# INDEPENDENT TESTING OF <LEVEL 50 BUOYANCY AIDS FOR SURF LIFE SAVING AUSTRALIA

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**SURF LIFE SAVING AUSTRALIA**
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## Executive Summary

Previous research has identified that current levels of buoyancy as stipulated by ISO standard (ISO 12402) for a Level 50 personal flotation device (35 to 50N) is excessive for the successful completion of *fit for purpose* lifesaving activities with an acceptable perception of exertion. Currently, non-compliant buoyancy aids (BA) are available on the open market for use in other aquatic activities such as big wave surfing, wake boarding and water-skiing. However, a paucity of evidence for the current minimum buoyancy requirements restricts the ability for policy makers to review existing standards.

Forty-two (males = 22, females = 20) 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 to participation. Participants were randomly allocated to each of the ten (10) non-compliant BA and a control condition. All trials were held in Sydney, New South Wales during April 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 standardised assessments including buoyancy assessments as well as physical assessments of swimming and duck diving. All physical tasks were completed as quickly as was comfortable while buoyancy assessments were completed at a comfortable pace by NATA accredited assessors. As per project design, all participants were randomly allocated to a BA or control condition for each of the tasks in accordance with participant's availability and suitable BA fit *in lieu* of manufacturer's guidelines and specifications. The same researchers assessed BA fit, which was considered suitable if secured firmly around the waist, shoulder straps were not riding high or cutting in under the arm and respiration was not impeded.

Buoyancy assessments identified that compared to the fresh-water environment, the salt-water environment resulted in 50% less negative or neutral freeboard results and fewer unsuccessful in-water stability and orientation results. Compared to the fresh-water environment, fewer participants failed to return to the surface in the salt-water environment during the simulated unconscious recovery task whilst the control condition identified most participants as positively buoyant. Participants felt slightly more *uncomfortable* and experienced greater levels of exertion during the simulated unconscious recovery task in salt-water compared to the fresh-water environment for both positive and negative/neutral freeboard BA.

All physical tasks were successfully completed whilst wearing BA that attained either positive freeboard or negative/neutral freeboard. There were minimal differences for time, comfort or perceived exertion during the swimming task between the two aquatic environments. In the fresh-water environment, participants perceived a greater degree of exertion and were more *uncomfortable* completing the swimming task in BA with positive freeboard. In contrast, duck diving in the salt-water environment resulted in slower completion times and an increased level of exertion. Differences between BA that achieved positive freeboard and those that were negative/neutral indicated an increased buoyancy requirement along with a resultant increased exertion and reduction in comfort for the physical tasks. This difference was most evident during the duck diving task.

The results of the current study suggest that an increased density of the salt-water environment appears to have positively aided the buoyancy of participants while somewhat negatively influencing their effort to perform the physical tasks. Based on the results of the current project, a number of recommendations were made to SLSA including: proposing an amendment to the current Australian and International standards governing buoyancy aids; assembling a taskforce to revise evidence and recommend amendments to current buoyancy standard authorities for consideration; continuing to work with manufacturers on PPE suitability design; and revisit *fit for purpose* assessments.

## Definitions

The following are definitions of acronyms used throughout this report:

| | |
|---|---|
| **AS#** | Australian Standard [number and version indicated] |
| **BA** | Buoyancy Aid |
| **ISO#** | International Organization for Standardization [number and version indicated] |
| **JCU** | James Cook University |
| **N** | Newtons |
| **NATA** | National Association of Training Authorities Australia |
| **RPE** | Rating of Perceived Exertion |
| **SLSA** | Surf Life Saving Australia |

## CONTACT DETAILS

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# 1. Aims of the research

The primary aim of this research project was to evaluate a range of buoyancy aids (<Level 50 buoyancy level and currently required as per AS4758) for the *fit for purpose* suitability during selected tasks directly associated with lifesaving sport in salt- and fresh-water. Additionally, this project sought to investigate further the minimum level of buoyancy required to attain a minimum positive freeboard in salt- and fresh-water.

# 2. Methods

## 2.1 - Participants

Forty-two participants (males = 22, females = 20) 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 (SLSA) affiliated, surf lifesaving clubs in the Sydney region and were pre-screened for any contra-indications prior 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 ($50) provided by SLSA. Twenty-five participants were able to attend both testing environments.

**Table 1:** Mean (±SD) participant characteristics (N = 42).

| Variable | Nippers | Juniors | Seniors | Masters |
|---|---|---|---|---|
| Number of participants (n) | 7 | 15 | 6 | 14 |
| Age (years) | 12.7 ±1.6 | 16.0 ±1.0 | 23.8 ±3.4 | 44.1 ±13.2 |
| Height (m) | 1.58 ±0.12 | 1.72 ±0.12 | 1.68 ±0.10 | 1.76 ±0.09 |
| Body mass (kg) | 50.0 ±12.5 | 64.3 ±9.1 | 70.7 ±19.9 | 85.4 ±21.2 |

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 ten (10) buoyancy aids (BA) and a control condition. All BA were assigned a code for randomisation (Appendix A). All trials were held in Sydney, New South Wales during April 2014 with salt-water pool-based assessments conducted at the Andrew (Boy) Charlton Aquatic Centre, Woolloomooloo Bay; and fresh-water pool-based assessments conducted at the Prince Alfred Park Pool, Sydney. 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 as well as tasks associated with AS4758.3 testing protocols.

An overview of those tasks includes:

- Water entry (as per AS4758.3) – ability of BA to remain on wearer in a usable state following the participant falling or jumping in to the water;
- Vertical stability (as per AS4758.3) – ability of the BA to maintain the participant static, vertically and with a positive freeboard;
- In-water orientation and stability (as per AS4758.3) – orientation: ability of participants to return to a relaxed, upright position after destabilisation; stability: determining whether the participant return to a face-up position following longitudinal destabilisation of 45°;
- Freeboard – participants were required to float vertically and horizontally in the water to assess buoyancy of the BA being assessed;
- Swimming – participants were required to swim 25m as quickly as possible;
- Duck diving – participants were required to duck dive in the water to retrieve 3 (if ≤18yr) or 5 (if ≥18yr) bottom fixed objects as quickly as possible; and
- Simulated Unconscious Buoyancy – participants were required to dive to the bottom of the pool, expel as much air as possible and allow BA to float them to the surface.

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

### 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 each of the swimming pools 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. Weather conditions remained relatively constant for the duration of each session with slight rain and cooler temperatures although there were slight differences between morning and afternoon sessions but not dissimilar between days.

All BA were assessed for a suitable fit by the research team and the participant *in lieu* of manufacturer's guidelines and specifications. The same researchers assessed fit for uniformity for all trials with a suitable fit considered as firmly secure around the waist, shoulder straps not riding high or cutting in under the arm and to ensure respiration was not impeded. Where a BA was unable to satisfactorily fit the participant, a '*did not fit'* (DNF) result was recorded for reporting purposes.

## 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 - Water entry, vertical and in-water orientation/stability and freeboard assessments

As water entry, vertical stability and in-water orientation/stability assessments fall under Australian Standards (AS4758.3), independent assessors and NATA Accredited Laboratory, VicLab (VicLab Pty Ltd., Boronia, Victoria) conducted these assessments as per AS4758.3. Furthermore, VicLab completed the Freeboard assessments concurrently with their other assessments for participant convenience.

### 2.3.3 - Swimming and simulated unconscious buoyancy assessments

Participants completed the 25m swimming and duck dive assessments for each BA and control condition with times (sec) manually recorded (Sports timer 898, Hart Sports, Australia). For the swimming and duck diving tasks, participants commenced on the "Go" command and had their completion time recorded once the 25m was complete or when the final object was visible above the water (participants were required to hold up and show each retrieved item). Additionally, participants completed the simulated unconscious buoyancy (SUB) assessment in a randomised order with the 25m swimming and duck dive assessments.

### 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 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.

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 as well as the control condition via the OMNI scale (Figure 1). The OMNI scale was preferred for its previous use with children as well as adult participants when performing progressively incremented laboratory-based exercise protocols. Participants were asked to quantify their response to the question "*How much effort did that task take while wearing what you are wearing*?"

