

**DEVELOPING A VOLUNTARY  
SAFETY STANDARD FOR STEP STOOLS**

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**ABSTRACT**

American Institutes for Research (AIR) assisted the Consumer Product Safety Commission (CPSC) to identify the human factors issues that should be addressed in a forthcoming voluntary safety standard for step stools. According to CPSC data, older people, children, and women of all ages are over-represented in step stool accidents. We studied the accident scenarios, recommended requirements for step stools, and evaluated the completeness of a draft of the standard with respect to user interaction.

**THE NEED FOR A STEP STOOL STANDARD**

According to the U.S. Consumer Product Safety Commission (CPSC), step stool injuries result in about three times as many hospitalizations (12%) as the average of all National Electronic Injury Surveillance System (NEISS)-reported injuries (Present, 1983). In September 1985, the CPSC and the American Society for Testing and Materials (ASTM) held a joint conference on Safety for Older Consumers, and determined that a voluntary safety standard for step stools was needed. While ASTM was well-prepared to develop strength and construction requirements, the CPSC recognized the need to evaluate the completeness of the standard with respect to user interaction. We at American Institutes for Research assisted the CPSC in determining the human factors issues to be addressed in the standard.

**WHO IS INJURED MOST OFTEN AND HOW?**

With CPSC's direction, this two-year study was limited to three types of step stools: (1) chair stools, which have steps and a seat, (2) folding stools, which may look like miniature step ladders or have an "X" or "A" frame construction, and (3) utility stools, which have a single platform about ten inches off the floor. Spring-loaded, library type stools also fall into the third category. We performed background studies to define the scope and nature of human factors requirements. We developed our recommendations independently from the committee writing the standard in order to

provide a viewpoint emphasizing human factors objectives.

Problem Assessment

We first analyzed in-depth and summary accident data from the NEISS. The accident data included information about the age, sex and health of the victims, as well as information about the products involved and how the accidents occurred. From this data and previous studies performed by the CPSC on step stool safety (eg. Present, 1983), we found trends in the demographics of step stool accident victims and created a list of the most common accident scenarios. Older consumers (people over 55) and children under five are the high risk groups. Women make up the majority of victims by almost two to one (see Figure 1). Seventy-five percent of the victims in one ten-year study were over 65 years of age (Present, 1983). The most common scenario involved people losing their balance while standing or kneeling on the stool. Other common scenarios were: the stool folded and collapsed; the stool broke and collapsed; the person fell while descending; and the person fell from a seated position. We also learned that:

- the majority of the step stools were metal
- most step stools were used indoors
- the products ranged in age from 5 to 25 years

- non-skid step surfaces were absent in wood models, but included in metal step stools
- the victims usually had something in their hands
- the victims were usually standing and reaching while on the stool

This information and data gathered through morphological charting of step stools on the market uncovered the most critical areas of needed safety improvements.

Task Analysis

Next, we observed and videotaped people performing structured tasks with each of seven sample step stools. The tasks were representative of common step stool usage. Through task analysis we identified (a) body positions during opening, carrying, positioning, ascending, standing, reaching, sitting, descending, and closing, (b) variations in interaction from one person to another and among various types of stools, and (c) errors users made and problems they encountered. We surveyed the subjects to provide insight into their preferences and attitudes toward step stools. Without this information, we could have overlooked safety requirements that were not identified in the CPSC statistics.

RECOMMENDED HUMAN FACTORS REQUIREMENTS

Using the most common accident scenarios, we created fault trees to aid in developing recommended human factors requirements for the standard. The fault tree analysis uncovered the primary factors contributing to the accidents in each scenario. From this, we developed a list of the issues contributing to step stool safety:

- sturdiness
- stability
- slip resistance
- ease and safety of use
- discouraging unsafe behavior by the user

We identified the functional characteristics influencing these five issues, and defined the unsafe behaviors that should be discouraged. We were then able to define the scope of the requirements. The requirements were performance-based rather than prescriptive in that they were not intended to restrict design freedom. For example, one of our requirements stated "The spreading mechanism (for folding stools) shall provide a positive lock to prevent inadvertent closing." We did not specify the type

