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In-Water Performance of Infant Lifejackets: Freeboard Height and Self-Righting Time: A Failure!

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Abstract

Canada published a new lifejacket standard in 2007, but at the time the literature on infant lifejacket performance was sparse and did not guide creation of the standard. Since that time the authors conducted a series of trials on currently available infant lifejackets against this standard. The purpose of this paper is to present the findings of the in-water performance trials of freeboard height and self-righting time. A total of 25 parents consented to have their child participate. The attempts at measuring in-water performance were generally unsuccessful. Principal reasons were that the children could not relax in the water and did not want to be placed in a face-down position. Only 17 (21%) reliable freeboard measurements could be taken; while only 2 (8%) participants even attempted the face-down position. It is recommended that Canada move to the use of manikins for evaluation of infant lifejacket freeboard height and self-righting time.

Keywords: Lifejacket; Standard; Performance

Introduction

Canada published a new lifejacket standard in 2007 (CAN/CGSB-65.7-2007); however, the literature on the performance of infant lifejackets was sparse [1-3] to guide the creators of the standard. Therefore, MacDonald et al. [4], commenced to conduct an extensive series of trials on currently available approved and non-approved infant lifejackets against this standard. The first paper MacDonald et al., [5] reported the results of the accuracy and timing of donning eight lifejackets on a soft infant manikin. The reason for the initial use of the manikin was to eliminate the effect of the child's behaviour which may confound the results of the donning process. Only one lifejacket passed all tests, and the speed of donning was increased by 10 seconds for each subtask involved in securing the lifejacket.

Typically, laboratories and test houses keep a 'pool' of volunteers to be participants in lifejacket approval trials. Therefore, our second paper [6] examined the effect of familiarity on lifejacket donning on the pass/fail process. Regardless of lifejacket type, this showed a significant effect on the first donning, but not with subsequent donning attempts. Thus, this effect "contaminates" the test participants, and we recommended that participants should only be used for one evaluation. Sex, age, marine equipment experience had no effect on the pass/failure rate.

Now we had baseline data for donning times, accuracy for eight 'well' and 'poorly' designed lifejackets, simply due to logistics, we chose to continue our experiments with four lifejackets including the best and worst performing lifejacket from the first study, as well as two other lifejackets that had fundamentally different design features. Our third experiment using new subjects was to validate the donning times and accuracy of the lifejackets on their children. We reported [6] that the findings were consistent with manikin findings for both best and worst performing jackets. But they were not consistent for 'mediocre' lifejackets. These jackets passed the human trials, but failed the manikin trials. This suggested that the manikin is a better, more reliable and stringent method of testing. Fundamentally, this is a good thing, but it may cause rejection of some borderline lifejackets. So, we recommended that test houses use the manikin, but in doubt resort to human testing in these cases. Like Coleshaw et al., [2] and Funkhouser & Fairlie [3] these tests confirmed our findings that the number of subtasks is directly related to the increase in donning time, and if the buckles and straps are not colour and size coded, the number of errors increases.

This now led us into the fourth, final and most important experiment, that of the in-water performance. The new group of 55 adults who had been asked to don one of four lifejackets on their own children [5] were asked if they would continue with the in-water trials.

Based on the requirements outlined in section 6.9, 6.10 and 6.11 of the Canadian lifejacket standard CAN/CGSB-65.7-2007, the purpose was to measure the freeboard height and self-righting time of each lifejacket while properly fitted on a child. To receive certification, the lifejacket must meet the following freeboard height and self-righting time performance criteria:

1. Freeboard Height: The total distance measured between the lower corner of an unconscious wearer's mouth and the level of the water (in a calm state) must be equal to or greater than 100 millimeters;
2. Self-righting Time: The time required for an unconscious wearer to be turned from a face down position to a position in which the airway becomes clear of the water's surface (in a calm state) must be less than or equal to 5 seconds; The experiment was approved by the Dalhousie University Ethics Committee.

Methods

Procurement of child lifejackets

Four child lifejackets which complied with the Canadian General Standards Board (CGSB) child lifejacket size requirements were procured for this study. Three of the lifejackets were procured from

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outside of Canada and were therefore not approved for use in the Canadian market place; while one lifejacket had been approved under the recently rescinded CGSB/CAN-65.7-M88 standard (Canadian General Standards Board, [7,8]). Until now, Canada has had a very conservative policy on child lifejacket design; and so, there are very few design options for customers wishing to purchase "approved" lifejackets. This was one of the benefits for conducting this experiment using lifejackets which were not approved in Canada; so that we could possibly identify other novel child lifejacket designs which may have the potential for future approval in Canada, under the new standard.

