Evaluation of the Helicopter Emergency Breathing Apparatus on Egress Performance

Michael King; Elizabeth Sanli; Kaitlin Mugford; Stefanie Martina; Robert Brown; Heather Carnahan

BACKGROUND: Emergency helicopter landing at sea is dangerous. Specialized training, known as helicopter underwater escape training (HUET), prepares occupants to quickly exit the helicopter, which often inverts and sinks. In most jurisdictions, helicopter occupants are equipped with a helicopter underwater egress breathing apparatus (HUEBA) to provide sufficient air for escape. HUET trainees report that the HUEBA is easy to use, but it is well known that learners are often overconfident in their judgement of learning. To better understand how the HUEBA affects HUET sequence performance, we investigated whether using the HUEBA influences the sequence movement time and number of errors.

METHODS: Twelve participants (7 men and 5 women, mean age 25.33 ± 9.57 SD) with no prior experience with HUET performed consecutive trials of the HUET sequence, 5 with the HUEBA and 5 without the HUEBA. Video of each trial recorded the total movement time and enabled movement time analyses of each component of the sequence: crossing arms, tucking the head, pushing the window, inserting the regulator, and releasing the seatbelt. These recordings were also used to score performance errors according to a checklist.

RESULTS: Analyses revealed that using a HUEBA increased the total movement time and time to release the seatbelt by 0.36 and 0.39 s, respectively, in comparison to without the HUEBA.

DISCUSSION: Our study illustrates that using the HUEBA during the HUET sequence increases total movement time and time to release the seatbelt. However, this difference is marginal and unlikely to have practical significance during underwater escape.

KEYWORDS: HUET, HUEBA, helicopter underwater escape training, helicopter underwater escape breathing apparatus.

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Helicopters that undergo ditching at sea frequently invert and sink.[1] Occupants without a supplementary air supply often drown because they are unable to hold their breath long enough to escape.[5] Specialized training, known as helicopter underwater escape training (HUET), effectively prepares crew and passengers to perform the necessary procedures to safely and quickly escape the helicopter.[6] However, exposure to cold water and disorientation decreases breath hold time and some occupants are not able to escape with breath holding alone.[4] As a result, helicopter underwater escape breathing apparatus (HUEBA) has been added to HUET courses in order to compensate for insufficient breath hold times.[3]

Early investigations on the use of the HUEBA during HUET indicate that trainees feel the HUEBA is either easy or very easy to use.[2] However, it is well known that learners are overconfident in their judgement of learning and future performance.[8] Also, the use of the HUEBA introduces an additional step in the escape sequence. It is thought that an increase in the number of steps of a learned motor sequence increases overall performance time, as well as movement time for subsequent steps.[9,10] To better understand how the introduction of HUEBA affects HUET performance, we investigated whether the addition of the HUEBA influences movement times of the HUET sequence. Our hypothesis was that movement times of the HUET sequence would increase with use of the HUEBA.

METHODS

Recruited for the study were 12 subjects (7 men and 5 women, mean age 25.33 ± 9.57 SD, 2 with previous scuba experience)

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with no prior experience with HUET sequences. This study was approved by the local human ethics board.

A stand-alone Emergency Breathing System Inversion Training helicopter seat was positioned in front of a video camera (SONY HDR-PJ340, Handycam) that was used to record each trial at a frame rate of 60 Hz. This seat rested flat on the ground in a quiet room adjacent to our lab and remained in the upright position during the entire experiment (i.e., was not inverted). All trials were recorded and the field of view included the participant's head, torso, and limbs. In the absence of an immersion suit, the HUEBA was attached to the seat so that the HUEBA regulator rested over the participant's left chest. The regulator was held in place above the HUEBA (Aqua Lung Survival Egress Air – LV2, 207 BAR/42.5 L) by a dust cover, which is the typical arrangement in flight and during training.

A rectangular mock window (42.7 cm wide × 49.2 cm high) was constructed of duct tape and placed on the lab wall to the right of the participant in the helicopter seat. The experiment was verbally coordinated by a member of the research team (i.e., indicate trial number, initiate recordings etc.) from a chair behind the video camera. Between participants, HUEBA regulator mouthpieces and dust covers were sanitized with MetriCide 28 according to the manufacturer's protocol.

