DOT/FAA/AM-99/5

Office of Aviation Medicine
Washington, D.C. 20591

Comparison of Buckle Release Timing for Push-Button and Lift-Latch Belt Buckles

Van Gowdy
Mark George
G. A. McLean
Civil Aeromedical Institute
Oklahoma City, Oklahoma 73125

February 1999

Final Report

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U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AM-99/5		

4. Title and Subtitle	5. Report Date
Comparison of Buckle Release Timing for Push-Button and Lift-Latch Belt Buckles	February 1999
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Gowdy, V., George, M., and McLean, G. A.	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
FAA Civil Aeromedical Institute P.O. Box 25082, Oklahoma City, OK 73125	11. Contract or Grant No.
12. Sponsoring Agency name and Address	13. Type of Report and Period Covered
Office of Aviation Medicine Federal Aviation Administration 800 Independence Ave., S.W. Washington, DC 20591	14. Sponsoring Agency Code

15. Supplemental Notes

16. Abstract

Small aircraft passenger restraint systems most commonly use lift-latch type buckle release mechanisms. Push-button buckle release mechanisms, similar to those used in contemporary automobiles, have rarely been used on passenger restraints. Although push-button buckles are not explicitly prohibited by Federal Aviation Administration (FAA) regulations, the human factors aspects of introducing push-button buckles in an aircraft environment are important considerations from the standpoint of safety. A test program was conducted by the FAA Civil Aeromedical Institute (CAMI) with volunteer human subjects to measure and compare the times it takes a passenger to release a push-button buckle on a 3-point restraint, a common lift-latch buckle on a 3-point restraint, and a lift-latch buckle on a common lap belt. Sixty subjects were tested in a repeated-measures counterbalanced test protocol, which included instrumentation to measure the response times to release the buckle. Response time for the subjects to exit the seat and press a remote button was also acquired. This report includes the physical profiles of the subjects, the test protocol, and a statistical summary of the results.

Based on the data acquired in this project, there was no major difference in the response times of the human subjects to release or egress from a 3-point restraint with a push-button buckle, compared with a lift-latch buckle on a 3-point or a common lap belt restraint.

This study was intended to address factors associated with the use of push-button buckles restraint systems in small airplanes. Any consideration of the use of push-button buckles on commercial transport aircraft passenger seats should include data on a broader range of human factors.

17. Key Words	18. Distribution Statement
Push-Button Buckles Small Aircraft Restraints	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	11	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Comparison of Buckle Release Timing For Push Button and Lift-Latch Belt Buckles

INTRODUCTION

The most common type of belt buckle release mechanism for small aircraft passenger restraint systems is the lift-latch buckle. Other release mechanisms, such as push-buttons, are less common in aircraft restraint systems, although they are not explicitly prohibited for use in small aircraft by the Federal Aviation Administration's (FAA's) standards and regulations published in 14 CFR Parts 23 and 91. In fact, there are no specific design or performance criteria in FAA advisory documents or Technical Standard Order approval procedures for restraint systems that preclude the use of push-button release mechanisms on aircraft passenger seat belts. Recent applications seeking approval for the installation of restraints with push-button buckles on small aircraft passenger restraints have been submitted to the FAA. Due to the novelty of push-button buckles on airplane passenger seats, it is important to examine the human factors related to the operation of push-button buckles and egress from a seat in order to ensure an equivalent level of safety. A key factor in determining safety equivalence is the time it takes for a passenger to release the restraint buckle and get out of the seat.

A study of restraint release mechanisms, using human subjects, was performed at the FAA Civil Aeromedical Institute (CAMI) to determine if there was a significant difference between the time it takes a subject to release a lift-latch buckle versus a push-button buckle. Also measured was the time taken for subjects to fully extricate themselves from the restraint system, and get out of the seat. The following summarizes the test procedure and results obtained from this project.

Description of Tests

Subjects. Sixty volunteer subjects participated in the study. Physical data, including sex, age, height, weight, waist girth, and handedness were recorded for each of the human subjects prior to testing. Table 1 contains the data summary of the subjects used for these tests.

Design. A repeated-measures counterbalanced design was chosen for economy of subjects and to control for the effects of trial sequence. 3 restraint release mechanisms (A, B, and C) were compared in the study. The subjects were randomly assigned to 1 of 6 possible experimental sequences (ABC, ACB, BAC, BCA, CAB, and CBA).

Apparatus. As shown in Figure 1, a triple occupant seat bench was configured with 3 restraint systems installed side-by-side. The bench seat had 2-inch thick foam cushions covered with a vinyl fabric installed on the seat and backrest areas. There were no armrests on the seat fixture. The lap belt and upper torso strap anchor point geometry were representative of a typical aircraft installation.