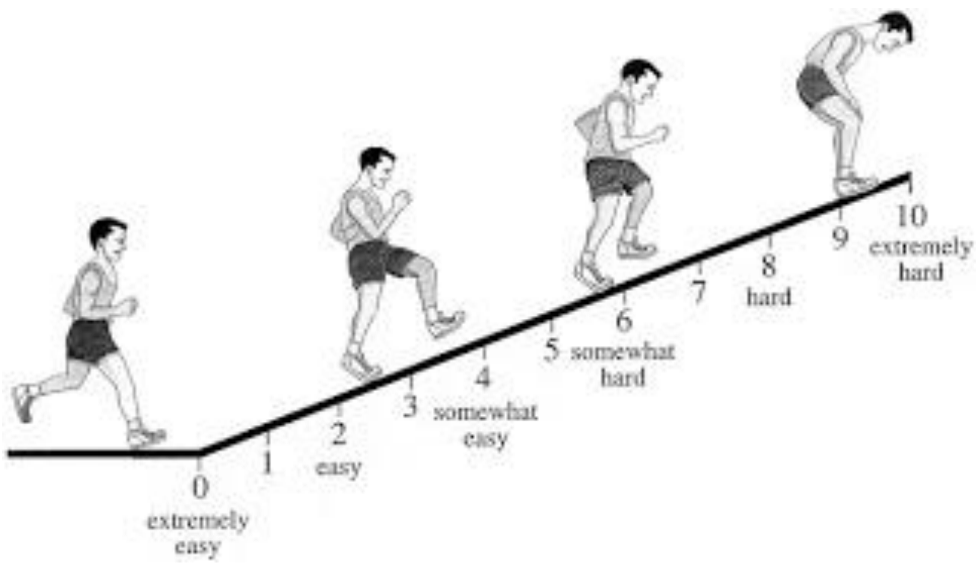


**Figure 1.** The OMNI scale presented to participants to assess their rating of perceived effort in performing tasks.

## 2.4 Analyses

Data has been presented as the mean ± SD for each BA that achieved positive freeboard and those that recorded neutral or negative freeboard for their respective environments. No statistical analyses were conducted due to the imbalance of numbers in each category across the various assessments or environments.

# 3. Results and Discussion

## 3.1 - Buoyancy assessments

### 3.1.1 - Freeboard and AS4758.3 assessments

Mean freeboard assessments were similar (Table 2) amongst the various BA. Group averages for horizontal freeboard in the salt-water (7.3 ±2.0cm, range: 2.5-12.5cm) were slightly lower than those in the fresh-water environment (8.1 ±1.9cm, range: 2.2-13.0cm). Interestingly, the opposite applied for vertical freeboard (5.2 ±3.0cm, range: 0.5-11.5cm) in the salt-water compared to in the fresh-water (3.5 ±1.8cm, range: 0.5-7.5cm). These differences may be explained by only 25 participants being assessed in both environments meaning different participant body shapes and sizes may have affected the results. Additionally, the number of negative or neutral freeboard results recorded for the salt-water environment (76) was vastly less than that achieved in the fresh-water (145) meaning fewer data points were available for the comparison (98 vs. 27 positive freeboard results for salt and fresh-water; Table 2).

Researchers were unable to equip participants with a BA on 175 occasions (Appendix B) due to failure of the BA to fit participants satisfactorily.

**Table 2:** Mean (±SD) measurements for participants performing the freeboard tasks in the flat salt- and fresh-water environments.

| | Saltwater | | | | Freshwater | | | |
|---|---|---|---|---|---|---|---|---|
| | **N** | Horizontal (cm) | Vertical (cm) | Negative or Neutral | **N** | Horizontal (cm) | Vertical (cm) | Negative or Neutral |
| **BA1** | **9** | 8.0 ±1.5 | 5.5 ±3.1 | *2* | **7** | 8.7 ±1.5 | 0.7 ±0.4 | *5* |
| **BA2** | **28** | 7.7 ±2.2 | 4.7 ±2.9 | *9* | **29** | 8.4 ±1.7 | 4.7 ±1.3 | *26* |
| **BA5** | **15** | 7.6 ±1.7 | 5.4 ±1.3 | *11* | **18** | 7.1 ±3.0 | Nil | *17* |
| **BA6** | **9** | 7.4 ±1.9 | 7.1 ±4.5 | *4* | **7** | 7.8 ±1.9 | 3.0* | *6* |
| **BA7** | **13** | 7.4 ±2.0 | 6.8 ±2.8 | *1* | **10** | 8.8 ±2.5 | 4.5 ±0.7 | *8* |
| **BA9** | **26** | 6.1 ±1.7 | 4.8 ±2.3 | *17* | **30** | 7.2 ±1.8 | 3.0* | *28* |
| **BA10** | **25** | 7.4 ±2.4 | 3.7 ±2.7 | *14* | **21** | 8.8 ±1.7 | 2.8 ±1.8 | *13* |
| **BA11** | **18** | 7.5 ±1.9 | 4.8 ±3.2 | *7* | **12** | 8.4 ±2.2 | 3.5 ±0.0 | *10* |
| **BA12** | **22** | 7.2 ±1.9 | 5.8 ±3.3 | *6* | **27** | 8.4 ±2.0 | 5.8 ±1.8 | *24* |
| **BA13** | **9** | 8.3 ±1.5 | 3.5 ±1.8 | *5* | **11** | 7.9 ±2.2 | 3.7 ±1.5 | *8* |

**N** = number of times that BA was assessed for that specific task; * denotes only one assessment and therefore no standard deviation

NB: Participant obtained a negative or neutral result for either their horizontal or vertical freeboard.

There were very few differences between the salt- and fresh-water environments during the water entry assessment (Table 3).

During the in-water stability and orientation tasks in the salt-water environment, fewer unsuccessful results were recorded compared to the same assessments in the fresh-water environment (0.8 vs. 15.1%; Table 4) further highlighting the different buoyancy requirements for the two aquatic environments (salt- and fresh-water).

**Table 3:** Successful completions of participants performing the water entry tasks (as per AS4758.3) in the flat salt- and fresh-water environments.

| | Saltwater | | | | | Freshwater | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **N** | **(a)** | **(b)** | **(c)** | **(d)** | **N** | **(a)** | **(b)** | **(c)** | **(d)** |
| **BA1** | **9** | 9 | 8 | 9 | 9 | **7** | 6 | 4 | 6 | 0 |
| **BA2** | **28** | 28 | 20 | 28 | 15 | **30** | 30 | 30 | 29 | 13 |
| **BA5** | **15** | 15 | 11 | 15 | 5 | **18** | 18 | 17 | 12 | 4 |
| **BA6** | **9** | 9 | 6 | 9 | 2 | **7** | 7 | 5 | 7 | 3 |
| **BA7** | **13** | 13 | 7 | 13 | 5 | **10** | 10 | 10 | 9 | 3 |
| **BA9** | **26** | 26 | 23 | 26 | 8 | **30** | 30 | 27 | 22 | 15 |
| **BA10** | **25** | 24 | 17 | 25 | 11 | **21** | 3 | 2 | 19 | 10 |
| **BA11** | **18** | 18 | 12 | 18 | 9 | **14** | 14 | 11 | 13 | 6 |
| **BA12** | **22** | 22 | 19 | 22 | 10 | **26** | 26 | 26 | 23 | 12 |
| **BA13** | **9** | 9 | 4 | 9 | 4 | **11** | 9 | 5 | 7 | 4 |

**(a)** BA were not damaged so as to not affect their in-water performance or their buoyancy;
**(b)** BA were not dislodged and no harm caused to the participant;
**(c)** BA brought participants to the surface; and
**(d)** BA brought participants to assume the attitude.

**Table 4:** Successful completions of participants performing the in-water orientation tasks (as per AS4758.3) in the flat salt- and fresh-water environments.

| | Saltwater | | | | | | Freshwater | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N** | **(a)** | **(b)** | **(c)** | **(d)** | **(e)** | **N** | **(a)** | **(b)** | **(c)** | **(d)** | **(e)** |
| **BA1** | **9** | 9 | 9 | 9 | 9 | 9 | **7** | 7 | 3 | 7 | 3 | 7 |
| **BA2** | **28** | 28 | 28 | 28 | 28 | 27 | **30** | 30 | 22 | 28 | 22 | 28 |
| **BA5** | **15** | 15 | 15 | 15 | 15 | 14 | **18** | 18 | 4 | 17 | 4 | 18 |
| **BA6** | **9** | 9 | 9 | 9 | 9 | 8 | **7** | 7 | 5 | 7 | 5 | 7 |
| **BA7** | **13** | 13 | 13 | 13 | 13 | 12 | **10** | 10 | 9 | 10 | 9 | 10 |
| **BA9** | **26** | 26 | 26 | 26 | 25 | 25 | **30** | 29 | 12 | 29 | 13 | 29 |
| **BA10** | **25** | 25 | 25 | 25 | 25 | 25 | **21** | 21 | 18 | 20 | 18 | 21 |
| **BA11** | **18** | 18 | 18 | 18 | 18 | 18 | **14** | 14 | 10 | 14 | 10 | 13 |
| **BA12** | **22** | 22 | 22 | 22 | 22 | 21 | **26** | 26 | 22 | 26 | 23 | 25 |
| **BA13** | **9** | 9 | 9 | 9 | 9 | 9 | **10** | 10 | 8 | 10 | 7 | 9 |

**(a)** All closures remained closed on the BA;
**(b)** Participants who successfully maintained an attitude of relaxed static balance (upright or backward);
**(c)** Participants that returned from destabilisation face-up;
**(d)** Number of positive freeboards attained following destabilisation; and
**(e)** Participants successfully returning to an upright, face-up position after 45° destabilisation.