Subjects visited the lab on a single day and provided written informed consent before participating. First, they were given an overview of the study and then completed a demographic form that included questions on age and past experience with HUET, HUEBA, or any prior training related to self-contained underwater breathing apparatus (scuba). In a separate and quiet room, each participant individually watched a 20-min video outlining the HUET sequence. This video was created and facilitated by a trained instructor and explained the proper underwater egress sequence.

After this, participants were familiarized with the experimental set up and performed 10 consecutive trials of the HUET sequence. Five consecutive egress sequences were performed with the HUEBA and then five consecutive egress trials were performed without the inclusion of the HUEBA. The presentation of these two conditions was counterbalanced across participants where half the participants performed the first five trials without the HUEBA. Subjects performed each helicopter egress sequence in response to verbal commands. The standardized commands were "Ditching, Ditching, Ditching", "Brace, Brace, Brace", and "Impact, Impact, Impact". The nine egress steps in the checklist that were scored for correctness were: 1) arms crossed, hands clasping seatbelt; 2) arm closest to window on top; 3) feet flat on the floor and clear of seat; 4) head tucked; 5) jettison window; 6) hand on window frame; 7) pull regulator clear of cover; 8) place HUEBA mouthpiece in mouth; and 9) release seatbelt. Without the HUEBA, steps 7 and 8 (pull regulator clear of cover and place HUEBA mouthpiece in the mouth) were eliminated. (**Table I**).

Video recordings of each trial were imported into Studiocode software version 5.8.6 (Digital Tec Solutions, Newark, DE, USA). Movement time (MT) was defined as the length of time from movement initiation to movement completion and was calculated for the following five movements: crossing arms, tucking the head, pushing the window, inserting the regulator, and releasing the seatbelt.

MT was recorded for use of the HUEBA, but not included in the comparison between conditions (i.e., with and without HUEBA). Total MT was calculated by adding each of these times together for each participant. We also calculated total number of errors in HUET sequence performance based on a checklist developed by Martina et al.[7] An error was defined if the participant did not perform a checklist item or if they performed it incorrectly. For example, an error was documented if a participant did not push the corner of the window (Table I, column 2, item 5) or if a participant had their feet on the ground but below the seat (Table I, column 2, item 3). Total egress errors were calculated by adding all errors across the 10 trials for each participant.

Total MT was compared using a paired *t*-test. To decompose the source of any possible differences in total MT, the MT data were analyzed as a two-way analysis of variance (ANOVA). The two factors were HUEBA use (two levels: with HUEBA and without HUEBA) and movement type (four levels: crossed arms movement, tucking head movement, pushing window movement, and releasing the seatbelt movement) with repeated measures on both factors. Statistical significance was defined as $P \leq 0.05$ and we reported means ± SD. A Sidak's test was performed in any instance where the ANOVA analyses showed a significant interaction. In addition, the total MT for the sequence was calculated.

The mean number of egress errors for each participant was calculated and compared using a Wilcoxon paired *t*-test between

Table I. Verbal Instructions, the Steps of the Sequence That Were Checked For Accuracy, and the Steps That Were Timed for Analyses of Movement Time.

VERBAL INSTRUCTION CUE	CHECKLIST FOR ACCURACY	ACTIONS MEASURED BY MOVEMENT TIME
"Ditching, Ditching, Ditching"	Prepare for brace cue	Prepare for brace cue
"Brace, Brace, Brace"	1. Arms crossed hands clasping seatbelt. 2. Arm closest to the window on top. 3. Feet flat on the floor and clear of the seat. 4. Head tucked.	1. Cross arms over chest. 2. Tuck head into chest.
"Impact, Impact, Impact"	5. Push corner of window. 6. Hand on window frame. 7. Remove regulator. 8. Insert regulator into mouth. 9. Release seatbelt.	3. Push corner of window. 4. Remove regulator cap and insert regulator into mouth. 5. Release seatbelt.

the conditions with and without the HUEBA. We also calculated the top three checklist errors that were most common.

