PERFORMANCE, PERCEIVED SAFETY, AND COMFORT OF THE ALTERNATING TREAD STAIR

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For:
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INTRODUCTION

LITERATURE REVIEW AND INTENT OF STUDY

For years stairs have been known to be the site of numerous accidents in the everyday environment. An estimated two million accidents occur each year of which 500,000 are serious enough to require hospital treatment (NEISS News, 1974). Further, it is believed that close to two million temporarily or permanently disabling injuries in the United States and 3,800 fatalities can be attributed annually to stair accidents (U. S. Dept of Housing and Urban Development, 1972). The total annual cost of stair accidents in terms of compensation paid, workdays lost, and direct medical expenses, using conservative estimates, exceeds $2,000,000,000 (Alessi and Brill, 1979).

Losses caused by stair accidents increased the need for more research on stair construction, stair characteristics, stair environments, and stair users. Studies were performed with unobtrusive techniques for gathering and analyzing detailed videotape and film records of stair users in natural settings (Archea, Collins, and Stahl, 1979; Templer, Mullet, and Archea, 1978). Archea et al. (1979) determined that visual perception is a major factor in successful stair use and that visual deception and distraction are major factors in stair accidents . Templer et al. (1978) reinforced these results by indicating that abrupt changes in stair conditions, such as sudden distractions, change in light level, etc., determined precisely where accidents would occur on each flight.

In 1982, Cohen and Compton reported the results of a study investigating work surface characteristics in the vicinity of 50 accidents in nine industrial and commercial settings. Local variations in slip-resistance characteristics were found to play an important

role in work accidents, including stair accidents. The transition from walking on a level surface to walking down a flight of stairs, which required users to look at the stair as they approached and stepped on it followed by "getting a feel" for the treads, became an important area of research. Interuptions of this procedure, like changes in slip-resistance or variations in riser height or tread depth suddenly putting the user in a nonconforming condition was found to cause accidents. Visual deceptions built into the design of the stair and distractions that drew the user's attention away from the stair were found to be leading causes of stair accidents (Archea et al. 1979; Templer et al., 1978).

Cohen, Templer, and Archea in their 1985 analysis of existing occupational injury data concerning stairway related falls found that 92% occurred during descent. Minute performance errors such as subtle missteps, bending, reaching, pushing, and pulling resulting in loss of balance were found to lead to stair accidents, not gross performance errors. Additionally, unexpected hazards like sudden changes on a familiar staircase and features the person is not familiar with on a unknown staircase were found to be major causes of accidents.

In 1985, Templer, Archea, and Cohen conducted a study on stairway risk factors. Four major factors were found to be associated with incident rates. They were: (1) riser and tread dimensions, (2) tread materials, (3) visual surroundings, and (4) handrail use. High risers (greater than 7 in.) and narrow treads (depth of less than 11 in.) were found to be highly associated with incidents on industrial stairs. Linoleum or tile treads were associated with higher incident rates per tread while low incident rates were associated with concrete or stone. Stairs with no views straight ahead and a high number of orientation changes from the previous treads were also highly associated with incident rates. Using the handrail to pull oneself up in ascent, for guidance and balance in descent, and failure to

use the handrail at all in descent had higher rates of incident than any other handrail condition.

In spite of the results of the research mentioned above, standards for stairs have changed little in the last three centuries. OSHA's standards for fixed industrial stairs (OSHA 1910.24) still specify minimum width (22 in.), minimum load-carrying capacity (1,000 lb.), angle of rise (30-50 deg.), tread nose extension (0.5 - 1 in.), slip resistance, uniformity of riser height and tread width, minimum platform width (30 inches), and vertical clearance (7 ft). Preferred dimensions of riser height (no greater than 7 in.), tread depth (no less than 11 in.), and nosing projections (less than 11/16 in.) with respect to low incidence rates were given by Templer et al. (1985), but up to now no alterations in the OSHA standards have been made.

The above studies have one factor in common: the experimenters studied one or more aspects of the conventional stair design and its user. No research has been conducted to find and test any designs different from the well known "normal" stair. Is the conventional design the optimal and safest design with only modifications to be made in its size, angle, composition, and surroundings?