	AGE	HEIGHT	WEIGHT	GIRTH
Mean	39.3 yrs	69.0 in.	170.4 lbs	34.1 in.
Std Dev	12.1	3.7	38.1	5.1
Minimum	18	62.3	106.3	26.0
Maximum	69	76.3	330.4	53.0

Total Subjects: 60 (28 Males, 32 Females)
Handiness: 57 Right Handed, 3 Left Handed

Table 1. Subject Data.

Figure 1. Test Apparatus.

Photos of the 3 restraint system buckles are shown in Figures 2, 3, and 4. Restraint A was a 3-point restraint with a push-button buckle on the left side, and an upper torso strap over the right shoulder into an inertia reel. The push-button buckle was similar to ones used in contemporary automobiles. The force required to release the restraint by pressing the push-button was measured to be approximately 20 N (4.5 lb), and the button travel was approximately 6.5 mm (.25 in.)

Restraint B was a 3-point restraint with a lift-latch buckle common to many aircraft restraints. It was similar to the Restraint A, having the buckle on the left side and an upper torso restraint over the right shoulder into an inertia reel. The lap belt tension for Restraints A and B were manually adjustable by pulling the webbing on the right belt through an adjuster mechanism. When adjusted to a snug fit, the buckles on Restraints A and B were positioned on the left side of the subject's pelvis.

Restraint C was a typical transport passenger seat lap belt with a lift-latch buckle. The buckle was approximately centered over the pelvis of an average-size adult passenger.

Electrical wires were connected to the metal insert and to the buckle receptacle hardware on each of the 3 restraint systems. Electrical continuity was established when the restraint was buckled, and an open circuit indicated the buckle had been unlatched. The wires from the buckle were connected through a simple interface circuit to an electronic interval timer.

A bright red light-emitting diode (LED) was positioned at table height, 80 cm (31 inches), approximately 102 cm (48 in) in front of the bench seat. The LED was illuminated by means of a toggle switch under the control of the test operator. Wires from the toggle switch were connected to the same interval timer as the wires attached to the buckles. The interval timer was set to start measuring time when the LED was illuminated by action of the toggle switch. The time interval measurement stopped when electrical continuity of the wires connecting the buckles was interrupted by the action of the subject unlatching the buckle. A 40 mm (1.5 in) diameter push-button switch was placed next to the red LED approximately 102 cm (48 in) forward of the bench seat. The button was mounted horizontally, and wires from the push-button were connected to a second time interval counter. The second interval counter was set to start measuring time when the red LED was illuminated and stop when the subject depressed the push-button switch.

Protocol. Subjects were given brief, individual oral instructions describing the task to be performed. After being seated on the test seat, the subjects were allowed to

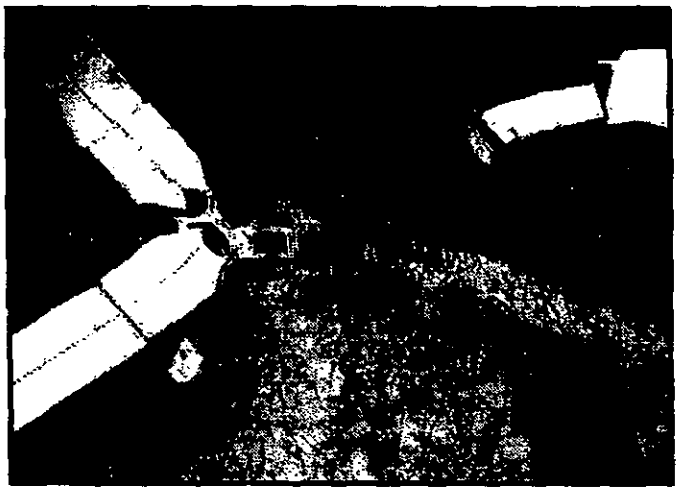

Figure 2. Restraint A: 3-point with push button buckle release.

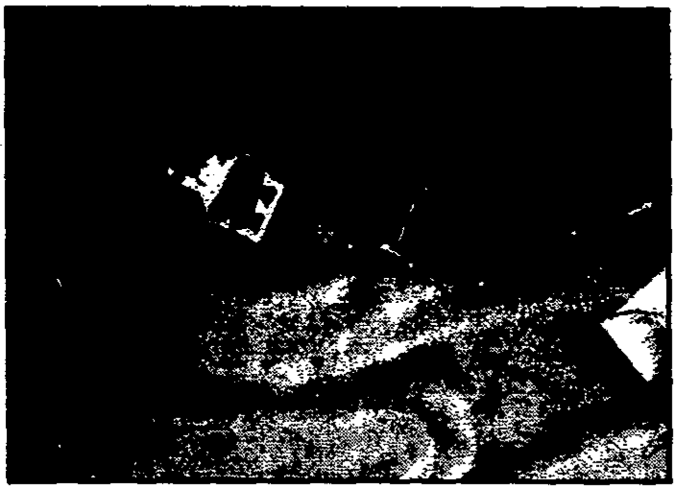

Figure 3. Restraint B: 3-point with lift latch buckle release.