### 3.1.2 - Simulated Unconscious Recovery task

During assessment of the simulated unconscious recovery task, there were 3 participants that failed to return to the surface in the salt-water environment: one in the control condition and another two in positive freeboard BA (BA11 and BA12). This is in stark contrast to the fresh-water environment in which 34 participants failed to return to the surface: 15 in the control condition, three BA with positive freeboard (BA1, BA2 and BA10) and the remaining 16 in BA with negative/neutral freeboard (1x BA1, BA2, BA6, BA7; 2x BA12; 5x BA9; 6x BA5).

Unlike the AS4758.3 and Freeboard tasks, participants were required to complete the simulated unconscious recovery task within the control condition in order to identify those participants that are positively buoyant irrespective of any additional buoyancy. The respective control conditions identified 32 (97%) participants in the salt-water and 16 (51.6%) in the fresh-water environment returned to the surface following maximal exhalation highlighting the influence of water density on buoyancy.

Although both environments were greater than their respective control condition for comfort and RPE when completing the simulated unconscious recovery task, the participants in the salt-water environment suggested their comfort (2.1 ±0.9 vs. 1.8 ±0.9) and RPE (4.2 ±2.2 vs. 3.6 ±2.0) were higher than those of the fresh-water environment (Table 7). Additionally, the BA that attained positive freeboard were similar for participant comfort during the simulated unconscious recovery task compared to the negative/neutral freeboard BA (salt-water: 2.1 ±0.9 vs. 2.1 ±0.9; fresh-water: 2.0 ±0.9 vs. 1.8 ±0.8) however required more effort to complete the task (salt-water: 4.3 ±2.2 vs. 3.9 ±2.0; fresh-water: 4.0 ±1.9 vs. 3.6 ±2.1) in both aquatic environments (Table 7).

**Table 7:** Mean (±SD) ratings of perceived comfort and effort (RPE) of the participants performing the Simulated Unconscious Recovery task in a flat salt-water and fresh-water environment compared to the control condition for that same environment.

| | Saltwater | | | | | Freshwater | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Comfort | | RPE | | | Comfort | | RPE | |
| | N | Positive | Negative/ neutral | Positive | Negative/ neutral | N | Positive | Negative/ neutral | Positive | Negative/ neutral |
| **BA1** | *18* | 2.0 ±0.8 | 1.8 ±1.1 | 4.0 ±2.1 | 5.0 ±1.4 | *14* | 1.7 ±0.5 | 1.3 ±0.4 | 3.4 ±2.1 | 5.0 ±2.5 |
| **BA2** | *31* | 2.1 ±0.6 | 2.2 ±0.6 | 4.6 ±2.2 | 4.3 ±1.3 | *29* | 2.2 ±1.0 | 1.8 ±0.7 | 5.3 ±1.5 | 2.9 ±1.3 |
| **BA5** | *14* | 1.4 ±0.5 | 1.9 ±0.7 | 4.5 ±1.9 | 2.8 ±1.5 | *18* | 2.0* | 1.6 ±0.6 | 1.0* | 4.6 ±2.9 |
| **BA6** | *9* | 1.6 ±0.4 | 2.1 ±0.5 | 3.4 ±3.0 | 5.5 ±1.3 | *7* | 2.0* | 1.8 ±0.9 | 4.0* | 3.3 ±2.9 |
| **BA7** | *12* | 2.1 ±0.9 | 4.0* | 5.1 ±2.3 | 2.0* | *10* | 1.5 ±0.7 | 1.5 ±0.5 | 2.5 ±0.7 | 3.5 ±1.9 |
| **CONTROL** | ***33*** | **1.2 ±0.5** | | **2.0 ±1.6** | | ***31*** | **1.2 ±0.3** | | **2.1 ±2.0** | |
| **BA9** | *27* | 2.2 ±0.6 | 2.1 ±0.9 | 3.7 ±1.6 | 3.7 ±1.6 | *30* | 1.8 ±1.1 | 1.5 ±0.7 | 5.0 ±1.4 | 3.2 ±2.1 |
| **BA10** | *28* | 2.0 ±1.1 | 2.2 ±1.0 | 3.3 ±2.0 | 3.9 ±2.6 | *23* | 2.8 ±1.3 | 2.6 ±1.4 | 4.5 ±1.8 | 4.2 ±2.2 |
| **BA11** | *9* | 2.8 ±0.6 | 1.7 ±0.6 | 5.7 ±1.9 | 2.7 ±0.6 | *10* | 1.5* | 2.1 ±0.8 | 4.0* | 3.4 ±1.8 |
| **BA12** | *22* | 2.5 ±1.3 | 1.8 ±0.8 | 4.3 ±2.3 | 4.4 ±2.3 | *28* | 1.5 ±0.6 | 1.7 ±0.6 | 2.8 ±1.5 | 3.5 ±1.9 |
| **BA13** | *10* | 2.1 ±1.1 | 2.2 ±0.8 | 6.8 ±3.6 | 4.2 ±1.5 | *11* | 1.8 ±0.3 | 2.3 ±1.1 | 5.7 ±1.2 | 3.3 ±0.7 |

N = number of times that BA was assessed for that task; * denotes only one assessment and therefore no standard deviation; Comfort: 1 = Comfortable to 5 = Extremely uncomfortable; RPE: 0 = Extremely easy to 10 = Extremely hard.

## 3.2 - Physical assessment of lifesaving activities

### 3.2.1 - 25m swimming task

The mean time for all participants to swim 25m while wearing BA with positive freeboard in the fresh-water environment was marginally slower (22.9 ±4.5 sec) compared to the salt-water environment (21.9 ±4.7 sec). Interestingly, both environments were similarly paced compared to the respective control condition (Figure 1) suggesting minimal influence of the assessed BA on 25m swimming performance.

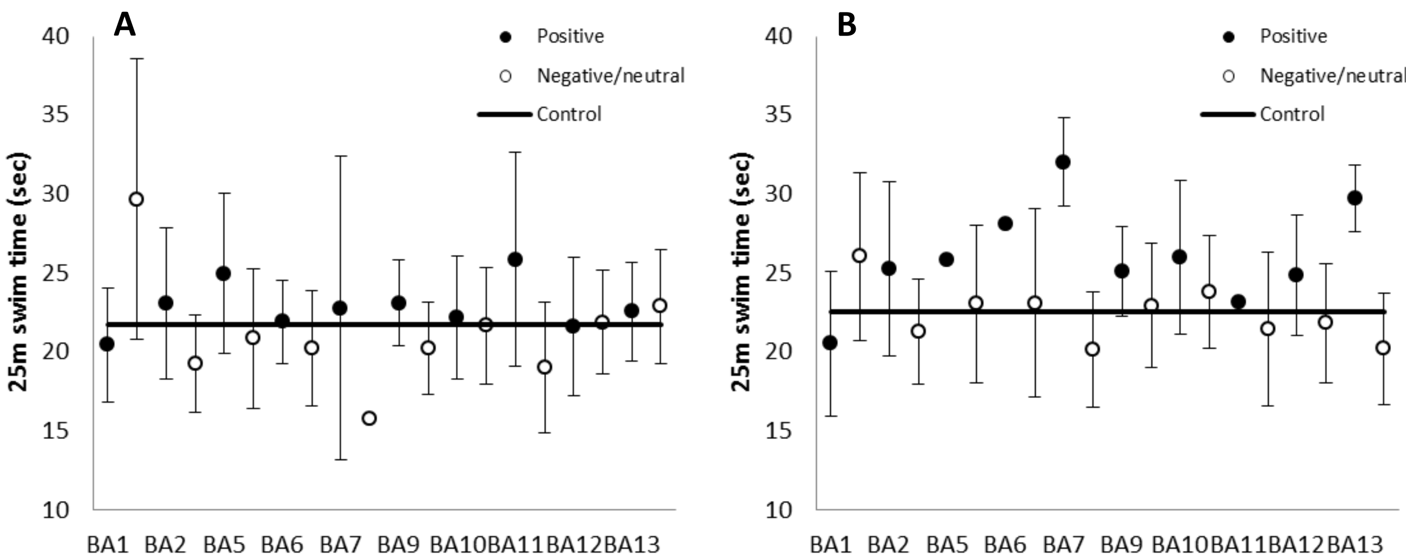


**Figure 2.** Mean (± SD) time to complete a 25m swim in a flat salt-water (A) and fresh-water (B) environment compared to the control condition for that same environment.

