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The Influence of Familiarity on Life Jacket Donning Performance: Implications for Participant Selection

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Laboratories and test houses keep a "pool" of test subjects that volunteer to be participants in life jacket approval testing, which is believed to be an incorrect procedure. Fifty-six participants donned 8 child/infant life jackets onto 4 infant manikins in random order with time and accuracy of donning recorded. Average donning time for all 8 life jackets decreased significantly after the first donning experience. The findings show that the effect of familiarity occurs immediately after the first test, regardless of life jacket type, thus "contaminating" the subject and making them unsuitable for further tests. These observations are important for life jacket standards where the life jacket must be donned by a naïve participant. Currently, a poorly designed life jacket may receive a pass as a result of the learning effect as shown by participants with previous donning experiences.

personal flotation device drowning survival marine donning standards

1. INTRODUCTION

Ergonomics is an important part of industry growth and development. The principle goals of ergonomics are to improve the productivity and the health and safety of the work systems. Ergonomics requires that there be a match between the capacities and the capabilities of the work and the work to be performed. This requires knowledge of the physical, cognitive and behavioral characteristics of the workers. When applying ergonomics to specific products this means that the design of the equipment must consider these traits of the intended users of the equipment. For the past few years the authors have assisted regulatory agencies in the review and modifications to existing standards especially in the area of personal protective clothing [1, 2]. What has become apparent through this work is that ergonomic principles are not always used in the design of standards and testing of equipment against a standard. The case in point in this study is the testing of lifejackets intended for children and infants.

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In particular, the second author has been involved in the testing and qualification of life jackets for over 30 years. He has also been involved in the inspection and auditing of various test houses across North America. In the past, in some of these houses and in some of the military research laboratories, it has been observed that the establishment kept a list of test participants that could be called upon at anytime to be participants in a series of life jacket approval testing. He consistently argued that this was the incorrect procedure to use because of the learning "practice" effect, and that each participant should be a naïve participant. When challenged on this subject, he could not produce any scientific evidence to support his opinion.

Recently, with a grant from the Transport Canada Marine Safety Branch, his team was asked to evaluate a series of child/infant life jackets [3]. This gave the researchers the opportunity to examine the practice effect of donning life jackets and report their findings in the process of testing the life jackets for a new Standard No. CAN/CGSB-65.7-2007 [4]. This work extended the initial work conducted by Funkhouser and Fairlie [5] and Coleshaw, Herrmann, Lindquist, et al. [6]. According to the standard the minimum number of participants to be tested in the evaluation of a life jacket varies according to the adjustment capabilities of the lifejacket. For the purpose of our study the number of test participants required is a minimum of 6 and a maximum of 12. We have also assumed that the child may not always be capable of self-donning and so we tested all the life jackets assuming an adult would be available to don the life jacket on the child. Therefore, the purpose of this study was to determine the effect of familiarity with life jackets on subsequent donning times of infant life jackets.

2. METHODS

Eight currently available child/infant life jackets were procured for evaluation and separated into two groups of four. This enabled us to statistically evaluate if a learning effect for donning time existed on subsequent life jackets after the first life jacket was donned. Fifty-six participants formed a sample of convenience from the general public to test the eight life jackets. The participants were assigned to one of two groups balanced for experience with life jackets and children. The groups were formed to reduce the number of life jackets each participant would don. The participants may have donned a life jacket on themselves or their children in the past, but had never been part of a participant pool for the qualification of a life jacket. Participants were allowed to participate even if they had had past experience with life jackets or safety equipment. In other words, they were similar to the type of participant that the test houses recruit for evaluation of a newly produced life jacket, or who tend to volunteer for such work.

A Red Cross soft manikin representing a 6–12-month-old child/infant was deliberately chosen for this series of evaluations. The manikin was used since it represented the best-case scenario of a compliant, co-operative child, which may not be the case in an emergency situation. Consequently, the donning time would be an accurate representation of both the donner and the life jacket, and not affected by the related emergency factors. The validation of these findings has been planned and a repeat of the evaluations using children/infants and the parent is currently underway.

Although not proven, it is suspected that in practice and especially in an emergency, no one ever reads the donning instructions since they are generally not easy to interpret or are absent, or the environmental conditions may impede the use of the written instructions. Even when present, the instructions on the life jackets are difficult to read in dim light, when the life jacket is soiled and aged; and nearly impossible to read if the adult wears corrective eyewear and has not got them with him or her. Unless the life jacket is brand new and unwrapped from its package on the spot, it is unlikely that extensive instructions are available.