Lapeyre Stair, Inc. has produced a stair that is designed to be safer and easier to use than ladders. The stair is also intended to save valuable floor space, and to be versatile and practical (Lapeyre Stair, Inc., 1987). The major difference between the Lapeyre Stair and conventional stairs is the alternating tread design, a new concept that eliminates the unnecessary half of the tread. Secure footing is created since the entire tread on which the user is about to step (the "next" step) is completely visible during both ascent and descent. Moreover, the treads are deeper on the Lapeyre stair than on the conventional stair, therefore directly supporting most of the users' feet to give better balance. High and relatively narrow handrails are intended to give good upper body support along the

person's sides, back, and under the arms. The handrails also help to catch a person in the event that he may lose his balance. The task of carrying objects such as a tool box or brief case on the Lapeyre Stair is done by suspending the object to the outside of the stair handrails and using the handrails to support the person's body. The Lapeyre Stair was reviewed and accepted by the U. S. Department of Labor with the comment that "the stair is safe for use" and that it "meets the intent of the Occupational Safety and Health Act." It also meets OSHA and Coast Guard requirements (Lapeyre Stair, Inc., 1987)

This research evaluated the Lapeyre Stair for ease of use, safety, and comfort. Its goal was to introduce participants to the alternating tread design, allow them to become familiar with it, give them the opportunity to evaluate the stair, and compare it with the conventional ship's ladder. The comparison determined any difficulties that exist in ease of use, safety, and comfort, other than its unfamiliarity. The research did not evaluate specific features of either the Lapeyre Stair or the ship's ladder; it assessed the participants' performance, and preference towards safety, and comfort.

The research in this report was sponsored by the Lapeyre Stair, Inc. for the purpose of objectively evaluating and comparing the Lapeyre Alternating Tread Stair with the conventional ship's ladder. Subjects participating in this research were at no time told that the research was sponsored by Lapeyre Stair, Inc. and every attempt was made to remove any reference to the manufacturer.

METHOD

Subjects

Eighty undergraduate male students attending Virginia Polytechnic Institute and State University participated in this experiment. All were randomly sampled Reserve Officer Training Corps (ROTC) students and were paid for their time. ROTC students were used for two reasons:

(1 anthropometrically, they are most representative of military personnel, and

(2 their standard clothing eliminated possible confounds introduced by using subjects with variable clothing and footwear.

The subjects wore their every day usage uniforms called the "Gray Back" uniform. All subjects performed the study wearing the shoes which came with the Gray Backs. The soles of these shoes were fairly smooth, and their height was just below the ankles.

Materials and Apparatus

This study used a conventional ladder, and an alternating tread stair (i.e., Lapeyre Stair), both at an angle of 68 degrees (to the horizontal). Both stairs had a vertical ground-to-top distance of 108 inches (9 ft). At the bottom, the stairs were mounted to a 8 ft-by-8 ft, 1.5-ft-high platform. At the top, they were connected to a 6 ft-by-4 ft, 10.5-ft-high platform. The top platform had protective railing on three sides to ensure safety. The fourth side was protected by the stairs' hand rails. Figures 1 and 2, and Picture 1 present the operational set-up for the study. Protective padding was placed on and around the lower platform for protection in case of falls. A VHS video recorder recorded all trials to double-check the misstep counts, and to have a record of the trials.