Whilst participant perceptions of comfort and exertion (RPE) for both environments were greater than their respective control condition, there was little difference between the flat salt- or fresh-water environments for participant comfort (2.3 ±0.8 vs. 2.2 ±1.0) or RPE (4.3 ±2.0 vs. 4.1 ±1.7)(Table 5).

Similarly, BA that attained positive freeboard and those that achieved negative/neutral freeboard presented very few differences for time (22.5 ±5.1 vs. 21.2 ±4.0 sec) and participant comfort (2.4 ±0.8 vs. 2.1 ±0.8) although perceived effort was greater for the positive freeboard BA (4.6 ±1.9 vs. 3.9 ±2.0) for the salt-water environment. However, in the fresh-water environment, trials with BA that attained positive freeboard were slower (25.2 ±5.0 vs. 22.3 ±4.1 sec) and participants perception of effort was greater (4.5 ±1.9 vs. 4.0 ±1.7) although participant comfort (2.2 ±0.9 vs. 2.2 ±1.0) was similar.

**Table 5:** Mean (±SD) ratings of perceived comfort and effort (RPE) of the participants performing the 25m swimming task in a flat salt-water and fresh-water environment compared to the control condition for that same environment.

| | Saltwater | | | | | Freshwater | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Comfort | | RPE | | | Comfort | | RPE | |
| | N | Positive | Negative/ neutral | Positive | Negative/ neutral | N | Positive | Negative/ neutral | Positive | Negative/ neutral |
| **BA1** | *16* | 2.1 ±0.4 | 2.0 ±0.0 | 4.2 ±1.6 | 6.5 ±0.7 | *13* | 1.8 ±0.8 | 2.4 ±0.9 | 2.9 ±1.1 | 5.4 ±1.3 |
| **BA2** | *29* | 2.5 ±1.0 | 2.2 ±0.9 | 4.7 ±1.9 | 4.0 ±2.3 | *29* | 1.8 ±0.8 | 2.3 ±0.9 | 4.5 ±0.9 | 3.5 ±1.2 |
| **BA5** | *14* | 1.8 ±0.3 | 1.6 ±0.6 | 4.3 ±1.3 | 3.0 ±1.1 | *18* | 3.0* | 1.9 ±0.8 | 3.0* | 4.2 ±1.9 |
| **BA6** | *11* | 2.2 ±0.7 | 2.8 ±0.6 | 4.3 ±1.8 | 6.3 ±1.0 | *7* | 3.0* | 2.0 ±0.8 | 6.0* | 4.3 ±1.9 |
| **BA7** | *13* | 2.4 ±0.8 | 3.0* | 5.5 ±1.8 | 7.0* | *10* | 2.5 ±1.4 | 1.9 ±0.6 | 5.5 ±3.5 | 3.6 ±1.6 |
| **CONTROL** | ***31*** | **1.2 ±0.4** | | **2.1 ±1.5** | | ***31*** | **1.2 ±0.4** | | **2.4 ±1.7** | |
| **BA9** | *26* | 2.2 ±0.8 | 1.9 ±0.7 | 4.2 ±2.1 | 3.9 ±1.8 | *30* | 2.3 ±0.4 | 1.7 ±0.9 | 4.0 ±0.0 | 3.4 ±1.6 |
| **BA10** | *27* | 2.4 ±0.9 | 2.4 ±1.1 | 3.7 ±2.1 | 3.6 ±2.2 | *23* | 2.9 ±0.9 | 3.3 ±0.7 | 5.8 ±1.8 | 5.5 ±1.3 |
| **BA11** | *9* | 2.8 ±0.8 | 2.5 ±1.3 | 5.8 ±1.9 | 3.3 ±1.2 | *11* | 1.0* | 3.3 ±1.0 | 3.0* | 5.5 ±2.1 |
| **BA12** | *22* | 2.6 ±0.9 | 2.0 ±0.7 | 4.1 ±1.6 | 3.0 ±2.0 | *28* | 1.8 ±0.5 | 1.9 ±0.8 | 3.6 ±1.4 | 3.5 ±1.5 |
| **BA13** | *9* | 2.9 ±1.4 | 2.1 ±0.9 | 6.3 ±2.2 | 4.2 ±2.7 | *11* | 1.8 ±0.6 | 2.6 ±1.0 | 6.0 ±2.0 | 4.8 ±1.8 |

N = number of times that BA was assessed for that task; * denotes only one assessment and therefore no standard deviation; Comfort: 1 = Comfortable to 5 = Extremely uncomfortable; RPE: 0 = Extremely easy to 10 = Extremely hard.

Collectively, all participants assessed were capable of successfully completing the 25m swimming task irrespective of whether the BA recorded a positive or negative/neutral freeboard. Although similar perceptions of comfort and exertion were noted for the two aquatic environments during the swimming task, the fresh-water environment identified that BA with positive freeboard slowed participants and required a greater effort to complete the task. This slower and greater effort response was not evident in the flat salt-water environment.

### 3.2.2 - Duck diving task

The mean time for all participants to complete the duck diving assessments while wearing BA with positive freeboard in the fresh-water environment was faster (22.0 ±8.8 sec) compared to the salt-water environment (24.1 ±12.3 sec). Additionally, both environments were slower than their respective control condition (Figure 3) with the greatest difference for the salt-water environment. Although both environments were greater than their respective control condition for comfort and RPE, when completing the duck dives in the salt-water environment, participant's comfort (2.3 ±0.9 vs. 1.9 ±0.8) and RPE (4.5 ±2.3 vs. 3.7 ±1.8) were higher than that of the fresh-water environment(Table 5; Table 6). One participant abstained from all duck diving assessments (including control condition) due to an inability to complete the task without vertigo.

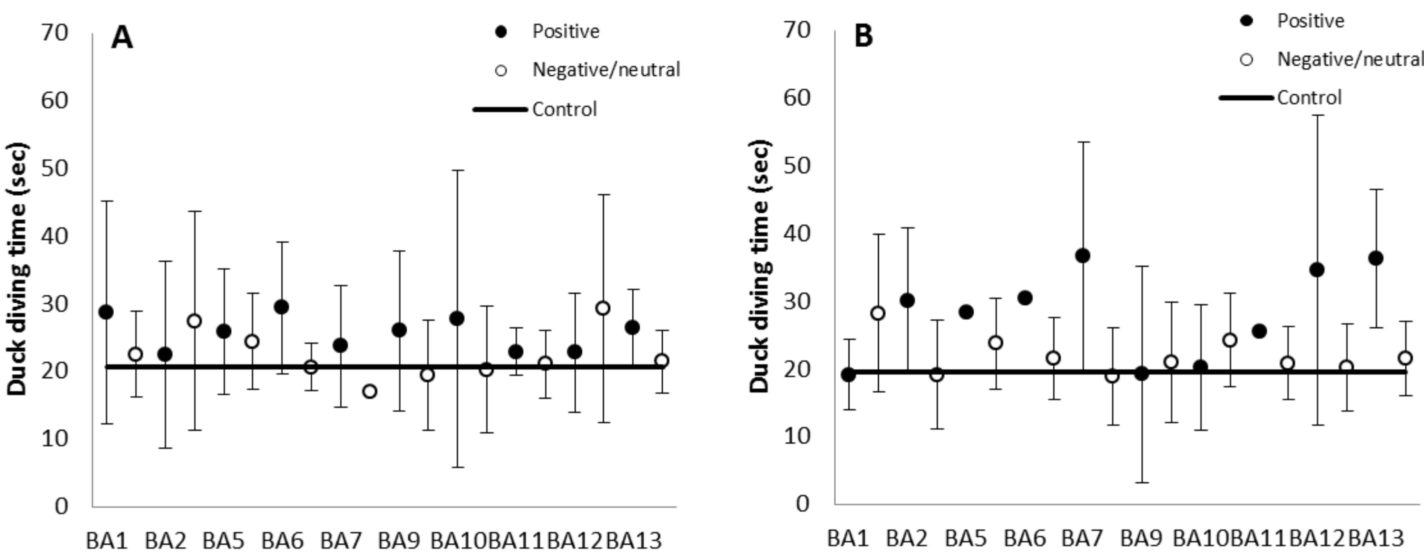


**Figure 3.** Mean (± SD) time to complete the duck diving task in a flat salt-water (A) and fresh-water (B) environment compared to the control condition for that same environment.

