – was over face
	Board paddling	– muffled hearing – did not have enough confidence in H4 to continue trial
	Surfboats	Not assessed during the surfboat assessment
Number of times PPE did not fit		***8***
H5	Pool tasks	No additional comments were made by participants during the pool-based assessments
	Ocean swimming	– dragged head upwards when underwater – helmet slipped – impacted vision and hearing – slight run off over face – impacted hearing muffled (suction effect in the swim) – did not feel comfortable to continue (H5 & BA1)
	Board paddling	– tight but still moves, uncomfortable, impacts on hearing via water splashing – head movement sideways making stability and negotiating waves more difficult – impacted vision and additional head movement – water on face and therefore more flicking
	Surfboats	– harder to hear, no visor resulted in sun impacting vision (no hat worn) – additional head movement due to compensation for hearing
Number of times PPE did not fit		***3***
H6	Pool tasks	– obstructed vision
	Ocean swimming	– fills with water, moving, impacts vision and hearing (OS and B), swaying side to side impacting stability, too heavy; colliding with BA1 – impacted vision – lifts head up going under water, pulls at head – slight impact to vision with water over face
	Board paddling	– dragged head forward a little when on knees, slight impact to vision and hearing – impact to vision and additional head movement to compensate for reduced vision
	Surfboats	– felt weight of it and required additional head movement
Number of times PPE did not fit		***5***
H7	Pool tasks	No additional comments were made by participants during the pool-based assessments
	Ocean swimming	– couldn't hear, felt a suction effect and preferred not to continue with H7, dragged head up when duck diving, pressed tight against chin

Surf helmet	Task	Participant comments
H7 ***(cont.)***		bones – impacted vision and hearing (a little), water over face – slight impact on hearing
	Board paddling	– couldn't hear, felt a suction effect and preferred not to continue with H7 – uncomfortable at ears and back of head, better fit compared to same brand/different style, extra head movement for water, slight stability issues due to H7 – slight impact on hearing
	Surfboats	Not assessed during the surfboat assessment
Number of times PPE did not fit		***9***
H8	Pool tasks	– helmet pulls up and chokes; visor issues – obstructive (face); slipped – slipped – strap obstructing throat – visor restricted vision – visor restricted vision; slipped – ideal for boat rowers with the visor and no need to submersed head in water to swim anywhere
	Ocean swimming	– impacted vision – impacted vision, visor was pushing water, visor limits vision, issues with negotiating waves due to visor – impacted vision – increased resistance against brim making it restrictive, impact to vision and slight impact to hearing – pulled head down so stopped swimming – resistance from visor, not easy to lift head, impacted vision – water catches visor, tight but still moving, heavy/weighing down head, visor gets in the way, impact to vision and hearing – drag pulling head down swimming and under waves
	Board paddling	– visor impacts vision (swimming/negotiating waves), stability (heavy) – impacted vision – impacted vision, visor limits vision, issues with negotiating waves due to visor – impacted vision and additional head movement, couldn't see/very difficult with waves – couldn't see while paddling – impacted vision and a little on hearing, floated quickly when rolling, difficulty negotiating waves and with stability due to visor – visor pulled head down, couldn't see when paddling, moved around a lot
	Surfboats	Not assessed during the surfboat assessment
Number of times PPE did not fit		***3***
H9	Pool tasks	No additional comments were made by participants during the pool-based assessments
	Ocean swimming	– impacted on hearing (terribly), minimal impact on vision, additional head movement as a result of the H – impacted hearing

Surf helmet	Task	Participant comments
H9 ***(cont.)***	Board paddling	– impacted hearing – slight impact to hearing – hard to hear, heavy and causing stability issues
	Surfboats	– impacted hearing and additional head movement, muffled and couldn't hear, felt head dragged to the right
Number of times PPE did not fit		***2***
H10	Pool tasks	No additional comments were made by participants during the pool-based assessments
	Ocean swimming	– filled with water, pulled head back, felt like it was choking – impacted hearing; – impacted vision; chin strap dug in, no streamline – visor impeded vision, filled with water and moved down over eyes
	Board paddling	– made rolling difficult, visor makes swimming harder – don't like visor, additional head movements
	Surfboats	No additional comments were made by participants during the surf boat assessments
Number of times PPE did not fit		***1***
H11	Pool tasks	– hard to hear
	Ocean swimming	– echoed a lot and created splashing/couldn't hear, filled with water which runs over eyes – impact on hearing – impacted hearing and balance – impacted hearing, filled up with water; impacted hearing – impacted on hearing – slight impact to vision via water over the eyes – stability, movement and vision impacted – wash over face impacted vision, impact on hearing
	Board paddling	– caused instability – helmet was great, very little to no impact (hearing) – rolled forward – impacted vision and hearing, felt top heavy which impacted stability/felt tippy – impacted hearing – extra awkward, creates instability due to hearing issues, looking around more to compensate for hearing – difficulty elevating head – water running from helmet into eyes – low at the back of the neck when prone paddling, floated when diving under – impacted hearing (felt blocked) and required additional movement of head, hearing issues created issues negotiating waves
	Surfboats	– strap rubbing on the jaw, impact to hearing and additional head movement – sweep: couldn't hear effectively
Number of times PPE did not fit		***0***

Surf helmet	Task	Participant comments
H12	Pool tasks	– water on face after surfacing
	Ocean swimming	– filled up with water and choked around the neck, hit the back of BA4 reducing ROM, felt like you were drowning (combination)
	Board paddling	– vision impeded/blocked, had to look down but not forward
	Surfboats	– head felt wobbly
Number of times PPE did not fit		***9***
H13	Pool tasks	– visor restricted vision
	Ocean swimming	– wash over face, caused head to roll – impacted vision
	Board paddling	– additional head movement as a result of wearing H
	Surfboats	Not assessed during the surfboat assessment
Number of times PPE did not fit		***4***

NB: There was surf helmet aid given the allocation BA5 – this was instead the control condition, which was also randomised amongst the seven buoyancy aids submitted for assessment.

- All surf helmets were assessed for a fit that both the researcher and the participant felt were appropriate. Where required and available, additional padding specific to the helmets that were being assessed were included or removed in order to attain the appropriate fit. The same researcher ensured uniformity to identify the appropriate fit throughout all trials and they conducted a head up-down-left-right movement assessment to assist with their assessment of fit.