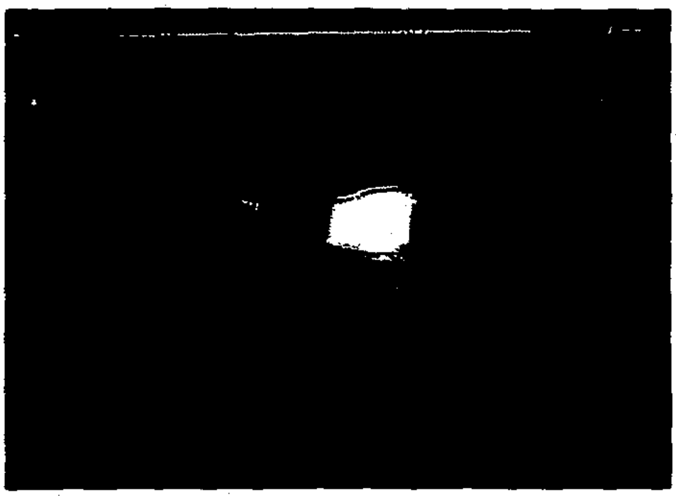

Figure 4. Restraint C: Lap belt with lift latch buckle release.

buckle the restraints and adjust the tension of the belts without assistance. They were instructed to place their hands on their knees prior to the test. Each subject was instructed to unlatch the buckle "quickly" when the red LED illuminated, then stand up, and quickly move to depress the push-button switch. The room lights were turned off, and a small lamp projected against a laboratory wall was the only illumination during the test. The lamp was adjusted to provide the equivalent of minimum aircraft cabin emergency lighting conditions (0.5 ft-candles), which was measured on the tabletop next to the LED. The test operator waited a few seconds to allow the subject's vision to adjust to the dim lighting condition, then switched on the red LED to begin the time interval measurement. After the test, this sequence was then repeated with the same subject using the other 2 restraint systems.

RESULTS

Figures 5 through 7 present the buckle release time data. The mean release time for the 3-point restraint with a push-button buckle (A) was 1.25 seconds, the mean release time for the lift-latch 3-point restraint (B) was 1.10 seconds, and the mean release time for the standard lift-latch seat belt (C) was 0.91 seconds. The cumulative frequency plot of all 3 restraint systems, shown in Figure 8, shows the release times for the 3 restraint systems.

Data for the time intervals for subjects to release the buckle, exit the seat, and then depress the push-button switch are presented in Figures 9 through 11. The mean times for buckles A, B, and C were 3.16 seconds, 3.14 seconds, 2.55 seconds, respectively. The cumulative frequency plot of times for button pushing for the 3 restraint systems is shown in Figure 12.

DISCUSSION

The small differences discovered in the mean times needed to release the buckles of the 3 restraint systems (ranging from 0.91 to 1.25 seconds) do not raise a serious concern related to the effect on occupant egress of restraint systems with a push-button, as compared with the lift-latch type buckle. As with the buckle release times, the small differences in times for an occupant to release the buckle and egress from the seat (ranging from 2.55 to 3.16 seconds) do not raise concerns about the abilities of aircraft occupants to egress from seats outfitted with these particular restraint systems.