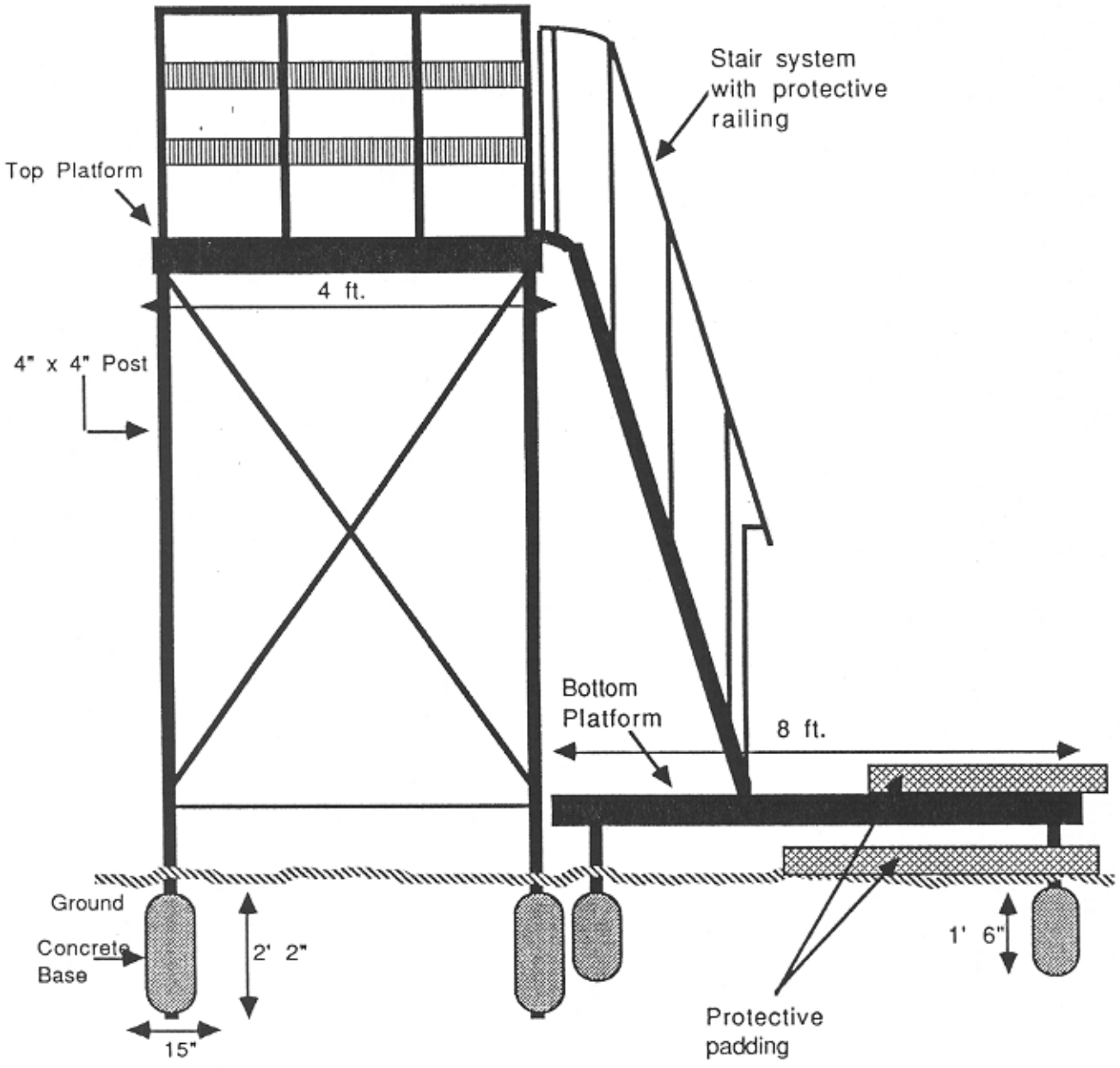


Figure 1. Side elevation view of the operational set-up.