Fifty-six participants conducted the donning process; there were 30 males and 26 females with a mean age of 34.3 years (±13.9). The mean age

of the males and females was 36.4 (±13.8) and 31.8 (±13.8) years, respectively.

2.1. Donning Instructions

The Canadian General Standards Board (CGSB) standard implies that donning should be performed by individuals who are "completely unfamiliar with the life jacket" (p. 11) [4]. However, this does not mean that they are necessarily unfamiliar with life jackets in general. Finally, it implies that the reading of any instructions and donning can be performed in less than one minute. So, it was decided to assume that all written, accessory instructions were unavailable, and the adult had simply picked up the life jacket in the emergency, followed any instructions provided directly on the life jacket itself and needed to don the life jacket on the infant/child as quickly and accurately as possible.

2.2. Life Jackets Characterization and Group Assignment

There were some common features on all the life jackets, but there were also several distinct differences. Life jackets were separated into two groups of four based on these similarities and differences. Any two jackets that showed the greatest similarities between each other were assigned into different groups (group 1 or group 2). The similarities between life jackets are as follows:

- both type A life jackets (A1 & A2) were inflatable and not inherently buoyant (i.e., they provided adequate flotation only if they were inflated orally or mechanically);
- both type B life jackets (B1 & B2) were designed with a zipper, tie and waist snap in similar positions; and were donned and zipped up exactly like one would secure a vest or a waist coat;
- type C life jackets (C1 & C2) had no common attributes as C1 was designed with five clips and no zipper, while C2 had two clips only and a single zipper;
- both type D life jackets (D1 & D2) encompassed the whole body, and each was of a novel design (i.e., D2 was a complete body bag in which the infant/child fitted).

This separation of life jackets was done to avoid having participants don life jackets that were similar to one another and to help reduce the time commitment of participants in the study. Once the life jackets were separated into two groups, each life jacket within a group was inherently different from the others in the group; while both life jacket groups were similar to one another.

The total number of subtasks required to don each life jacket correctly, including the number of zips, clips and ties on each jacket is presented in Table 1. In the remainder of the text the lifejackets are coded to represent the group and type designation, i.e., life jacket 1A represents group 1, life jacket A.

TABLE 1. Total Number of Subtasks Required to Don Each Life Jacket Correctly, as Well as the Total Number of Zips, Clips and Ties on Each Life Jacket

Group	Life Jacket	Subtasks	Fastenings		
			Zips	Clips	Ties
1	A	7	1	3	1
1	B	8	1	3	2
1	C	8	0	5	0
1	D	6	0	2	1
2	A	7	1	2	1
2	B	7	1	2	1
2	C	6	1	2	0
2	D	6	1	1	0

Participants were requested to don each life jacket on the manikin under controlled circumstances and using the instructions and conditions associated with Standard No. CAN/CGSB-65.7-2007 [4]. The total time required, sequence of subtasks, and any general difficulties in each donning trial were noted.

2.3. Measurement and Evaluation of Donning Performance

To evaluate the donning accuracy an ordered list of the subtasks necessary to don each life jacket was created. For the evaluation of the order or sequence of the subtasks, sufficient flexibility

was provided given that some subtasks could be completed in a variety of sequences without directly leading to a failure of the donning procedure. This produced a list of the subtasks and a recommended order of these tasks for each jacket.

By using the donning list it was possible to determine average donning times, whether the features on the life jacket made it easy to naturally don in the correct sequence of steps, or whether the design caused confusion. Occasionally participants would elect to complete the donning of the life jacket in a completely different order than the methods identified by the investigators. For instance, the life jacket may be correctly donned, even if a chest strap connection was completed out of sequence with a zip or a tie. This more inefficient method of donning was not deemed a failure, but noted for comment. If the participant did not don the life jacket on the manikin in the "correct" sequence, then they were shown a short video of the correct sequence and asked to repeat the donning process. A new donning time was recorded and any problem that the participants had in conducting this process was recorded (Trial 2).

A pass was given if the time was ≤60 s and the accuracy of donning was 100%. If the participant did not meet either one of these requirements, the trial was rated as a fail. The participant then proceeded to complete donning of the remaining life jackets in their group, before repeating any failures.

2.4. Subject Assignment to Groups

Participants were randomly split into the two life jacket groups on the basis of their answers to a questionnaire. An example of the method of selection of participants to group 1 or group 2 was as follows. When one participant selected the same number of *yes* answers on both the child and water experience portions of the questionnaire as another participant, he or she were considered to have "equal experience with children and water", and thus one participant was assigned to group 1 and the other one to group 2, in random order.