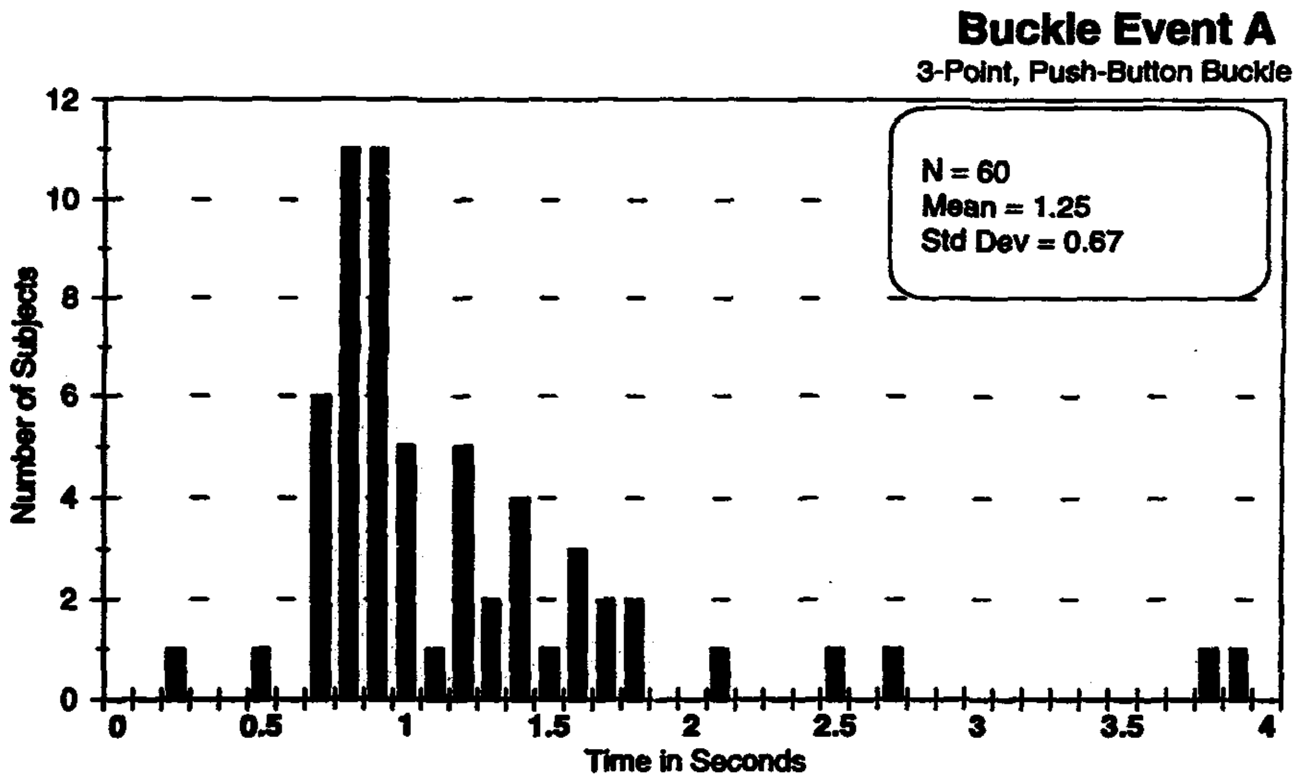

Figure 5. Buckle release time for restraint A.

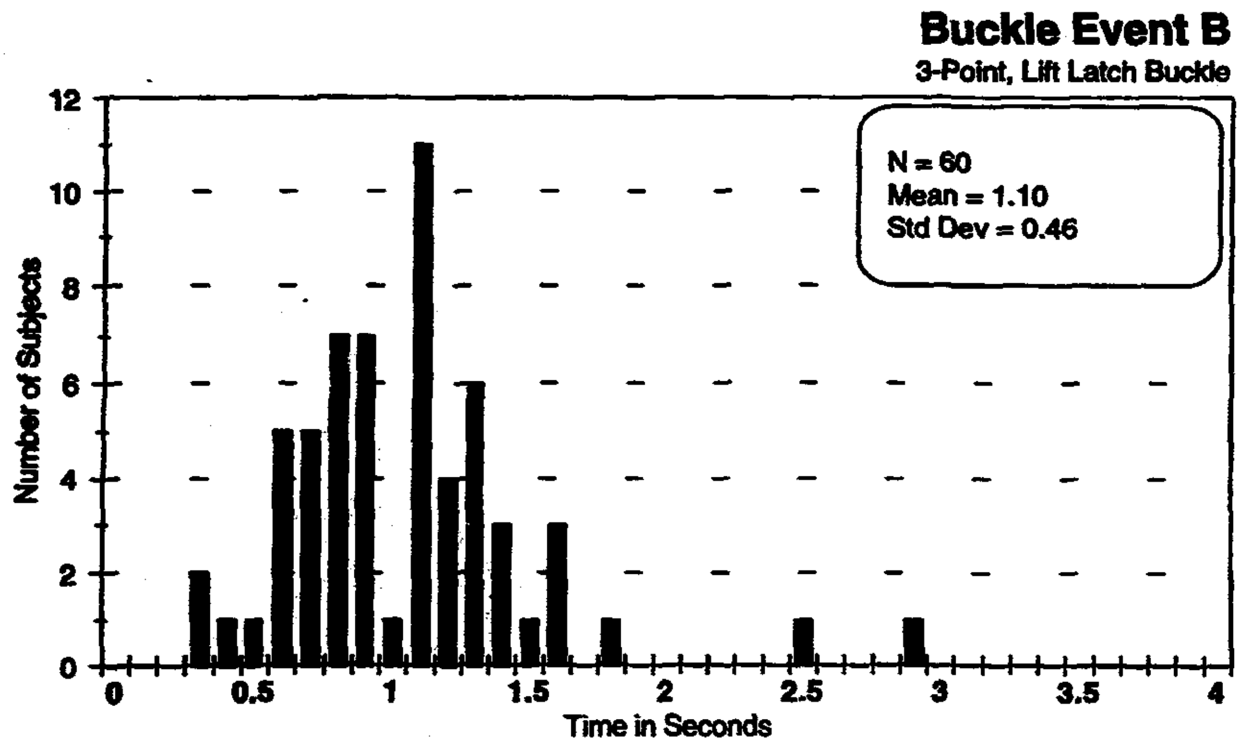

Figure 6. Buckle release time for restraint B.