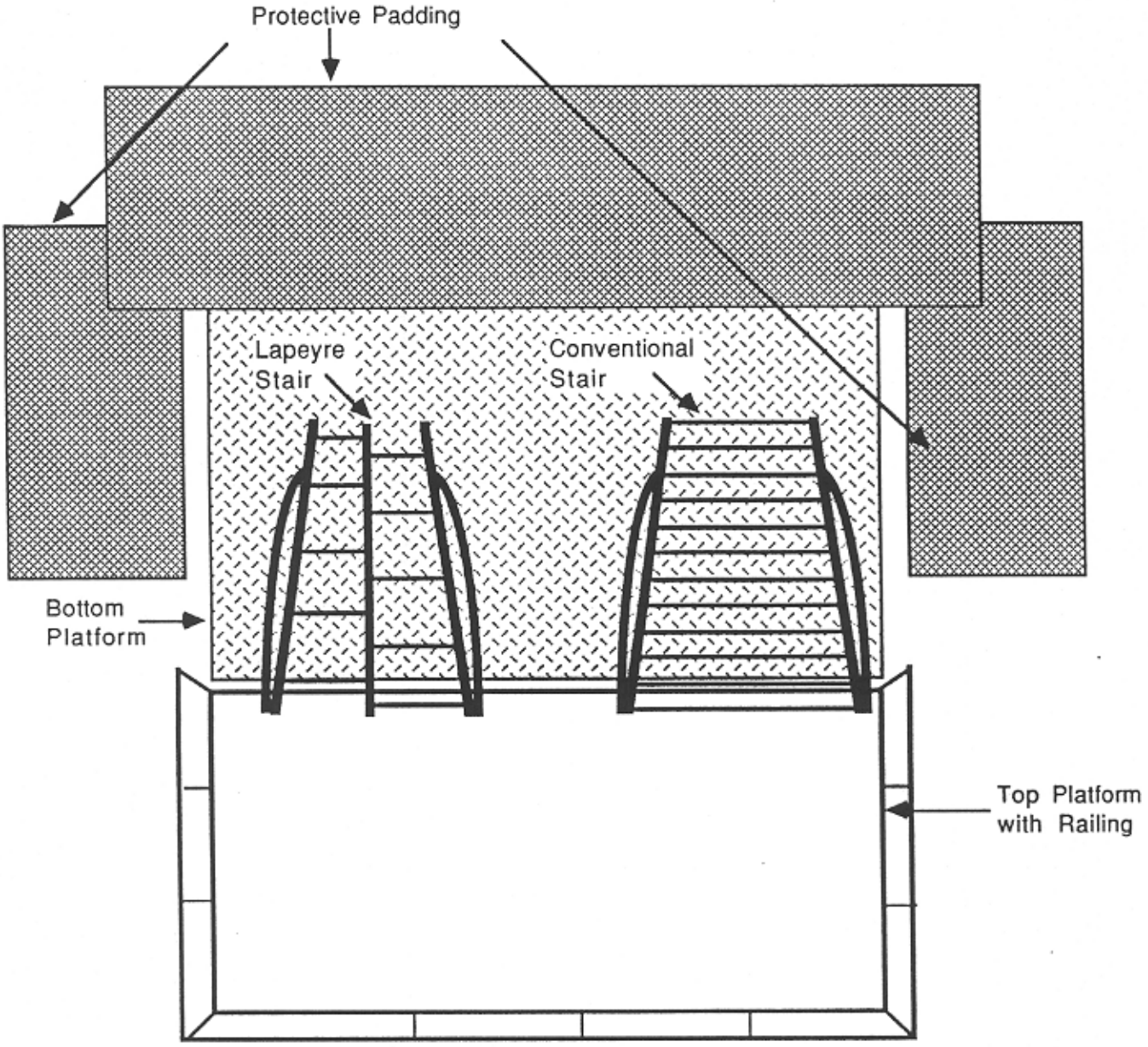


Figure 2. Plan view of the operational set-up.