Choice of participants

Adult and child participants were chosen using a sample of convenience from the general public within the surrounding Halifax, Dartmouth and Cole Harbour, Nova Scotia, Canada region. Adult participants provided written informed consent to allow their child to participate in both the donning and in-water portions of the study. This paper only presents the findings of the in-water portion of the study.

Lifejacket allocation

A questionnaire was administered to each adult participant prior to testing. This was done to quantify their experience in and around open water and their experience with lifejackets. Based on the answers to the questionnaire, adults were stratified by experience and then randomly assigned into lifejacket groups A, B, C or D. Once each adult and child had completed a donning performance trial and the child was correctly secured in their allocated lifejacket, they were asked if they would like to continue with the study and perform the in-water portion to measure the freeboard height and self-righting time of their allocated lifejacket. This proved to be very difficult because many children did not wish to participate after their donning performance trial. Furthermore, even those children who did choose to participate were unable to remain still while the in-water performance measurements were recorded. So, in an attempt to gather as much in-water performance data on each of the four lifejackets as possible, we asked any children who were capable of remaining calm during their in-water performance trial to repeat the process with more than one lifejacket. This was found to be a fairly effective strategy and was similar to a strategy employed by Coleshaw et al [2].

Observations during evaluation

Due to the difficulties encountered with children remaining calm during testing, a measure of each child's "compliance" was recorded by both the principal investigator (PI) and the parent during the in-water performance trials. This compliance measure was taken so that any problems encountered during testing could be noted and used to either: 1) make note of the reliability of the measurements; 2) provide feedback to the manufacturer and/or Canadian General Standards Board; and 3) to improve the wording in the standard.

Procedure

Before commencement of the in-water portion of the study, adult participants provided written informed consent (in accordance with Dalhousie Ethics Committee guidelines), completed the experience questionnaire, and had their child's height, body mass and chest circumference (CC) measured to ensure that they met the CGSB's anthropometric requirement for children's lifejackets.

Freeboard height: Each child presented themselves at the pool-side dressed in a bathing suit and their allocated lifejacket. The PI then checked to ensure that the lifejacket was donned correctly on the child. The child then entered the pool with the PI and in some cases with the parent as well to help calm the child. At this point, the lifejacket was examined again to ensure that it still remained securely and correctly fastened on the child. To gain the child's confidence, the child was then provided with a few minutes to play and float around in the lifejacket. Once ready, the child was asked to adopt the natural face-up floating position created by the lifejacket, and remain as still as possible. The PI and/or the parent then slowly positioned the floating child beside a vertical measuring tape that was suspended from the end of a bar that projected over the pool side. Once in position, the child was slowly released, allowing them to float unassisted. The difference in height between the water level and the lower corner of the child's mouth was recorded and the process repeated three times, or until the child became uncooperative and no further reliable measures could be made. The number of trials completed by each child was recorded and any reasons for stopping were noted.

Self-righting time: If the child remained cooperative for the duration of the freeboard height measurements and the adult and child gave consent, the child was then asked to perform a self-righting trial. This was conducted by having the child assume a prone position in the water with his/her face just below the surface. If the child was not cooperative, he/she was instructed to "blow bubbles", while the adult and/or PI mimicked the action. This was done in an effort to help relax the child and have him/her gain confidence that nothing untoward would happen. Once the child was relaxed with his/her face just below the water's surface, the PI started the timer, while at the same time the child was released to float freely. The time taken from release in the initial face down position to the time when the child's mouth lifted above the water was recorded. This process was repeated two more times, or until the child became uncooperative and in which case reliable measures could not be made. If at any point the child remained face down for greater than 5 seconds, he/she was physically self-righted by the adult and/or PI. The number of trials completed by each child was recorded and any reasons for stopping were noted.

Data reduction and analysis

The measurements of freeboard height and self-righting time were collected and recorded in Microsoft Excel 2003. Each participant's data were reviewed and checked for errors by the PI. Descriptive statistics (mean and standard deviation) were calculated for the freeboard height and self-righting time of each lifejacket. In addition, the frequency of pass/fail for freeboard height and self-righting time were determined. To ensure that the groups were similar in general demographics, an ANOVA (General Linear Model) was performed to test for any differences in age of adults, as well differences in age, mass, height, and CC of children among the four groups in Minitab version 15®.