**Table 6:** Mean (±SD) ratings of perceived comfort and effort (RPE) of the participants performing the duck diving task in a flat salt-water and fresh-water environment compared to the control condition for that same environment.

| | Saltwater | | | | | Freshwater | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Comfort | | RPE | | | Comfort | | RPE | |
| | N | Positive | Negative/ neutral | Positive | Negative/ neutral | N | Positive | Negative/ neutral | Positive | Negative/ neutral |
| **BA1** | *15* | 2.3 ±1.1 | 1.8 ±0.4 | 3.9 ±2.4 | 6.0 ±2.8 | *12* | 1.4 ±0.4 | 2.0 ±0.9 | 2.9 ±1.0 | 4.5 ±1.7 |
| **BA2** | *28* | 2.6 ±0.8 | 2.4 ±0.7 | 5.0 ±2.7 | 4.9 ±1.6 | *29* | 2.3 ±1.2 | 1.9 ±0.8 | 5.2 ±2.8 | 3.4 ±1.5 |
| **BA5** | *13* | 1.5 ±0.5 | 1.9 ±0.9 | 5.7 ±2.1 | 2.8 ±1.3 | *17* | 2.5* | 1.7 ±0.6 | 3.0* | 3.2 ±1.3 |
| **BA6** | *10* | 2.1 ±0.8 | 2.1 ±0.6 | 5.2 ±2.8 | 5.8 ±1.5 | *6* | 2.0* | 2.2 ±0.8 | 5.0* | 4.8 ±2.6 |
| **BA7** | *12* | 2.6 ±1.2 | 3.0* | 5.5 ±1.7 | 5.0* | *10* | 2.0 ±0.7 | 1.8 ±0.6 | 5.5 ±3.5 | 3.9 ±2.2 |
| **CONTROL** | ***31*** | **1.1 ±0.6** | | **1.7 ±1.2** | | ***31*** | **1.2 ±0.5** | | **2.0 ±1.7** | |
| **BA9** | *25* | 2.6 ±0.5 | 1.9 ±0.5 | 4.4 ±1.8 | 3.3 ±1.5 | *29* | 1.5 ±0.7 | 1.6 ±0.6 | 3.5 ±2.1 | 2.7 ±1.6 |
| **BA10** | *27* | 2.3 ±1.1 | 2.3 ±1.1 | 3.9 ±2.9 | 3.8 ±2.1 | *22* | 2.7 ±1.1 | 2.9 ±1.1 | 4.8 ±2.0 | 4.8 ±2.2 |
| **BA11** | *9* | 3.1 ±0.5 | 1.8 ±0.3 | 6.3 ±2.3 | 3.7 ±0.6 | *11* | 1.5* | 2.6 ±0.9 | 6.0* | 4.4 ±2.2 |
| **BA12** | *21* | 2.6 ±1.1 | 2.0 ±0.5 | 4.7 ±2.4 | 4.7 ±2.4 | *27* | 1.5 ±0.4 | 1.7 ±0.7 | 4.0 ±2.4 | 3.2 ±1.2 |
| **BA13** | *8* | 3.0 ±1.6 | 1.8 ±0.6 | 7.0 ±3.5 | 3.5 ±1.7 | *10* | 2.3 ±0.4 | 2.1 ±0.5 | 5.5 ±0.7 | 4.1 ±1.6 |

N = number of times that BA was assessed for that task; * denotes only one assessment and therefore no standard deviation; Comfort: 1 = Comfortable to 5 = Extremely uncomfortable; RPE: 0 = Extremely easy to 10 = Extremely hard.

The BA that attained positive freeboard were both slower in the salt- (25.2 ±13.5 vs. 22.5 ±10.2 sec) and fresh-water environments (25.3 ±12.4 vs. 21.2 ±7.6 sec) compared to the negative/neutral freeboard BA and required more effort to complete the task (salt-water: 4.8 ±2.5 vs. 4.0 ±1.9 6; fresh-water: 4.3 ±2.0 vs. 3.5 ±1.8). The comfort levels of participants completing the duck diving task were worse (i.e. more uncomfortable) for positive freeboard when in the salt-water compared to those BA with negative/neutral freeboard (2.5 ±1.0 vs. 2.1 ±0.7; Table 6) but similar in the fresh-water (2.0 ±0.9 vs. 1.9 ±0.8).

These results highlight an increased effort and level of exertion required to complete the duck diving task in the salt-water environment whilst also being performed slower than that of a fresh-water environment. These differences could be attributable to participants being required to search for the submerged objects with their eyes open and minus swim goggles. It is likely that the density of the salt-water (specific gravity 1.046 vs. 1.003 $g{\cdot}mL^{-1}$) presented an issue with opposing resistance to the BA when diving as well as affecting the vision of participants. The duck diving results suggest that the increased density of the salt-water environment appears to have contributed positively to the buoyancy of the participants while negatively influencing their ability to perform the duck diving task via slower times and higher perceptions of effort required to complete the task.

## 3.3 - Minimum buoyancy requirements

### 3.3.1 - Minimum buoyancy to achieve positive freeboard task

One of the buoyancy aids (BA10) allowed buoyancy inserts to be added or removed to the vest that therefore allowed this BA to be utilised specifically to assist with investigating the minimum buoyancy required to achieve a positive freeboard in both the flat salt- and fresh-water environments. During this assessment, 14 of 25 (56%) participants in the salt-water and 13 of 21 (61.9%) participants in the fresh-water successfully acheived positive freeboard. Additionally, during the fresh-water trial, researchers were unable to successfuly fit the BA on four occassions.

For this task, participants were asked to don the BA with minimal buoyancy initially, slide into the water, and exhale with the position of the lowest point of respiration noted as either positive or negative/neutral. If the task result was negative/neutral, then the next least buoyany insert was added and the protocol repeated until, where achieveable, positive freeboard was attained at which time the task was assessed as complete.

An obvious limitation of this protocol was that the BA utilised was a single design and that each of the removeable buoyancy inserts represented standardised increments rather than a sliding scale of buoyancy. Each vest comprised four buoyancy inserts: two (1x 5mm, 1x 10mm) smaller inserts for the chest region and two (1x 5mm, 1x 10mm) larger inserts for the back of the vest. The buoyancy of these inserts was consistent with the 5mm insert exhibiting half the buoyancy of that for the 10mm inserts (Appendix A) for the standardised increments.

Figure 4 indicates the relationship between participants' body mass and the minimum buoyancy required to achieve positive freeboard in the flat salt- and fresh-water environments. The figure clearly identifies a greater buoyancy requirement for the fresh-water environment as opposed to the salt-water environment.

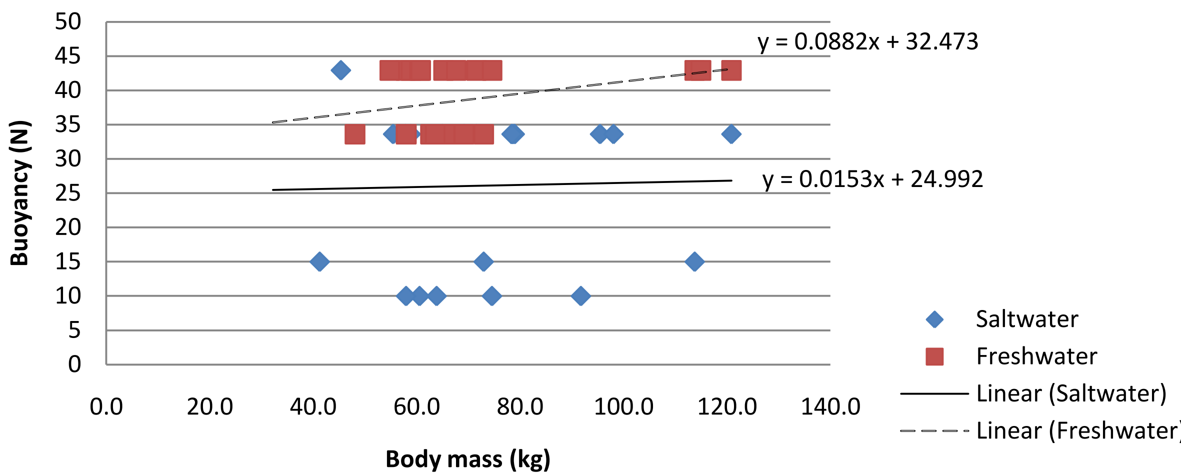


**Figure 4.** Minimum buoyancy required to obtain a positive freeboard in the flat, salt- and fresh-water environments.

Based upon the relationship between body mass and the minimum level of buoyancy required to acheive positive freeboard for participants (Figure 4), the required buoyancy to acheive a positive freeboard utilising the same buoyancy aid for a range of body masses was developed (Table 8).