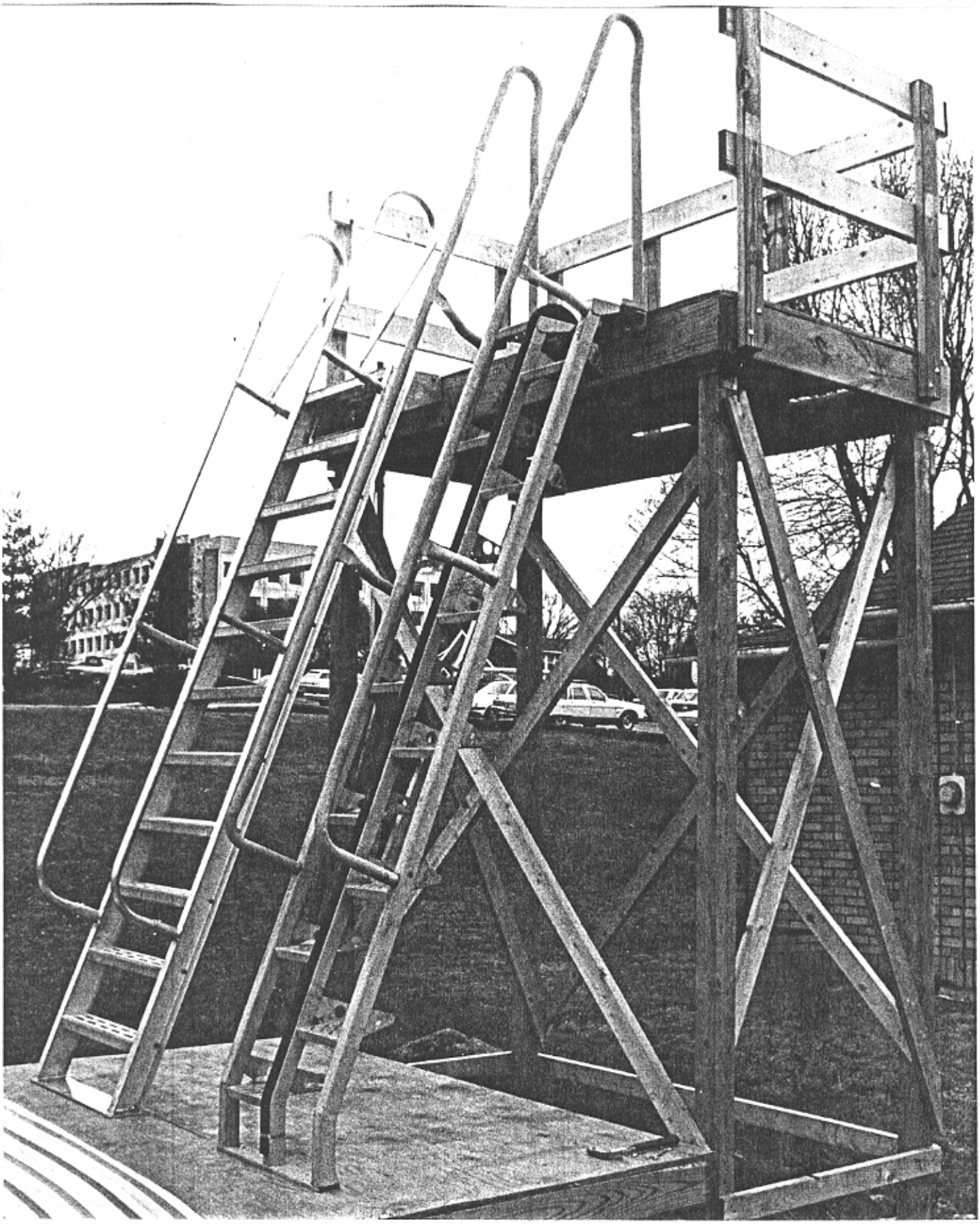


Figure 3. Quarter view of the operational set-up.

Dependent Measures

Two types of dependent measures were used: objective and subjective measures.

Objective measures. Time data and misstep data constituted the objective measures. Each subject was timed during both ascent and descent. For timing purposes, ascent started when the subject raised his foot to begin the action. Ascent ended at the first contact between the subject's (first) foot and the top platform. Termination of ascent was operationally defined as above since it was observed that many pilot subjects stopped the fluid climbing motion when they made initial contact with the top platform. The time difference between first foot contact and second foot contact was highly variable. To obtain fairly consistent times, the experimenters chose to end the ascent at the time of initial contact.

Subjects' were directed to descend the stairs while facing away from them. This form of descent was required since it is commonly used to descend both types of stair, particularly in military environments. Descent began when the subject raised his foot to start the descent and ended at the first contact between the subject's foot and the bottom platform.

Subjects' missteps were recorded during both ascent and descent. A misstep was defined as an observable hindrance to fluid motion during ascent or descent. The video tapes were reviewed to double-check the misstep count for each subject. A sample of the time and misstep data sheet is included in Appendix I.

Subjective measures. Questionnaires were devised to measure the perceived comfort and safety of the two stairs. In all, three questionnaires were used. See Appendix II for a copy of the questionnaires. Questionnaires 1 and 2 were given to the subject after he had

finished the trials for each stair. Thus, the subject completed these questionnaires twice, once for each stair. This procedure provided for an absolute rating of the stairs.

At the end of the experimental session, the subject completed the third questionnaire. This questionnaire was designed as a comparison questionnaire and incorporated all of the items from Questionnaires 1 and 2, and an additional 11 items (see Appendix II). This third questionnaire required the subject to compare the two stairs with respect to the items on the questionnaire, and to make a relative judgement.

Note that in the comparison questionnaire the stair systems are referred to by colors. The conventional ship's ladder was assigned the color yellow, while the alternating tread stair was blue. Colors were used since they do not imply any rank, order, or preference. Numbers (i.e., stair 1 and stair 2) or letters (i.e., stair A and stair B) might have conveyed a bias to the subjects. For instance, a subject might presume that 1 is better than 2, or that A is better than B.

The final two items in the comparison questionnaire asked the subject to provide a ranking for the overall use of each stair. The subject ranked each stair on a scale of 1 to 10 (1 being lowest and 10 being highest). Finally, subjects were provided with a comment sheet. Subjects used this sheet to make any pertinent comments about ascent and descent (with or without load) on each stair (see Appendix III).