2.5. Standardization of Rater Performance

Prior to the donning observations, two of the researchers completed a series of pretests to ensure that both of them evaluated the donning procedures correctly or not and were consistently in agreement. During each donning process, one of the two researchers scored participants on both (a) time needed to complete a full donning and (b) accuracy of the donning noting any mistakes. Time measurements were gathered using a standard stopwatch while accuracy measurements were gathered using the checklist of the tasks and subtasks associated with that specific life jacket.

Before attempting trial 2, each participant was shown a brief instructional video describing how each jacket was to be donned correctly. This took place within 5 min of the completion of trial 1. Once participants had watched the video they were immediately presented the same jacket in the same manner and asked to repeat the donning. Again, both the participant's time and accuracy to don the life jacket on the manikin were measured and recorded.

2.6. Statistical Analysis of the Learning Effect—Overall

Descriptive statistics of means and standard deviations and all other analyses were performed in Minitab 15 English version 15.1.30. The data were separated into groups (1 and 2) and trials (1 and 2) and were analyzed in separate two-way repeated measures analysis of variance (ANOVA, general linear model) with a post-hoc analysis using the Bonferroni correction. The ANOVA model tested for the main and interaction effects of life jacket and order on the donning times. The data were separated for the two analyses to accommodate the differences in the sample sizes across the different lifejackets in trial 2. For example, in trial 1 all jackets and the order had equal occurrences across the design. However, only jackets that were rated as failed attempts in trial 1 were represented in trial 2.

3. RESULTS

There were 32 participants assigned to group 1 and 24 assigned to group 2. All 56 participants completed the four donning attempts in trial 1 for a total of 224 attempts. In only 41 cases (18%) was the life jacket donned accurately in under 60 s. Of the 224 attempts at donning in trial 1, there were 78 cases of just a donning accuracy failure, 16 cases of just a timing failure and 89 cases of failures in both the donning and the donning times.

Common themes in the donning errors were selecting the incorrect crotch strap to match the size of the baby, no one identified the use of the carrying strap, the life jacket was put on completely backwards (with the name tag on the inside, but on the front of the chest) and in one particular life jacket there was complete confusion about matching the buckles, all connectors matched each other (all the buckles were the same size and color, etc.). As noted earlier while the standard states two criteria for passing of a lifejacket, this study focused on the effect of familiarity on just the donning times.

3.1. Trial 1

The shortest time taken for any life jacket to be donned correctly was 23 s (life jacket 2C) and the maximum time taken for any life jacket to be donned was 212 s (life jacket 1A, which also failed in accuracy). As a result of the trial 1 performances, all the 56 participants were required to don at least one or more life jackets again, producing 183 donnings in trial 2.

Table 2 presents the mean and standard deviations of donning times for groups 1 and 2, respectively. The data for all eight life jackets are separated by the order in which the life jackets were donned. There were clear differences in the overall mean donning times among the life jackets. The mean values ranged from 40 to 89 s for life jackets 2C and 1C, respectively. Only three of the eight life jackets had mean times below the 60-s criterion. More importantly there were large changes in the donning time performances based on the order in which the life jackets were tested. As presented in the table, the order identifies whether the lifejacket was donned in the participants' first, second, third or fourth attempt. Thus the times presented represent the time required to don a particular jacket depending on whether it was the first, second, third or fourth jacket in the donning sequence of each trial.

Examining the donning times within the groups, it was shown that the mean time for group 1 dropped by 18 s (89–71) after the first attempt and then there was little change in the remaining times (71, 71 and 68 s). In group 2 the mean of the first donning time was 64 s. This value decreased by 15 s for the second donning

TABLE 2. Mean and Standard Deviation Time (in Seconds) Required to Don Each Life Jacket by Order of Donning in Trial 1