**Table 8:** Minimum buoyancy required to obtain a positive freeboard in the flat, salt- and fresh-water environments.

| Body mass | Saltwater | Freshwater | Body mass | Saltwater | Freshwater |
|---|---|---|---|---|---|
| **10** | 25.15 | 33.36 | **65** | 25.99 | 38.21 |
| **15** | 25.22 | 33.80 | **70** | 26.06 | 38.65 |
| **20** | 25.30 | 34.24 | **75** | 26.14 | 39.09 |
| **25** | 25.37 | 34.68 | **80** | 26.22 | 39.53 |
| **30** | 25.45 | 35.12 | **85** | 26.29 | 39.97 |
| **35** | 25.53 | 35.56 | **90** | 26.37 | 40.41 |
| **40** | 25.60 | 36.00 | **95** | 26.45 | 40.85 |
| **45** | 25.68 | 36.44 | **100** | 26.52 | 41.29 |
| **50** | 25.76 | 36.88 | **105** | 26.60 | 41.73 |
| **55** | 25.83 | 37.32 | **110** | 26.68 | 42.18 |
| **60** | 25.91 | 37.77 | **115** | 26.75 | 42.62 |

#### 3.3.2 - Variations in positive freeboard between salt- and fresh-water environments

The distinctive number of negative or neutral freeboard results recorded for the salt-water (76, 43.7%) compared to the fresh-water (145, 84.3%) environment significantly highlights the variations in buoyancy between the two aquatic environments which are illustrated in Figures 5 and 6.

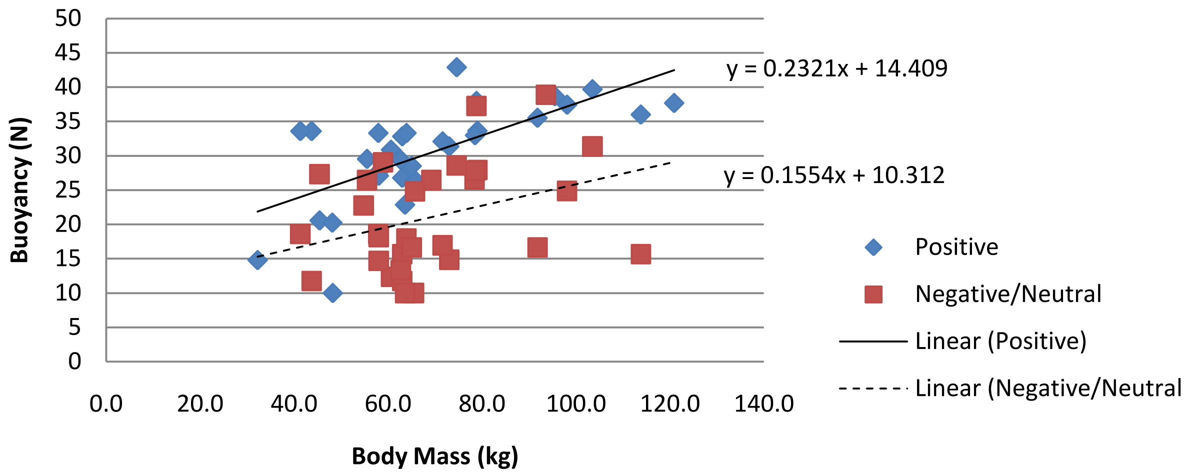


**Figure 5.** The level of buoyancy (N) vs. participant body mass (kg) that achieved positive or negative/neutral buoyancy during the freeboard assessment in the salt-water environment.

The correlations derived from the relationship between body mass and the minimum level of buoyancy required to acheive positive freeboard in the salt-water environment (Figure 5) were considered to develop the required buoyancy to acheive a positive freeboard utilising the same buoyancy aid for a range of body mass in salt-water environments (Table 9).

**Table 9:** Indication of the buoyancy (N) required to achieve positive freeboard compared to that of negative/neutral freeboard based on the relationship observed during the salt-water trials.

| Body mass | Positive | Negative/ neutral | Body mass | Positive | Negative/ neutral |
|---|---|---|---|---|---|
| **10** | 16.73 | 11.87 | **65** | 29.50 | 20.41 |
| **15** | 17.89 | 12.64 | **70** | 30.66 | 21.19 |
| **20** | 19.05 | 13.42 | **75** | 31.82 | 21.97 |
| **25** | 20.21 | 14.20 | **80** | 32.98 | 22.74 |
| **30** | 21.37 | 14.97 | **85** | 34.14 | 23.52 |
| **35** | 22.53 | 15.75 | **90** | 35.30 | 24.30 |
| **40** | 23.69 | 16.53 | **95** | 36.46 | 25.08 |
| **45** | 24.85 | 17.31 | **100** | 37.62 | 25.85 |
| **50** | 26.01 | 18.08 | **105** | 38.78 | 26.63 |
| **55** | 27.17 | 18.86 | **110** | 39.94 | 27.41 |
| **60** | 28.34 | 19.64 | **115** | 41.10 | 28.18 |

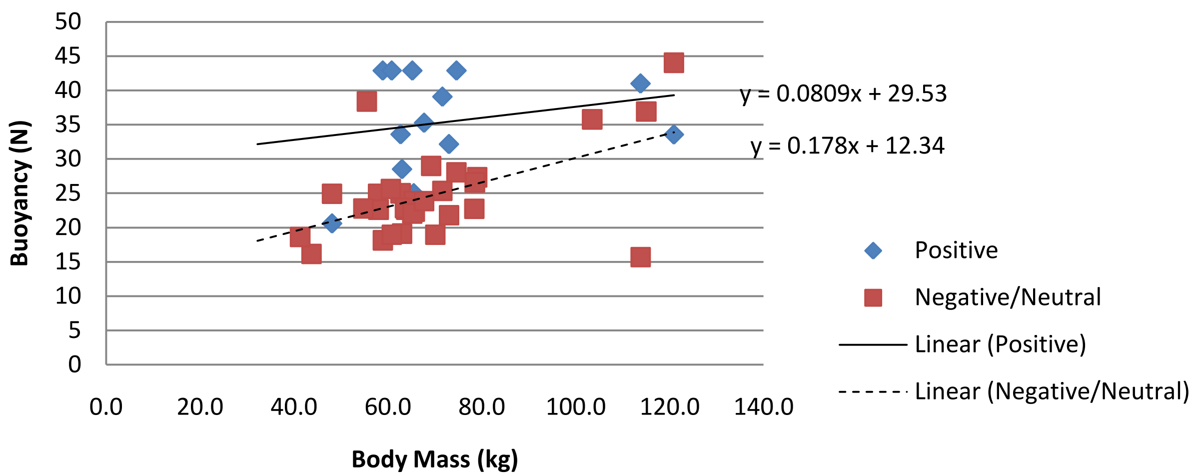


**Figure 6.** The level of buoyancy (N) vs. participant body mass (kg) that achieved positive or negative/neutral buoyancy during the freeboard assessment in the fresh-water environment.

The correlations derived from the relationship between body mass and the minimum level of buoyancy required to acheive positive freeboard in the fresh-water environment (Figure 6) were examined to develop the required buoyancy to acheive a positive freeboard utilising the same buoyancy aid for a range of body mass in fresh-water environments (Table 10).

**Table 10:** Indication of the buoyancy (N) required to achieve positive freeboard compared to that of negative/neutral freeboard based on the relationship observed during the fresh-water trials.

| Body mass | Positive | Negative/ neutral | Body mass | Positive | Negative/ neutral |
|---|---|---|---|---|---|
| **10** | 30.34 | 14.12 | **65** | 34.79 | 23.91 |
| **15** | 30.74 | 15.01 | **70** | 35.19 | 24.80 |
| **20** | 31.15 | 15.90 | **75** | 35.60 | 25.69 |
| **25** | 31.55 | 16.79 | **80** | 36.00 | 26.58 |
| **30** | 31.96 | 17.68 | **85** | 36.41 | 27.47 |
| **35** | 32.36 | 18.57 | **90** | 36.81 | 28.36 |
| **40** | 32.77 | 19.46 | **95** | 37.22 | 29.25 |
| **45** | 33.17 | 20.35 | **100** | 37.62 | 30.14 |
| **50** | 33.58 | 21.24 | **105** | 38.02 | 31.03 |
| **55** | 33.98 | 22.13 | **110** | 38.43 | 31.92 |
| **60** | 34.38 | 23.02 | **115** | 38.83 | 32.81 |

The clear discrepancy between the minimum buoyancy requirements to achieve a positive freeboard in flat salt- and fresh-water environments appears to diminish with increased body mass up to 100 kg. However as expected, greater buoyancy requirements were associated with the positive freeboard.