Experimental Design

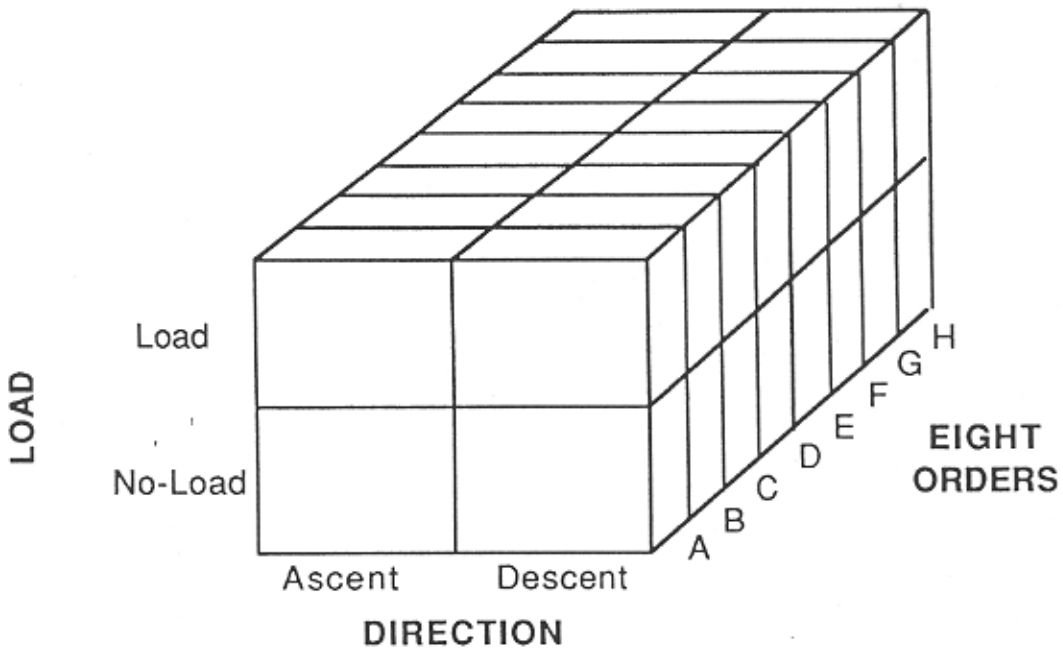
A 2 x 2 x 2 x 8 mixed factor factorial design was used for data collection. The independent variables were stair system, load, direction (ascent vs. descent), and order (see Figure 4 for illustration). The stair system variable had two levels: conventional ladder

and alternating tread (Lapeyre) stair. The load variable also had two levels: load condition, and no-load condition. In the load condition the subject performed trials while carrying a 20 lb tool box (with handle). In the no-load condition the subject performed trials without the tool box. Direction had two levels: up (i.e., ascent) and down (i.e., descent).

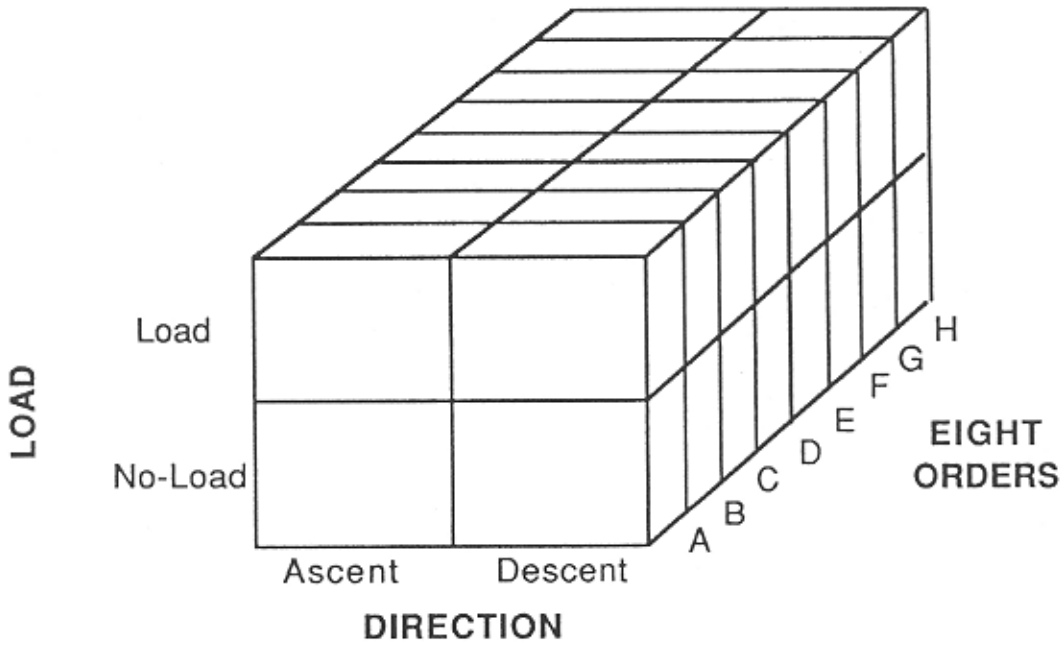
The order variable had eight levels. With eight levels, the ordering of the conditions was completely counterbalanced to rule out any order or learning effects. Thus, half the subjects started their trials on the alternating tread stair, while the other half started on the conventional ladder. The load variable was balanced in a similar fashion. One-fourth of the subjects received the load first on both stairs, while one-fourth received the load second on both stairs. Another fourth received the load first on one stair and second on the other stair, while the last fourth received the opposite combination. Figure 5 illustrates the eight possible stair-load ordering combinations. Ten subjects were randomly assigned to each of the eight conditions.