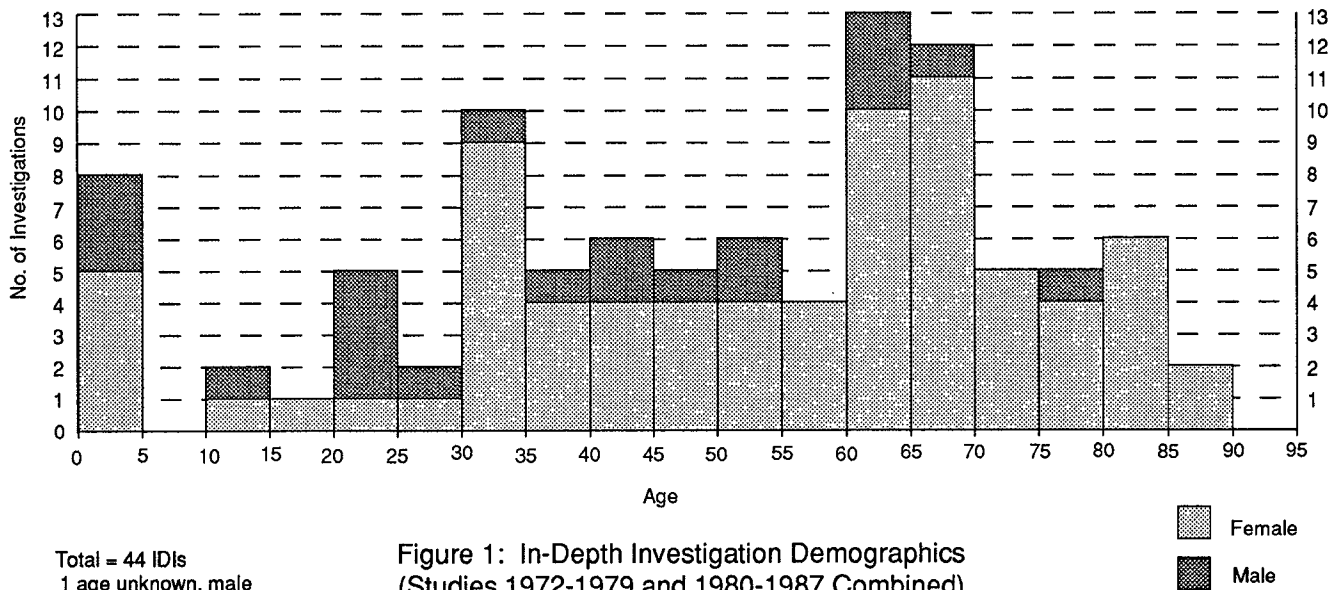


Figure 1: In-Depth Investigation Demographics (Studies 1972-1979 and 1980-1987 Combined)

of locking mechanism, since many designs would be effective. We did not address issues relating to the physical strength of the materials used unless they directly affect the human factors of the step stool.

#### EVALUATION OF THE DRAFT STANDARD

When a draft of the standard became available (ASTM, 1988), we created a cross-reference matrix to show where the standard addressed human factors issues and areas where it did not. For example, the standard requires at least one and one-half threads of each bolt to be exposed beyond the nut, but does not define a maximum number of threads that can be exposed. Such a requirement is necessary, since the CPSC has received complaints about step stools having bolts that protrude dangerously. These bolts have caused users to injure themselves (NEISS, 1987). We also critiqued the organization of the standard and its readability and usability, based on past experience in document design (Felker et al., 1988).

In general, the draft ASTM standard is well prepared, and an important step forward. However, there are areas in which it does not address human factors engineering considerations. Specifically, the following design considerations should be considered as additions to the standard:

- the position of the stepping surfaces with respect to the footprint of the stool on the floor, to reduce the chance that the stool will tip when people lean over
- the proportion of stool height to width, to eliminate tall, narrow stools that tip easily from side to side
- the maximum weight of the step stool, so that people with limited strength, particularly the elderly, are not injured trying to lift the stool
- the appearance of areas, such as seats, that are not meant to be used as steps, so that they do not have a step-like appearance

- an indication of the orientation of the step stool, so that people do not step off on the wrong side of the stool, expecting the steps to be there
- the need for little or no routine maintenance, since people tend to use step stools on the spur of the moment and it is unlikely that they will consider maintenance on a routine basis
- the maximum inclination of the steps, to reduce the chance of people falling backward (particularly when no handhold is provided), or falling during descent because a step could not be easily located
- safe and easy operation of the spreaders and hinges to eliminate pinch points and the need for excessive force
- the addition of locking mechanisms on the hinges, to prevent inadvertent collapse, particularly to protect the hands of children
- the minimum force required to operate spring-loaded casters, so that a small weight is sufficient to cause them to compress, allowing the rim of the stool to form a seal with the floor
- the ease of understanding the instructions for assembly, use, and maintenance
- the design, height, and diameter of hand holds, which should be considered as safety features and would particularly help the elderly

In the last phase of the project, we tested a sample of seven step stools using the procedures described in the draft standard and reported areas where the procedures were successful and areas where they could be improved. We evaluated the technical accuracy and appropriateness of the proposed values (e.g., "the step stool shall not slip more than 1/4 inch when the force is applied") by comparing the values with (a) performance standards for step ladders (ANSI, 1982), (b) data in human factors literature, (c) our previous

research on the step stool problem, and (d) our experience during testing.

In the process, we recorded the performance of each individual step stool. It was notable that six of the seven step stools we tested did not pass all of the tests, and consequently would not be acceptable according to the draft standard.

#### CONCLUSION

The draft standard is a step toward improving the safety of this common household product. However, it could be improved by addressing more than safety as related to the quality of manufacturing and strength of materials. It needs to address the human interaction issues necessary to ensure safe use. We expect that the final standard will incorporate test procedures that evaluate the safety of interaction between people and step stools.

#### REFERENCES

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