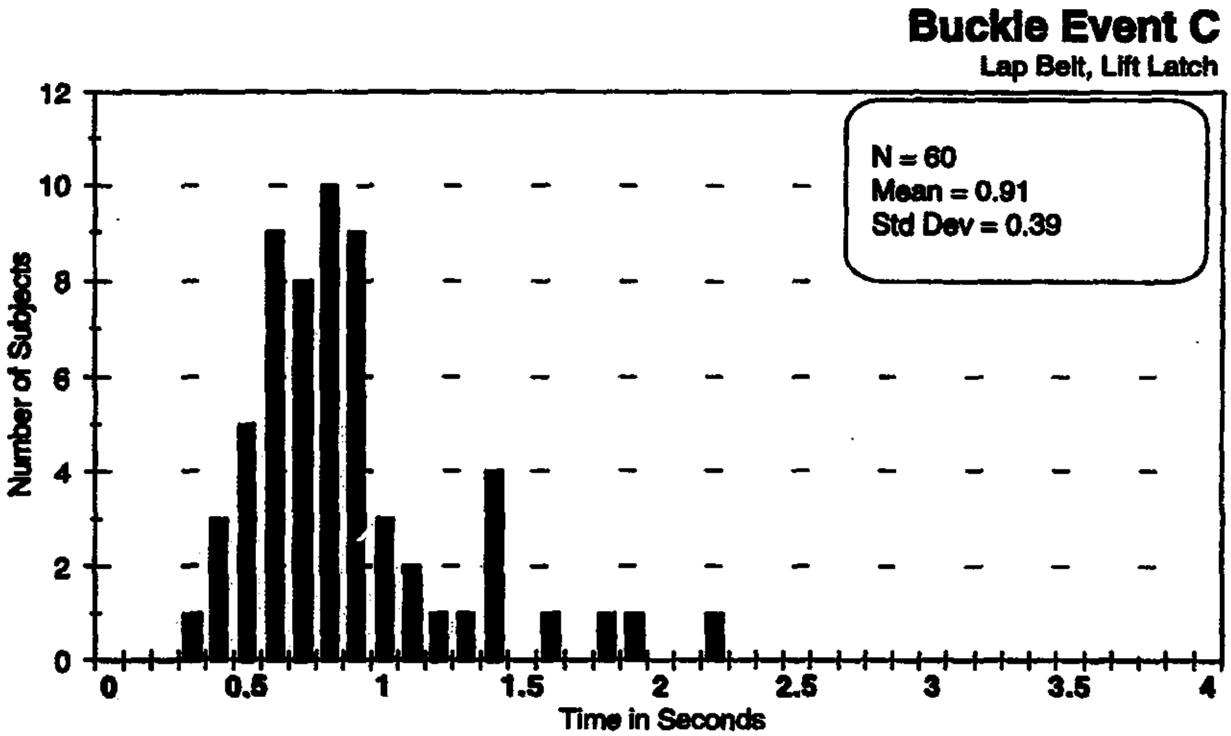

Figure 7. Buckle release time for restraint C.