Experimental Procedure

The experimental procedure required approximately 60 minutes per subject. First, the subject was given an informed consent form to read and sign. This form also served as subjects' instructions since their tasks were clearly stated therein (see Appendix IV for informed consent form). The subject was then taken to the platform area. The researchers brushed off the bottom of the subject's shoes (to clean the soles) and instructed him to spend 10-15 minutes familiarizing himself with both stair systems. After the subject was comfortable with the stairs the trials began. One researcher stood close by to time the subject and visually monitor his feet for any missteps. The second researcher operated the video recorder. No systematic ordering was used in assigning these tasks to the researchers. Both researchers performed the tasks in random order.



FOR THE LAPEYRE STAIR



FOR THE CONVENTIONAL STAIR

Figure 4. The experimental design.

LOAD ORDERING	STAIR ORDERING: Blue 1st ; Yellow 2nd	STAIR ORDERING: Yellow 1st ; Blue 2nd
Load 1st on both	n = 10	
Load 2nd on both		
Load 1st on stair 1 Load 2nd on stair 2		
Load 2nd on stair 1 Load 1st on stair 2		

Figure 5. The possible stair-load combinations (n refers to the number of different subjects in each category).

Trials were performed in a standard fashion. Each subject was reminded to proceed as rapidly as possible **without** compromising safety. The researcher then instructed the subject to start at his leisure. After each ascent or descent, the subject was required to wait for the researcher to record the time, missteps (if any), and clear the stop watch. When the researcher had recorded the appropriate data, he instructed the subject to begin the next action.

After completing all trials on one stair, the subject was asked to complete Questionnaires 1 and 2 with respect to that stair. Following completion of the questionnaires, the subject began trials on the second stair. Identical procedures were applied for trials on the second stair.

The subject completed all trials on the second stair. The next step was to complete Questionnaires 1 and 2 for that stair. Finally, the subject completed the comparison questionnaire and made any necessary comments on the comment sheet. After completion of all trials and questionnaires the subject was shortly debriefed, paid, and dismissed.

RESULTS

For each dependent measure, statistical analyses were employed to test for any significant differences between the two stairs. For each test we include the probability that the observed difference is due to chance. This is denoted by the term "$p <$ [the probability of chance difference]." Thus, we are "1.00-p" sure that the observed difference is a real (not random) difference. We believe that $p < 0.05$ is an acceptable level of confidence in dealing with the data obtained in this study (i.e., we are at least 95% confident that the observed difference is a real one).

Comparison Questionnaire

A binomial test was used to test for differences between the stairs with respect to items on the comparison questionnaire. Of the 39 comparison questions, 25 yielded a significant difference ($p < 0.05$). Twenty-four of the 25 differences were favorable to the alternating tread stair. For instance, the alternating tread stair was more preferred for balance, foot support, and lower likelihood of slippage and tripping during descent. In addition, 80% of subjects ($p < 0.00006$) preferred this stair for safety and comfort during descent. For ascending, the alternating tread stair was preferred for safety, foot support, and lower likelihood of slippage and tripping. For overall safety and comfort 68% ($p < 0.0022$) preferred the alternating tread stair. Subjects preferred step width on the conventional ship's ladder, but that was anticipated since (by nature) each step on the alternating tread stair was half the width of its counterpart on the former stair.

Table 1 presents the percentages of subjects preferring each stair for all the items in the comparison questionnaire. Appendix V provides a complete graphical presentation of

Table 1. Results of the Comparison Questionnaire.

QUESTION	% PICKING LAPEYRE	% PICKING CONVEN.	p <
Beginning ascent safer for	60.0%	40.0%	-
Beginning descent safer for	70.0%	30.0%	0.0003
For ascent steepness safer for	71.8%	28.2%	0.0003
For descent steepness safer for	82.1%	17.9%	0.0003
For ascent step width safer for	38.8%	61.2%	-
For descent step width safer for	52.5%	47.5%	-
For ascent step distance safer for	53.8%	46.3%	-
For descent step distance safer for	72.5%	27.5%	0.0001
For ascent slips/twists higher for	31.3%	68.8%	0.0014
For descent slips/twists higher for	12.5%	87.5%	0.00006
For ascent likelihood of tripping higher for	40.0%	60.0%	-
For descent likelihood of tripping higher for	17.5%	82.5%	0.00006
Tread depth safer for	88.8%	11.3%	0.00006
For ascent better support on	81.3%	18.7%	0.00006
For descent better support on	86.3%	13.8%	0.00006
For ascent more secure on	76.3%	23.8%	0.00006
For descent more secure on	83.8%	16.2%	0.00006
For ascent knee movement.more impaired	50.0%	50.0%	-
For descent knee movement.more impaired	45.0%	55.0%	-
Overall ascent safer on	66.3%	33.7%	0.0052
Overall descent safer on	81.3%	18.7%	0.00006
Beginning ascent more comfortable for	51.3%	48.8%	-
Beginning descent more comfortable for	67.5%	32.5%	0.0026

Table 1 Cont. (* indicates items with significant differences favoring conventional ladder).