RESULTS

The paired *t*-test for total MT demonstrated that total MT while using the HUEBA was 0.36 s longer in comparison to the total MT without using the HUEBA [$t(11) = 4.83$, $P = 0.0005$, 6.13 ± 1.58 vs. 5.78 ± 1.72 s]. Total MT and movement time for releasing the seat belt were 0.36 ($P = 0.0005$) and 0.39 s ($P < 0.0001$) longer, respectively, for the HUEBA conditions compared to the without HUEBA conditions. The ANOVA of movement time demonstrated that there was a main effect of HUEBA use [**Fig. 1**, $F(1, 11) = 23.3$, $P = 0.0005$] and movement type [Fig. 1, $F(3, 33) = 289.3$, $P < 0.0001$]. There was also an interaction between movement type and HUEBA use [$F(3, 33) = 29.46$, $P < 0.0001$]. Sidak's multiple comparison test revealed that seatbelt movement time was 0.39 s slower during HUEBA trials than during the without HUEBA trials [$t(33) = 10.52$, $P < 0.0001$]. Mean movement time of using the HUEBA during HUEBA trials was 2.752 ± 0.7509.

The paired *t*-test for average number of checklist errors demonstrated that there was no difference between conditions. The top three errors for the HUEBA condition were: hand on the window frame (45%, 39 errors), arm closest to window on top (22%, 19 errors), and head tucked (9%, 8 errors). The top three errors for the without HUEBA condition were: hand on the window frame (58%, 45 errors), arm closest to window on top (31%, 24 errors), and jettison window (6%, 5 errors).

DISCUSSION

The main finding of this study was that total MT was longer in trials where participants used the HUEBA compared to trials where participants did not use the HUEBA. It is important to note that this MT did not include the HUEBA movement itself. While statistically significant, it is important to note that the differences in total MT and seat belt release time were marginal (0.36 s and 0.39 s) and are unlikely to have an effect on a person's overall egress time from a ditched, submerged helicopter. The amount of total MT added to the sequence represents 1.4% of the typical time required to escape a Super Puma helicopter (28 s).[4] There was no difference in checklist errors between groups, which illustrates that adding the HUEBA to HUET egress does not increase difficulty. This study supports the use of the HUEBA device as it does not practically impact helicopter egress time, but provides a valuable oxygen source to prevent drowning during extended escape periods.

We suggest that there are two possible reasons for increased MT in the with HUEBA trials. Firstly, it has been proposed that when generating sequential movements, the brain has a finite capacity to store and implement motor sequences prior to execution.[10] In this model, an increase in movement sequence length is thought to cause an increase movement time. In the current study, the addition of the HUEBA adds two movements to the overall sequence (removing the regulator cap and inserting the regulator) and this could have led to the increased movement time of the subsequent step (release seatbelt).

Given that the present study was carried out in a laboratory setting, there may be limits to its ecological validity in both training and real-world settings. For example, if this study were to be replicated underwater and inverted, then the time required to complete these tasks could be expected to increase and thus the associated increase in movement time may also increase.[6] In addition, participants received less familiarization with the task than they would have received if they were taking a full HUET course.

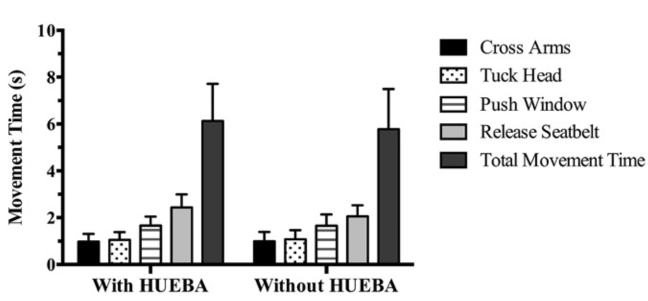

Fig. 1. MT for all movements (columns 1–4) and total MT (final column) for with and without HUEBA conditions. HUEBA: helicopter underwater escape breathing apparatus; MT: total movement time.

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