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An ergonomic evaluation of infant life jackets: Donning time & donning accuracy

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ABSTRACT

Canada is considering the development of a new standard for infant/child life jackets. Eight currently available (approved and non-approved) infant/child life jackets were procured for evaluation. Fifty-six participants were chosen as a sample of convenience from the general public for testing. The life jackets were divided into two groups of four, which were donned on a soft infant manikin procured from the Red Cross. In 224 attempts at donning, only 43 (19%) attempts resulted in the life jacket being donned correctly in less than 1 min. Only one life jacket came close to a good design and passed the life jacket standard for donning time and accuracy. Failure rates were observed across all the participants irrespective of age, gender, experience with children and experience with recreational marine equipment. Accuracy and speed of donning the life jacket were hampered as the number of donning sub-tasks increased. It was concluded that it is possible to design a life jacket that can be donned correctly in under 1 min. The life jacket must be of simple, intuitive design and fall naturally into the anatomical shape of the child. A minimum number of ties, zips and clips should be used in the design, and if such connectors are used they should be color coded or of different shapes and sizes to avoid confusion.

1. Introduction

Over the last 20 years, more and more adults own recreational watercraft and regularly infants/children accompany them. Due to the popularity of taking infants/children on maritime vacations, in 2010 the International Maritime Organization (IMO) intends to legislate the issuing of life jackets to infants/children on cruise liners and passenger ships for the first time (Safety at Sea International Magazine, 2008).

Devices to prevent drowning are called life jackets or flotation aids in Europe and personal flotation devices (PFDs) in the U.S.A. In Canada, they are all referred to as life jackets and for the rest of this paper they will be referred to as such.

In 1991, Funkhouser and Fairlie (1991) evaluated 4 infant life jackets and noted that confusing straps and buckles delayed donning. The device that was most quickly donned was an inflatable type with a mean donning time of 28.8 s. Brooks (1995) noted very little data had been published on infant/child life jackets and commented that "they appeared to be scaled down versions of their adult counterparts". Subsequently, Coleshaw et al. (2001) published further data related to donning time. They found that fathers donned three of five different life jackets on children in a mean time of under 1 min, a fourth life jacket in a mean time of 72 s and a fifth life jacket in a mean time of 76 s. They found that children donned the life jackets on themselves in a mean time of 87 s, although they could not make the tightening adjustments and some could not tie a bow.

Canada has just published a new life jacket standard (CAN/CGSB-65.7-2007), which includes infants/children, youths and adults in one standard (Canadian General Standards Board, 2007). The standard identifies two distinct Classes of life jackets and 3 sub-classifications of the Class 1 life jacket. The sub-classifications in Class 1 are infant/child (9–18 kg), youth (>18–40 kg) and adult (>40 kg) life jackets. For each life jacket sub-classification, there are mandatory buoyancy requirements of 30, 60, and 150 N for infants/children, youth and adult life jackets, respectively (Canadian General Standards Board, 2007).

The section in the standard on infant/child life jackets specifies that where appropriate, the life jacket must accommodate infants/children between 9 and 18 kg in body mass and those with a chest circumference of equal to or less than 625 mm.

The standard also makes specific reference to donning accuracy (donning a life jacket correctly), but there is no evidence in the literature to support the specific requirement of ≥80% of participants to perform a correct donning on the first attempt and 100% of participants to perform a correct donning on the second

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attempt. It seems as if these two requirements have been copied from previous Canadian and International standards (American Code of Federal Regulations, 2002; Canadian General Standards Board, 1988a,b, 2007; European Committee for Standardization, 1993a,b,c; International Maritime Organization, 2003; International Organization for Standardization, 2003; Underwriters Laboratories Inc., 1976, 1990, 2000) and may not have been re-considered in the light of some new life jackets that have far more sub-tasks involved with their donning (ties, tapes, buckles, zips, etc.).

For this reason it was not known whether a manufacturer who produces a very credible novel new infant/child life jacket might be penalized and the design rejected because, for instance the life jacket required a slightly longer donning time, but in return provided superior in-water performance.