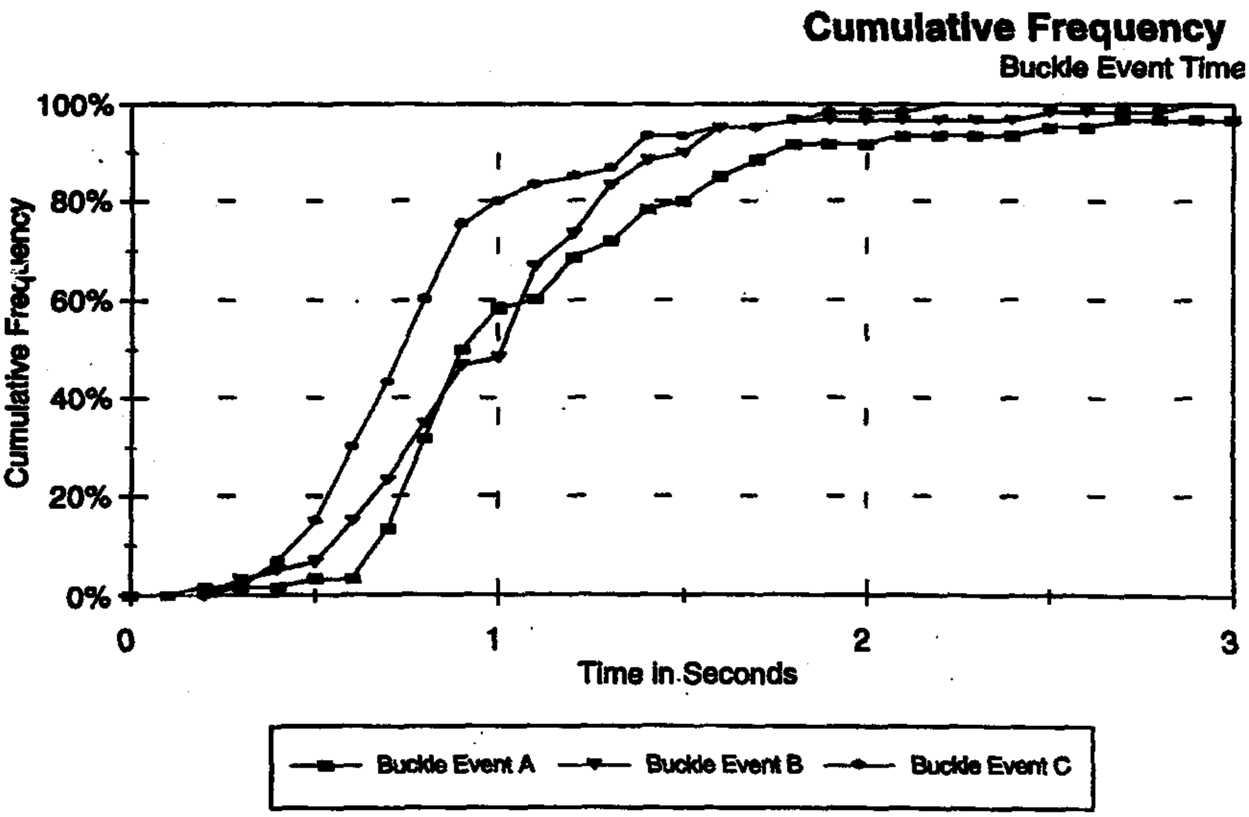

Figure 8. Cumulative frequency for release times of restraints A, B, and C.

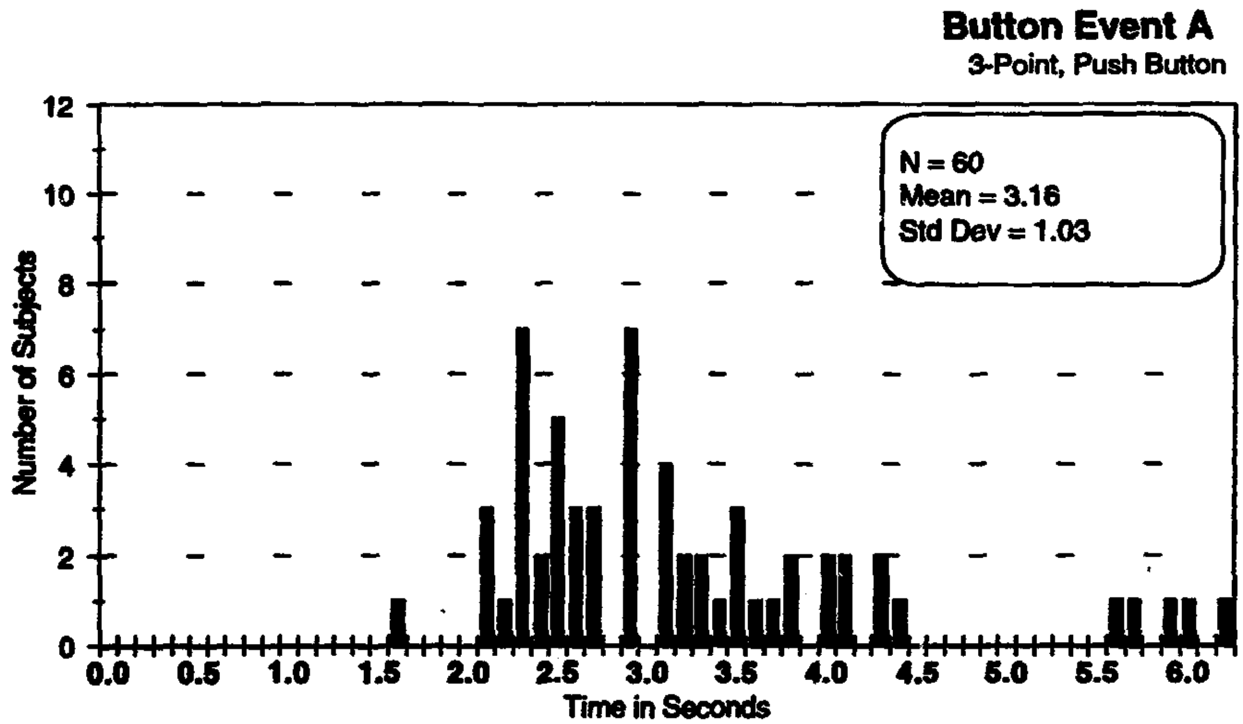

Figure 9. Button event egress time for subjects in restraint A.