## 4. Conclusions

The current research project was conducted by the Institute of Sport and Exercise Science at James Cook University to assess the suitability of submitted, non-compliant (<Level 50) buoyancy aids currently available on the open market for the *fit for purpose* use for selected lifesaving sport tasks in salt- and fresh-water environments. Additionally, the project sought to identify the minimum level of buoyancy required to achieve positive freeboard in the same aquatic environments. Although the majority of tasks associated with lifesaving sport are conducted in a salt-water environment, for the standardisation of compliance testing in accordance with AS4578.3, a fresh-water environment and NATA accredited assessors were utilised. As a follow up from the previous phase of testing (Leicht, 2013), results obtained from the current study should also be utilised to assist with the potential revision of buoyancy requirements and personal protective equipment (PPE) design for more robust critical evaluation of the suitability for such equipment to be utilised within lifesaving sport.

Results from the 25m swimming and duck diving tasks identified that the density of the salt-water imposed an increased level of exertion and reduced comfort and time to complete tasks which was exacerbated by BA with greater buoyancy. This response was most evident during the duck diving task where participants were required to submerge all of their body as opposed to the swimming task where participants were on the water's surface. The differences between those BA that achieved a positive freeboard and those that were negative/neutral not only indicated an increased buoyancy requirement, but also a resultant increased effort requirement and reduction in comfort for the physical tasks, especially the duck diving task.

Potentially these differences may be a result of the increased density of the salt-water compared to that of the fresh-water environments with a two-fold number of negative or neutral freeboard results recorded for the fresh-water compared to the salt-water environment. Collectively, the results of the current study indicate that the increased density of the salt-water environment positively aided the buoyancy of participants while somewhat negatively influenced their ability to perform the physical tasks via greater efforts to complete the assessed tasks. However, all physical tasks were successfully completed by the participants whilst wearing the <Level 50 buoyancy aids assessed. The evidence from this study should be used in conjunction with previous recommendations, to address the minimum buoyancy requirements for manufacturers designing PPE for lifesaving activities.

## 5. Recommendations

The following recommendations for the minimum buoyancy requirements and *fit for purpose* use of non-compliant PPE are based on the findings of the current research project:

- Proposing an amendment to relevant authorities for a reduced level of minimum buoyancy (<Level 50) for lifesaving activities which are currently governed under ISO Standard (ISO 12402) and AS4578.3;
- Surf Life Saving Australia to assemble relevant stakeholders and experts to collate evidence and recommend revised minimum buoyancy requirements to current buoyancy standard authorities for an evidence-based review of minimum buoyancy level(s);
- Establishment of a panel of accredited, experienced coaches and/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 research should revisit previous *fit for purpose* task assessments and investigate the physiological demands of wearing PPE whilst completing standard lifesaving tasks of varying intensities, durations and environments.

# 6.0 Appendices

## Appendix A

Code allocation for the brand of BA supplied for the current project. Each brand consisted of various sizes during the testing. All buoyancy testing was conducted as per AS4758:3 by VicLab Pty Ltd (NATA accredited testing laboratory).

**[TABLE REMOVED FOR DEIDENTIFICATION VERSION OF REPORT]**

## Appendix B

Number of trials for each BA utilised within the salt- and fresh-water testing environments.

| | AS4758.3 | Freeboard | 25m swimming | Duck diving | SUB | DNF* | ***Totals*** |
|---|---|---|---|---|---|---|---|
| **Saltwater** | | | | | | | |
| **BA1** | 9 | 9 | 16 | 15 | 18 | 10 | **77** |
| **BA2** | 28 | 28 | 29 | 28 | 31 | 1 | **145** |
| **BA5** | 15 | 15 | 14 | 13 | 14 | 6 | **77** |
| **BA6** | 9 | 9 | 11 | 10 | 9 | 13 | **61** |
| **BA7** | 13 | 13 | 13 | 12 | 12 | 7 | **70** |
| **CONTROL** | n/a | n/a | 31 | 31 | 33 | n/a | **95** |
| **BA9** | 26 | 26 | 26 | 25 | 27 | 1 | **131** |
| **BA10** | 25 | 25 | 27 | 27 | 28 | 0 | **132** |
| **BA11** | 18 | 18 | 9 | 9 | 9 | 11 | **74** |
| **BA12** | 22 | 22 | 22 | 21 | 22 | 1 | **110** |
| **BA13** | 9 | 9 | 9 | 8 | 10 | 11 | **56** |
| **Totals** | **174** | **174** | **207** | **199** | **213** | **61** | **1028** |

* DNF = The buoyancy aid "*did not fit*" the participant satisfactorily

| | AS4758.3 | Freeboard | 25m swimming | Duck diving | SUB | DNF* | ***Totals*** |
|---|---|---|---|---|---|---|---|
| **Freshwater** | | | | | | | |
| **BA1** | 7 | 7 | 13 | 12 | 14 | 15 | **68** |
| **BA2** | 29 | 29 | 29 | 29 | 29 | 2 | **147** |
| **BA5** | 18 | 18 | 18 | 17 | 18 | 12 | **101** |
| **BA6** | 7 | 7 | 7 | 6 | 7 | 19 | **53** |
| **BA7** | 10 | 10 | 10 | 10 | 10 | 20 | **70** |
| **CONTROL** | n/a | n/a | 31 | 31 | 31 | n/a | **93** |
| **BA9** | 30 | 30 | 30 | 29 | 30 | 1 | **150** |
| **BA10** | 21 | 21 | 23 | 22 | 23 | 4 | **114** |
| **BA11** | 12 | 12 | 11 | 11 | 10 | 22 | **78** |
| **BA12** | 27 | 27 | 28 | 27 | 28 | 2 | **139** |
| **BA13** | 11 | 11 | 11 | 10 | 11 | 17 | **71** |
| **Totals** | **172** | **172** | **211** | **204** | **211** | **114** | **1084** |

* DNF = The buoyancy aid "*did not fit*" the participant satisfactorily

## 7.0 Addendum

Whilst compiling the "Independent testing of <Level 50 buoyancy aids for Surf Life Saving Australia", a working group was established to further analyse the minimum recommended buoyancy levels to include data collated during this project in addition to observations noted during the testing days. The working group was established in response to an impending meeting of the Standard Committee CS-060 overseeing a revision to the Australian Standard (AS4758) held in Sydney, May 7th-8th 2014. The working group who met in Townsville on Thursday, May 1st 2014 included:

- Mr Richard Donarski, Team Leader (Health and Safety), Product Services (Assurance Services), SAI Global and member of the Australian Standards CS-060 Committee for Personal Flotation Devices
- Mr Anthony Bradstreet, Coastal Risk & Safety Manager, Surf Life Saving Australia and member of the Australian Standards CS-060 Committee for Personal Flotation Devices
- Mr Wade Sinclair, James Cook University
- Mr Rob Vickery, Director, VicLab Pty Ltd and member of the Australian Standards CS-060 Committee for Personal Flotation Devices (*attendance via phone and email only*)

During the subsequent analysis, numerous data points were removed because of the following reasons:

- Data was considered an outlier;
- Data was incorrectly labelled or recorded;
- Data was removed for those participants that were only assessed in the salt-water environment; and
- All BA10 results were withdrawn due to concerns over reduced buoyancy and appropriate fit of the BA as the testing sessions progressed.

Therefore, following the above filtering process, the subsequent dataset resulted in the inclusion of only those BA that recorded positive freeboard, which included 79 in the salt-water and 17 in the fresh-water environments (Table A1).