The purpose of the study is to layout a systematic methodology for the development and/or evaluation of standards of protective equipment that is based on the application of a human factors approach (Wickens et al., 2004). To conduct this study 4 steps were undertaken: 1) A review of current national and international life jacket standards for infants/children; 2) a review of the critical factors in these standards that are directly related to human factors issues; 3) the procurement of approved and non-approved representative infant/child life jackets available in Canada; and 4) the performance of a series of donning trials using the representative life jackets.

2. Methods

2.1. Systematic review of standards

In order to establish a methodology for the evaluation of a standard for an infant/child's life jacket, a review of existing national and international standards was performed, including the Canadian General Standards Board (CGSB), Ottawa, Canada; the International Standards Organization (now combined with the European Committee for Standardization (ISO/CEN)), Brussels, Belgium; the International Maritime Organization (IMO), London, United Kingdom; and the United States Coast Guard (USCG), delegated to the Underwriters Laboratories Inc., North Carolina, U.S.A. A comparative analysis of the Canadian standard to each international standard was performed. The critical issues for dry-land testing related to human factors that were deemed important were donning time and accuracy of donning are listed in Table 1.

2.2. Critical components of infant/child life jackets influenced by human factors

There were two key elements in the dry-land donning standard that were influenced by human factor issues.

- Donning Time: The time in seconds required to complete a donning.
- Donning Performance: The measured accuracy of completing a donning.

This study examines these two donning elements. The Canadian life jacket standard states that a life jacket must be donned in $\leq$1 min by $\geq$80% of participants without instruction correctly on the first attempt, and by 100% of participants after instruction on the second attempt. The standard does not specifically identify whether this donning process must be completed by the infant/child, adult, or both.

The assessment of donning performance and donning time is dependent on the behavior of the infant/child at the time of donning. There are two possible ways to address this issue. The first is to attempt a series of donning trials on manikins, representative of the intended population; while the second is to perform the donning trials on infants/children who represent the intended users. The first option provides the best test of an adult's ability to don a life jacket on a "compliant child", and therefore eliminates any problems associated with infant/child behavior, making any donning time or accuracy issues directly attributed to the adult performance and/or the life jacket design. Both of these approaches have merit, however for the purpose of this study it was decided to use manikins to evaluate donning time and accuracy.

Table 1
Comparison of current international flotation device standards (Canadian General Standards Board, 2007; International Organization for Standardization, 2006; International Maritime Organization, 2003; Underwriters Laboratories Inc, 1976).

Regulating Authority	Donning Time (min)	Donning Accuracy
CGSB	$\leq$1	$\geq$80% of participants after Trial 1 100% of participants after Trial 2
ISO/CEN	$\leq$1	$\geq$75% of participants after Trial 1 $\geq$75% of participants after Trial 2
IMO	$\leq$1	$\geq$80% of participants after Trial 1 100% of participants after Trial 2
USCG	$\leq$1	No Requirement – No Second Trial

2.3. Procurement of representative infant/child manikins and life jackets

In order to obtain consistent data and to control for the effect that an uncooperative infant/child may have on life jacket donning time and accuracy, four simple soft infant manikins were procured from the Red Cross and used for the dry-land static testing. The physical dimensions (but not mass) of each manikin represented a 12-month old infant/child.

Survival Systems Ltd. procured a representative sample of 10 currently available approved and non-approved flotation devices for practical evaluation and because the origin of manufacture was Canada or Europe, the manufacturers called them life jackets. Some of the devices had been approved under an older Canadian personal flotation device (PFD) standard (CAN/CGSB-65.15-M88) (Canadian General Standards Board, 1988a). However, the purpose of this paper is to analyze the representative life jackets against the new standard, which superseded Canadian standard (CAN/CGSB-65.7-M88) (Canadian General Standards Board, 1988b).

Two of the 10 life jackets were almost identical in design compared to two other life jackets; therefore, one of each was removed from evaluation since it was expected that little differences would be found during testing. Eight life jackets were thus selected to be included in the study and were assigned as Type A ($n = 2$), Type B ($n = 2$), Type C ($n = 2$) and Type D ($n = 2$).

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.