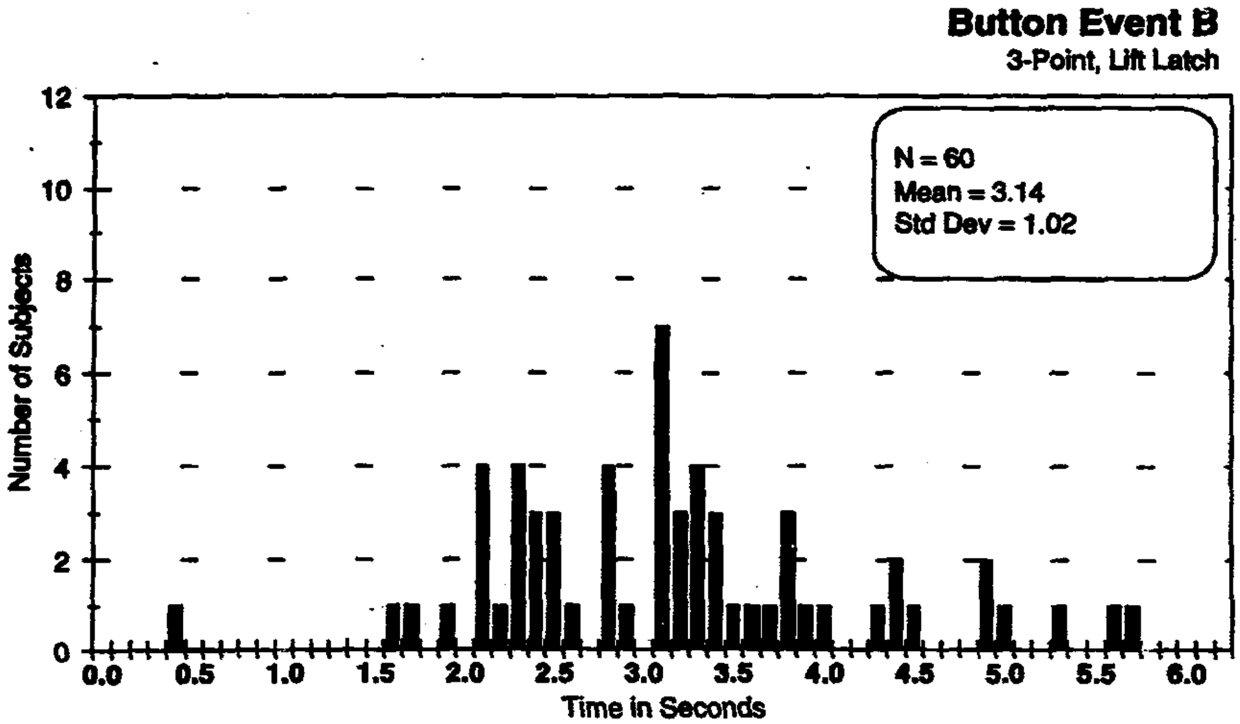

Figure 10. Button event egress time for subjects in restraint B.