**Table A1:** Number of observations for positive, negative and neutral freeboard from the refined dataset.

| **Salt-water** | **BA1** | **BA2** | **BA5** | **BA6** | **BA7** | **BA9** | **BA11** | **BA12** | **BA13** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive freeboard | 9 | 19 | 1 | 5 | 12 | 8 | 8 | 15 | 2 | **79** |
| Neutral freeboard | 0 | 3 | 1 | 1 | 0 | 4 | 2 | 0 | 1 | **12** |
| Negative freeboard | 2 | 6 | 10 | 3 | 1 | 13 | 5 | 6 | 4 | **50** |
| BA did not fit | 10 | 1 | 6 | 13 | 7 | 1 | 11 | 1 | 11 | **61** |
| Total number of observations conducted in the saltwater pool | | | | | | | | | | **202** |

| **Fresh-water** | **BA1** | **BA2** | **BA5** | **BA6** | **BA7** | **BA9** | **BA11** | **BA12** | **BA13** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|
| Positive freeboard | 2 | 3 | 0 | 1 | 2 | 1 | 2 | 3 | 3 | **17** |
| Neutral freeboard | 5 | 13 | 7 | 2 | 5 | 11 | 7 | 7 | 4 | **61** |
| Negative freeboard | 0 | 14 | 10 | 4 | 3 | 18 | 5 | 16 | 4 | **74** |
| BA did not fit | 15 | 2 | 12 | 19 | 20 | 1 | 22 | 2 | 18 | **111** |
| Total number of observations conducted in the freshwater pool | | | | | | | | | | **263** |

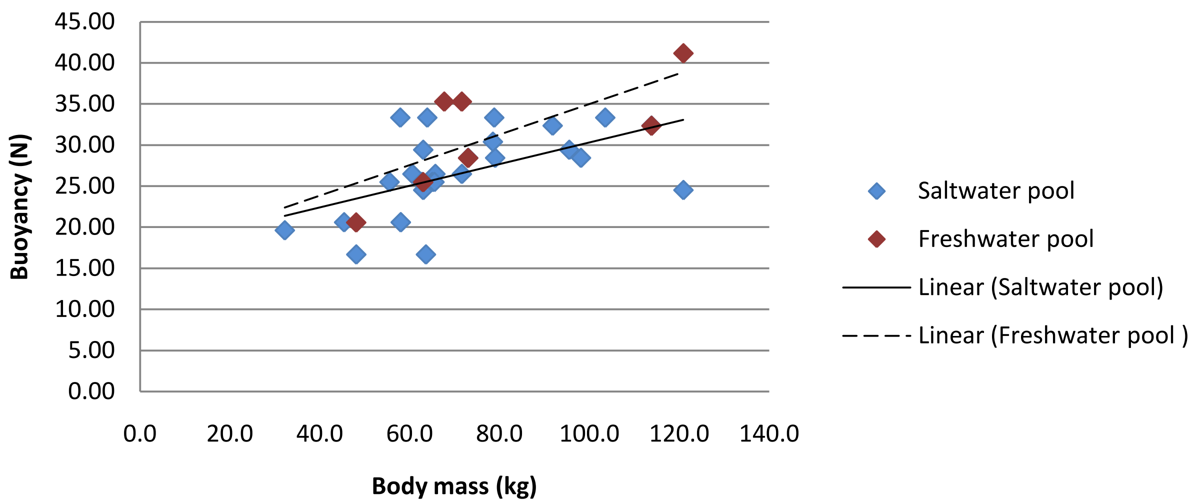


**Figure A1.** Minimum buoyancy required to obtain a positive freeboard in the flat, salt- and fresh-water environments.

Figure A1 represents the average minimum buoyancy required to obtain a positive freeboard for each participant during testing in both the salt- and fresh-water environments. Table A2 uses the regression equation derived from Figure A1 to represent the minimum buoyancy requirement for the corresponding body mass (in kg) to obtain a positive freeboard.

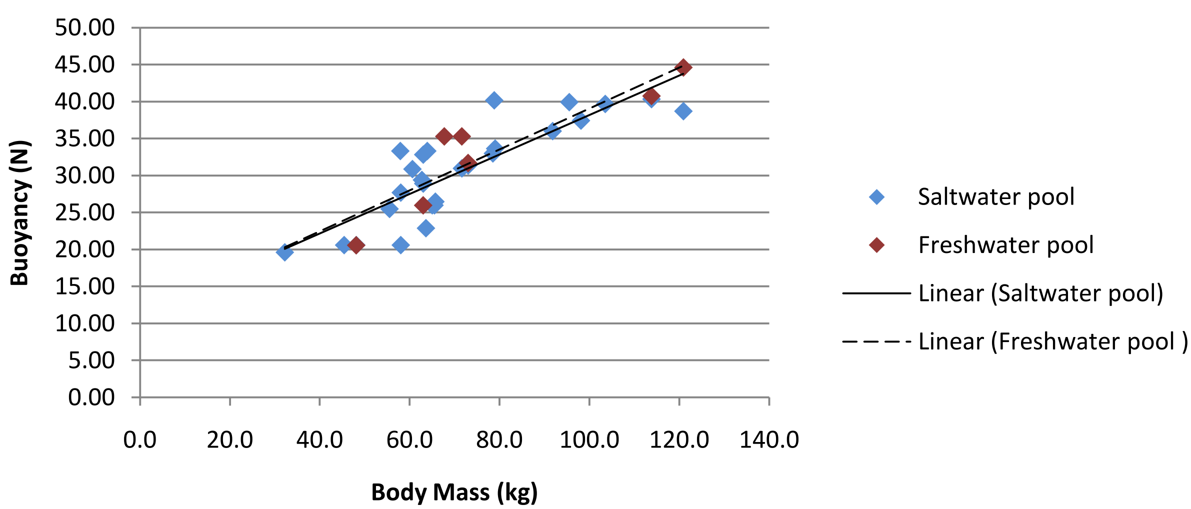


**Figure A2.** Average buoyancy required to obtain a positive freeboard in the flat, salt- and fresh-water environments.

Figure A2 represents the average buoyancy required to obtain a positive freeboard for each participant during testing in both the salt- and fresh-water environments. Table A3 uses the regression equation derived from Figure A2 to represent the average buoyancy requirement for the corresponding body mass (in kg) to obtain a positive freeboard.

**Table A2:** Minimum buoyancy required to obtain a positive freeboard in the flat, salt- and fresh-water environments (as derived from the results in Figure A1) and comparison to existing standards.

<table>
<tr><th>Body mass (kg)</th><th>Saltwater (N)</th><th>Freshwater (N)</th><th>AS1900</th><th>AS4758.1</th></tr>
<tr><td>5</td><td>17.82</td><td>17.32</td><td rowspan="2"></td><td></td></tr>
<tr><td>10</td><td>18.48</td><td>18.25</td><td rowspan="2">16.00</td></tr>
<tr><td>15</td><td>19.14</td><td>19.18</td><td rowspan="3">20.00</td></tr>
<tr><td>20</td><td>19.79</td><td>20.11</td><td rowspan="2">22.00</td></tr>
<tr><td>25</td><td>20.45</td><td>21.04</td></tr>
<tr><td>30</td><td>21.11</td><td>21.97</td><td rowspan="4">25.00</td><td rowspan="3">35.00</td></tr>
<tr><td>35</td><td>21.76</td><td>22.90</td></tr>
<tr><td>40</td><td>22.42</td><td>23.83</td></tr>
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<tr><td>55</td><td>24.39</td><td>26.62</td><td rowspan="2">45.00</td></tr>
<tr><td>60</td><td>25.05</td><td>27.55</td></tr>
<tr><td>65</td><td>25.71</td><td>28.48</td><td rowspan="2">53.00</td></tr>
<tr><td>70</td><td>26.36</td><td>29.41</td></tr>
<tr><td>75</td><td>27.02</td><td>30.34</td><td rowspan="16">60.00</td></tr>
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<tr><td>150</td><td>36.87</td><td>44.29</td></tr>
</table>

**Table A3:** Average buoyancy required to obtain a positive freeboard in the flat, salt- and fresh-water environments (as derived from the results in Figure A2) and comparison to existing standards.

<table>
<tr><th>Body mass (kg)</th><th>Saltwater (N)</th><th>Freshwater (N)</th><th>AS1900</th><th>AS4758.1</th></tr>
<tr><td>5</td><td>12.83</td><td>12.79</td><td rowspan="2"></td><td></td></tr>
<tr><td>10</td><td>14.16</td><td>14.17</td><td rowspan="2">16.00</td></tr>
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<tr><td>30</td><td>19.49</td><td>19.70</td><td rowspan="4">25.00</td><td rowspan="3">35.00</td></tr>
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<tr><td>55</td><td>26.16</td><td>26.61</td><td rowspan="2">45.00</td></tr>
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<tr><td>135</td><td>47.50</td><td>48.72</td></tr>
<tr><td>140</td><td>48.83</td><td>50.10</td></tr>
<tr><td>145</td><td>50.16</td><td>51.48</td></tr>
<tr><td>150</td><td>51.50</td><td>52.87</td></tr>
</table>