Results

Participants

Fifty-five children started the original donning trials [6] and were randomly assigned to the four lifejackets A, B, C or D. Only 25 (45%) adults and children chose to continue in the study and participate in the in-water performance trials. This was a drop-out rate of 55%, as illustrated in Table 1. Twenty-two (88%) of the 25 children who participated had or were currently taking swimming lessons. By random chance and the high drop-out rate, lifejackets A and C were both seriously underrepresented in the in-water trials, with only 1 (4%) participant from group A and 2 (8%) participants from group C participating in the in-water measurements. The remaining 22 (88%)

Lifejacket Group	Number of Children in Original Donning Portion	Number of Children who Dropped Out of Study	Number of children Remaining for In-Water	Adjusted Number of Children per Group
A	13	12	1	7
B	15	4	11	11
C	13	11	2	7
D	14	3	11	11
Total	**55**	**30**	**25**	**36**

Table 1: Number of participants per lifejacket group from original donning trials (MacDonald et al., 2016) to final in-water performance trials.

participants were purely by coincidence split evenly among groups B and D. Due to this limited number of participants in groups A and C, willing children in groups B and D were asked if they would conduct more in-water measurements with lifejackets A and/or C.

Consequently, 6 (27%) participants from groups B and D also performed in-water trials with lifejacket A, and 5 (23%) participants from groups B and D performed in-water trials with lifejacket C. This resulted in a total of 36 in-water measurements recorded for the four lifejackets. The progression from the original 55 participants, to the 25 in-water participants, to the final adjusted groups is presented in Table 1.

Of the 25 children who participated, their body masses ranged from 9.5 to 18.1 kg, with a mean mass of 14.9 kg and a standard deviation of 2.6 kg; heights ranged from 75 to 113 cm, with a mean height of 98 cm and a standard deviation of 11 cm; CC ranged from 47 to 64 cm, with a mean CC of 54 cm and a standard deviation of 4 cm (Table 2). An ANOVA (General Linear Model) was performed to test for main effects of mass, height and CC. No significant differences ($p < 0.05$) were found for any main effects of mass, height and CC between any of the lifejacket groups, regardless of sex.

Freeboard height

A total of 36 freeboard height measurements were made with 25 children. The freeboard height of lifejacket A ranged from 13 to 68 mm, with a mean height of 47 mm and a standard deviation of 18 mm. The freeboard height of lifejacket B ranged from 32 to 65 mm, with a mean height of 48 mm and a standard deviation of 12 mm. The freeboard height of lifejacket C ranged from 50 to 108 mm, with a mean height of 78 mm and a standard deviation of 23 mm. The freeboard height of lifejacket D ranged from 3 to 53 mm, with a mean height of 33 mm and a standard deviation of 18 mm (Table 3).

None of the participants wearing lifejacket A, B or D attained the 100 mm level, while only one (14%) of the 7 participants wearing lifejacket C attained the 100 mm level. Overall, the mean freeboard height for each group was less than the 100 mm level required by the Canadian standard.

Self-Righting time

Of the 25 children who commenced the freeboard height measurements, only two (8%) children attempted to complete a self-righting measurement. This represented a total drop-out rate of 96% from the original 55 participants. One child attempted to self-right while wearing lifejacket A and 1 child attempted to self-right while wearing lifejacket D. Mean self-righting time for lifejacket A was 2.8 seconds, with a standard deviation of 0.6 seconds, while mean self-righting time for lifejacket D was 1.2 seconds, with a standard deviation of 0.1 seconds. In all 4 (100%) trials (2 trials per lifejacket), the child pulled their head out of the water voluntarily, without allowing the lifejacket to cause the self-righting movement, they were not a valid measurements.

Observations of the in-water performance procedure

The adult and the PI agreed that the child's behaviour during the in-water trials influenced the measurement of freeboard height in 17 (47%) of the 36 cases, while it was agreed that both children's behaviour had an influence on the measurement of self-righting time. One parent suggested that their child would have been more comfortable and better behaved if other children had been present and participating together.