		Order				
Group	**Life Jacket**	**1**	**2**	**3**	**4**	***M* (*SD*)**
1	A	84 (56)	52 (12)	62 (20)	73 (22)	67 (28)
1	B	71 (33)	71 (27)	69 (24)	59 (21)	67 (26)
1	C	109 (42)	70 (14)	95 (42)	81 (32)	89 (33)
1	D	93 (42)	93 (53)	61 (25)	60 (15)	77 (34)
	M (*SD*)	89 (43)	71 (27)	71 (28)	68 (23)	75 (30)
2	A	66 (21)	53 (9)	68 (20)	60 (29)	62 (20)
2	B	54 (12)	53 (14)	45 (14)	54 (25)	51 (16)
2	C	43 (18)	39 (12)	37 (12)	40 (14)	40 (14)
2	D	92 (39)	52 (23)	44 (10)	54 (12)	60 (21)
	M (*SD*)	64 (23)	49 (15)	48 (14)	52 (20)	53 (18)
	grand mean (*SD*)	77 (33)	61 (20)	62 (25)	61 (22)	64 (24)

performance and subsequently showed little change for the third and fourth donning attempts within the trial. The overall or grand mean values across the groups were 77, 61, 62 and 61 s for the first to fourth donning performance within trial 1.

There was no interaction effect of life jacket and order in either group 1 or 2. There was a significant effect of both main effects of order and life jackets for both groups. The donning time for the first attempt was significantly greater than the second, third and fourth donning attempts in both group 1 ($F = 4.54$, $p < .05$) and group 2 ($F = 5.85$, $p < .05$). There was no significant difference in the donning attempts for the second, third and fourth attempts in either group. Donning times also showed significant differences among life jackets in both group 1 ($F = 4.47$, $p < .05$) and group 2 ($F = 4.03$, $p < .05$).

3.2. Trial 2

All participants who failed either the donning performance or the donning time repeated a second trial after watching a video of the proper donning procedures. The timing data for trial 2 are presented in Table 3. The order of the donning trials in trial 2 was the same as the order in trial 1, except when there was no second attempt necessary for a particular life jacket. This means that the first attempt in trial 2 would actually be the fifth attempt overall and similarly for all subsequent attempts. As shown in the Table 3 there was no significant difference in the mean donning times by order in trial 2. However, significant differences in the mean time among the lifejackets existed for group 2 ($F = 16.37$, $p < .05$), but not for group 1.

The presentation of the "not applicable" entries in Table 3 indicates that there was insufficient data to calculate the appropriate value. In the case of life jacket 2C, there were only 2 participants who repeated the donning trial. So, life jackets 2A, 2B and 2D had too few observations for order 4 ($n = 2$) to allow for a calculation of the standard deviation.

4. DISCUSSION

There exists a variety of standards used to evaluate products for their performance, quality and safety-related characteristics. The testing of products for entry in the marketplace is an important component in consumer safety. This study examined a particular component of the new CGSB life jacket standard for providing guidance and clarity in participant selection for market testing of products. Neither of these issues were addressed by Funkhouser and Fairlie [5] and Coleshaw [6]. Life jacket use has been shown to reduce the number of drownings [7]

TABLE 3. Mean and Standard Deviation Time (in Seconds) Required to Don Each Life Jacket by Order of Donning in Trial 2

		Order				
Group	Life Jacket	1	2	3	4	*M* (*SD*)
1	A	68 (16)	69 (35)	56 (12)	61 (19)	63 (21)
1	B	56 (15)	53 (7)	64 (25)	76 (34)	62 (20)
1	C	70 (46)	64 (32)	68 (21)	85 (36)	72 (34)
1	D	50 (15)	85 (54)	68 (31)	62 (37)	66 (34)
	M (*SD*)	61 (23)	68 (32)	64 (22)	71 (32)	66 (27)
2	A	45 (9)	56 (8)	67 (27)	n/a	56 (15)
2	B	36 (5)	41 (9)	42 (11)	44 (n/a)	41 (8)
2	C	38 (n/a)	25 (n/a)	n/a	n/a	32 (n/a)
2	D	64 (14)	49 (8)	55 (10)	63 (n/a)	58 (11)
	M (*SD*)	46 (9)	43 (8)	55 (16)	54 (n/a)	47 (11)
	grand mean (*SD*)	56 (17)	67 (22)	60 (20)	65 (32)	62 (23)

Notes. n/a—not applicable.

and provisions for life jacket use are standard in many national and international standards [4, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17]. The applications of the results are much broader than this one particular standard. In fact, the information is of significance to any product testing in which the conditions of use are life threatening and where the user is identified to be naïve. In the context of children and infants there appear to be two general classifications of life jacket use. The first would be a regular user of the life jacket anytime children are in and around water such as pools, lakes and oceans. The second case is for infrequent users such as people on cruise liners, the occasional recreational boater and the regular commercial ferry trips across bodies of water. The current CGSB standard evaluates the life jacket for the latter use and includes provisions related to donning accuracy and donning performance before a product can receive standards approval.