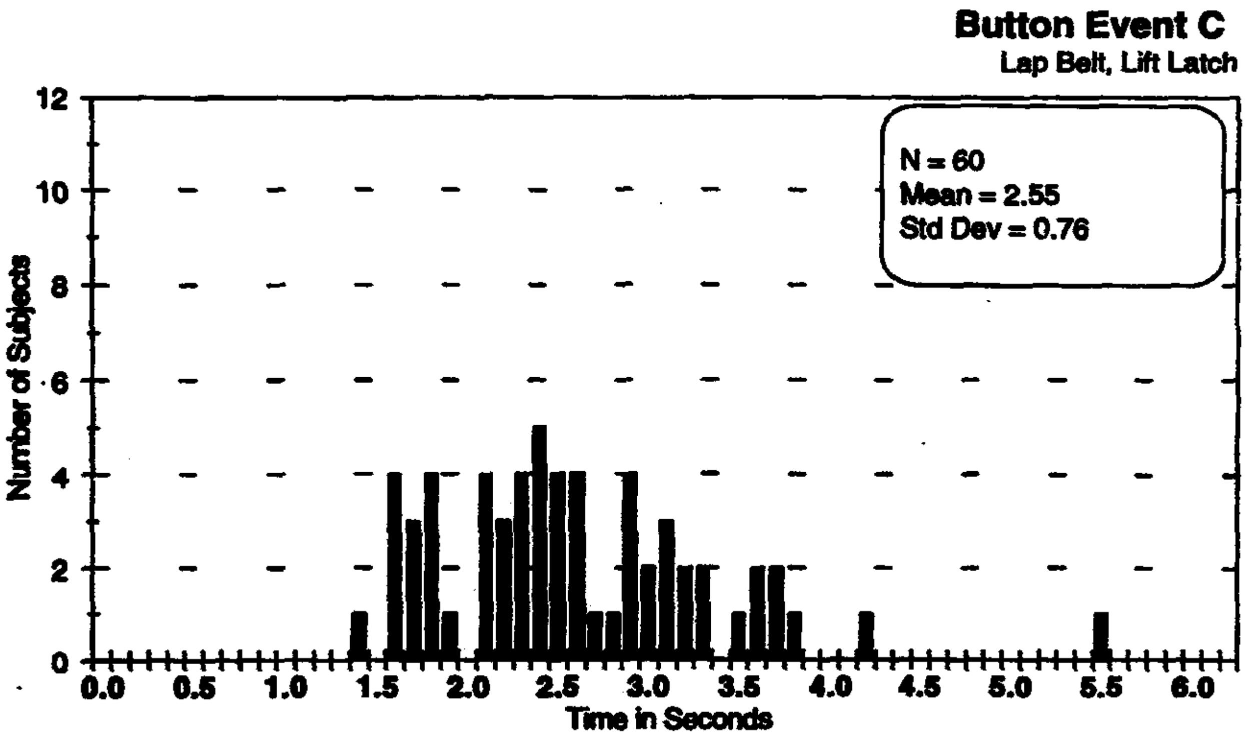

Figure 11. Button event egress time for subjects in restraint C.

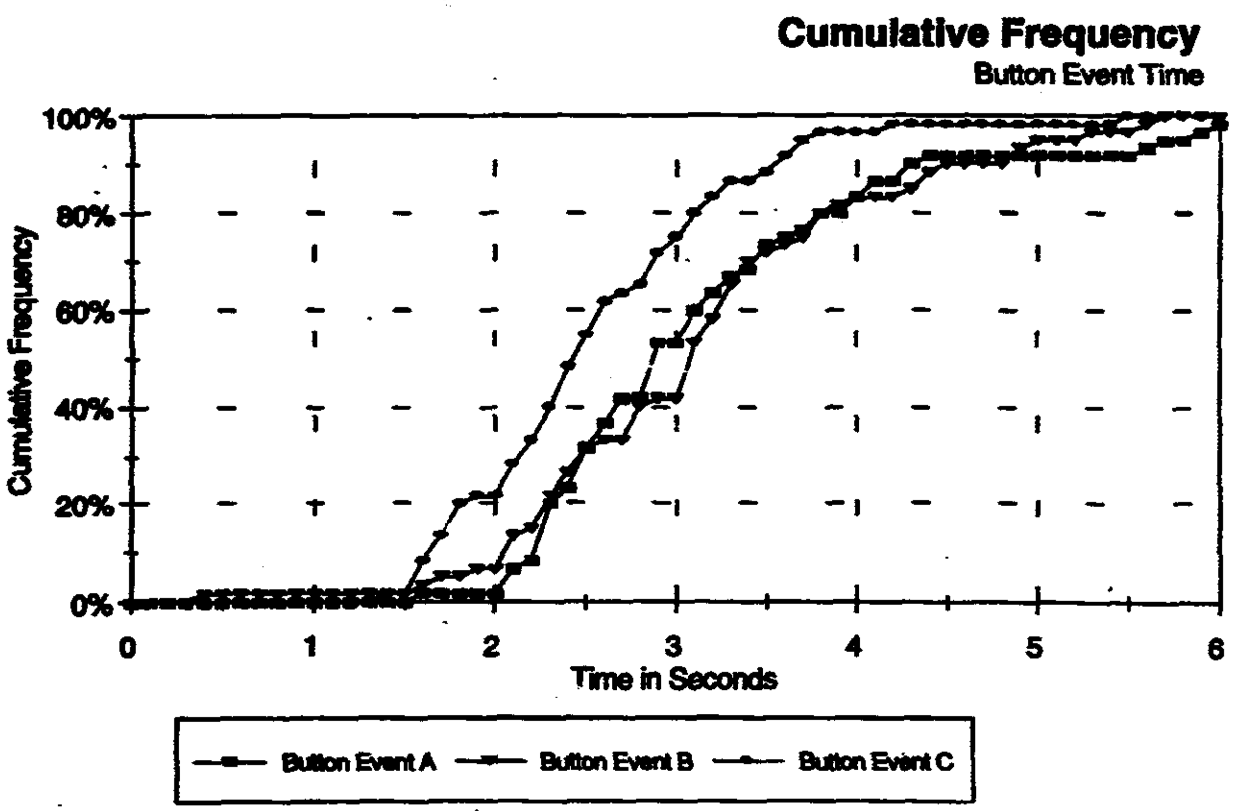

Figure 12. Cumulative frequency for button event egress times for subjects in restraints A, B, and C.

Variables not included in this limited study were arm rests and seat width. In narrow width seats, arm rest interference with access and/or release actions could affect the time for an occupant to release the buckle, and should be considered in the design of passenger seats with 3-point restraints. Another important variable not addressed in this study was the push-button release force. Although design and performance specifications are imposed for automobile push-button restraints (1,2), previous studies indicate significant variation in the relationship between age and strength capability to press/release a push-button buckle (3,4).

It must be emphasized that this study was intended to address factors associated with the use of push-button buckle restraint systems in small airplanes. Any consideration of the use of push-button buckles on commercial transport aircraft passenger seats should include data on a broader range of human factors, such as the effects of age, familiarity with operation of the buckle, cultural differences, physical limitations, and contrariety with the universal use of lift-latch buckles in air transport operations.