Discussion

Even with everyone's best effort, the results in this study were to put it bluntly, a complete failure. Yet, we feel morally duty-bound to report the findings. The first problem encountered was getting the Human Ethics Committee to approve the study. The protocol was designed to be not unlike that used by swimming instructors teaching children swimming lessons every weekend in the shallow end of the local swimming pool. The Committee got the impression that we may be putting the children through some terrifying event. This included having to persuade one member that we did not need a child psychologist by the side of the pool to counsel any child who may have had an unpleasant experience. We knew that adults would not volunteer their children if both they and their children (irrespective of age) were not comfortable in the water, and that no harm would come as a result. A criticism of this study was that the parents and children were a pre-selected group as 88% of the children had or were currently taking swimming lessons. However, this didn't improve the success rate of the study. As discovered, most parents and children did not wish to participate in the in-water trials, particularly the in-water portion.

From initial recruitment, the drop-out rate for the in-water trials was an astonishing 51%; and even then, of the 25 children who did volunteer, only 2 (8%) attempted a self-righting. Funkhouser and Fairlie [3] reported similar findings with a 23% participant drop-out rate between donning trials and in-water measurements.

The first practical observation made was that in only 1 of all 36 attempts at freeboard height did a lifejacket (C) meet the 100mm requirement. This was surprising considering that all four lifejackets were intended for children with the same anthropometric dimensions as those who participated in the study. Even then this finding was only reliable in 47% of measurements; as the adult and PI agreed that the child behaved anxiously in 17 of the 36 attempts. This finding was similar to that of Coleshaw et al., [2] who found that 17 (71%) of the 24 children who participated in freeboard height measurements did not remain calm for a length of time long enough to take a reliable measurement.

As for our second practical measurement of self-righting time, it was not possible to make any reliable measurements; as both children who attempted the measurement brought their heads above water prematurely, rather than allowing the lifejacket to do its work. In 47% of freeboard height measurements and 100% of self-righting time measurements, the data was unreliable. Furthermore, the technique of

Lifejacket Group	Adjusted Number of Children per Group	Mean (SD) Body Mass (kg)	Mean (SD) Height (cm)	Mean (SD) CC (mm)
A	7	15.5 (2.5)	102 (8)	550 (50)
B	11	14.8 (3.1)	97 (12)	530 (40)
C	7	15.0 (2.3)	96 (8)	540 (30)
D	11	15.1 (2.2)	98 (11)	540 (50)
Total	**36**	**15.1 (2.5)**	**98 (10)**	**540 (43)**

Table 2: Mass, height (Ht) and CC values for all children who wore each lifejacket during each in-water performance measurement.

Lifejacket Group	Adjusted No. of Children per Group	Mean (SD) FB Height (mm)	Range FB Height (mm)
A	7	47 (18)	13 - 68
B	11	48 (12)	32 - 65
C	7	78 (23)	50 - 108
D	11	33 (18)	3 - 53
Total	**36**	**50 (23)**	**3 - 108**

Table 3: Mean and SD freeboard height (FB) for each lifejacket group.

asking children to blow bubbles was a desperate attempt to relax them and gather more data was flawed, simply because reducing the lung volume altered the whole dynamics of the flotation position.

To our knowledge, except for our three recently published papers, there are only two other papers published on infant lifejackets in the literature, one by [3], and the second by Coleshaw et al., in [2]. The reasons suggested for this are three fold: 1) difficulties with human ethics approval; 2) difficulties in recruiting adults and children; and finally 3) the unreliability of the children's ability to perform in-water tests.

For the reasons stated above, we can no longer support the use of children in conducting freeboard and self-righting tests. Canada should move as soon as possible to using adjustable manikins for this purpose.

Conclusion

The attempts at measuring freeboard height and self-righting properties of 4 children's lifejackets on a group of representative children were generally unsuccessful. The principal reasons were that the children could not relax in the water and did not want to volunteer to be placed in a face-down position. This resulted in an overall drop-out rate of 96% from the original group of 55 volunteers.

It was only possible to take reliable freeboard measurements on 17 (21%) of 25 children. Of the only 2 children that volunteered to assume the face-down position and perform a self-righting test, neither did so correctly.

None of the 4 lifejackets had a mean freeboard height equal to or greater than the 100 mm level as required by the Canadian Standard.

Recommendations

Canada should move as soon as possible to use manikin testing for the children's in-water measurements of freeboard height and self-righting time.

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