What is not specifically clear in the standard is the expertise/familiarity of the test subjects with the single product or family of products being evaluated. The standard clearly states that the participant should not be familiar with the specific product to avoid a bias in the testing. The results presented in this study suggest a secondary issue, which is the participant's familiarity with the general family of products being tested. For example, it is clear from the data presented that in terms of donning times, the effect of having just one trial on another life jacket can significantly improve one's performance on the donning of a second life jacket. This learning effect is more pronounced on some jacket than others. This is a very important finding because, as the standards are currently written, a poor life jacket may receive a pass due to the learning effect. This study also demonstrated another important finding, that there was little decrease in donning time at the second attempt for a well-designed life jacket such as C2. This occurred because there was not enough room to improve since there were fewer and not as many difficult subtasks that needed to be learned to reduce the donning time at the second attempt. Specifically, life jackets that are simple in design and donning process do not benefit from prior practice to the same extent as life jackets that are more complex in their donning procedures or life jackets that have multiple fastenings. This latter group can have a significant improvement in the donning times simply as a result of having the participants practice on one or more life jackets before testing the life jacket in question. In three of the eight jackets tested the time difference was enough to have lifejackets 1A, 2A and 2D move from a failed donning time to a passing donning time simply on the basis of the order of testing.

When the life jackets were divided into two groups, we did not know how the subjects would perform during the donning process. In fact, on completion of the entire experiment it became clear that the results were different between the two groups. After close observation of each subject during the donning process, it became apparent that the life jackets assigned to group 2 were unexpectedly easier to don, but still there was a significant learning effect. It is unlikely that this difference in donning performance between groups occurred due to subjects in group 2 being more competent than those in group 1, since groups were stratified for previous experience with life jackets and children.

The primary principle to be considered is the intended user population for the life jackets and the conditions of use. If the intended user population is naïve and conditions are those of an emergency, then the participant test pool should reflect this. If, however, the intended user population and conditions of use are habitual users in non-emergency conditions then the participant test pool can be a group that have some general familiarity of life jacket use.

This experiment was conducted in daylight, in warm conditions on a stable level platform under no stress; however, a standard for a life jacket that is to be used in an emergency should not approve a life jacket too complicated to don. The donning time is directly proportional to the degree of complication of the life jacket.

This simple series of donning tests has confirmed what the test houses have noted (but does not appear to be published in any journal),

i.e., that a number of participants do not don the life jacket correctly on time in the first attempt. This would account for why standards boards many years ago inserted a clause in their standards that allowed for 80% of participants to don the life jacket correctly on time in the first attempt, and 100% on a second attempt [4, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17].

It could be argued that this donning test was done by adults onto an inert manikin, not onto themselves; therefore, the findings may not be appropriate for standards for an adult donning a life jacket onto an adult. The process of donning a life jacket onto a manikin is theoretically very easy, the manikin can be lifted and rotated to make adjustments and all the steps are in front of the adult; there is no need for the person donning the jacket to turn around to tighten straps, bend and squeeze to put the arms through the armpit holes and connect and tighten crotch straps, etc. Thus, a further experiment should be conducted with adults and children donning life jackets to validate these findings.

While researchers of this study are very much in favour of developing and applying life jacket standards for consumer safety, more work is required on defining the target consumer group and on matching test participants who evaluate the product during the testing process to target consumers.

These observations are extremely important for life jacket standard regulations. Since in an emergency no one gets a second chance to don a life jacket, the test must clearly challenge the life jacket to be donned by as naïve a participant as possible. Therefore, the regulations should be amended to state that each test house must use naïve participants to conduct their testing. It is recommended that a naïve participant should be selected to don only one life jacket once, or a repeat time only for the first donning test request. That person should not test a jacket again. This amendment should be added to Standard No. CAN/CGSB-65.7-2007 [4].

5. CONCLUSIONS

- Of the 8 infant/child life jackets what were evaluated, 32 participants tested the first 4 life jackets and 24 tested the other 4. In total, of the 56 participants who donned the 8 infant life jackets, only 41 (18%) of the 224 attempts at donning were done correctly in less than one minute.
- A clear learning effect was revealed between the first and second attempt at donning the life jacket, but not on subsequent donning attempts.

6. RECOMMENDATIONS

- Standard No. CAN/CGSB-65.7-2007 [4] should be amended to state for life jacket donning trials, a naïve subject should be selected to don only one life jacket once or a repeat of the same life jacket once, and the subject should not test subsequent life jackets.
- These findings should be re-examined using adults donning life jackets on themselves.

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