QUESTION	% PICKING LAPEYRE	% PICKING CONVEN.	p <
For ascent steepness more comfortable for	62.5%	37.5%	0.0348
For descent steepness more comfortable for	85.0%	15.0%	0.00006
Stair width (between rails) more comfort. for	36.3%	63.7%	0.019*
For ascent step width more comfortable for	37.5%	62.5%	0.035*
For descent step width more comfortable for	58.8%	41.2%	-
For ascent step distance more comfort. for	46.3%	53.7%	-
For descent step distance more comfort. for	75.0%	25.0%	0.00006
Step depth more comfortable for	85.0%	15.0%	0.00006
Overall ascent more comfortable on	47.5%	52.5%	-
Overall descent more comfortable on	83..8%	16.2%	0.00006
Overall load was easier to carry on	58.8%	41.2%	-
For ascent you had better balance on	60.0%	40.0%	-
For descent you had better balance on	82.5%	17.5%	0.00006
Which would you select for ascending?	48.1%	51.9%	-
Which would you select for descending?	79.7%	20.3%	0.00006
Overall, which stair would you select?	67.9%	32.1%	0.0022

these percentages. For the items with significant differences (i.e., $p < 0.05$) the p values are noted.

Absolute Rating Questionnaires

An analysis fo variance (ANOVA) was used to test for any differences between the stairs on each of the absolute rating questions (Questionnaires 1 and 2). Fourteen of the 30 questions yielded significant differences. These differences were similar to those of the comparison questionnaire. For example, the alternating tread stair was rated significantly higher for both safety and comfort during descent. The Lapeyre stair was rated higher for secure footing and foot support as well. Moreover, the conventional ladder was rated as having a higher likelihood for foot slippage and tripping during ascent and descent. Appendix VI presents the mean ranks assigned to the stairs for each question. The p values are listed for significant differences.

Descending and Ascending Time

A four-way ANOVA technique was used to test for any time differences due to the stair, load, direction, and order variables, and any interactions thereof. The test yielded significant stair, load, and direction effects. Subjects traveled more rapidly on the conventional ship's ladder than on the alternating tread stair, $F(1, 79) = 24.70$, $p < 0.0001$. The mean travel times for the conventional and alternating tread stairs were 5.48 seconds and 5.90 seconds, respectively. The difference (albeit small) was not surprising since most subjects had 20-25 years of experience with the conventional ship's ladder, but only 15 minutes with the alternating tread stair. Additionally, most subjects descended more rapidly on the conventional ship's ladder because this stair forced their body forward. To keep their balance, subjects had to move their feet more rapidly.

Subjects traveled more rapidly without a load than with a load, $F(1,79) = 149.80$, $p < 0.0001$. The mean travel time with a load was 6.26 seconds, while for travel without a load it was 5.12 seconds. Subjects also descended more rapidly than they ascended, $F(1,79) = 80.93$, $p < 0.0001$. The mean ascent and descent times were 6.00 and 5.38 seconds, respectively.

Missteps

Table 2 presents the number of missteps on each stair for each condition. In total there were 22 missteps on the alternating tread stair and 38 on the conventional ladder. A Sutcliffe chi-square test revealed that there were significantly fewer total missteps on the alternating tread stair than on the conventional ladder, $\chi^2 = 4.27$, $p < 0.05$. Additionally, there were significantly fewer missteps during ascent than during descent (regardless of stair), χ^2 $(1, N=80) = 5.40$, $p < 0.05$. Based on the χ^2 results outlined in Table 3, some interesting issues are observed (see Appendix VII for a graphical illustration of the points listed below):

1) There were significantly fewer misstpes on the alternating tread stair during both ascent and descent.

2) There were significantly fewer misstpes on the alternating tread stair for both load and no-load conditions. The conventional ship's ladder was proportionally worse with load.

3) Additionally, there were significantly fewer misstpes on the alternating tread stair during descent with load, and ascent with no load. There were no significant differences among other specific combinations.

Table 2. The number of missteps for each stair under each condition.

STAIR	Ascending		Descending		
	Load	No-load	Load	No-load	
Lapeyre	4	3	7	8	Tot. = 22
Conventional	5	9	16	8	Tot. = 38
	Tot. for ascent=21		Tot. for descent=39		

Table 3. χ^2 values for missteps.

Variable	Chi-Squared Value	p ≤
Total	15.20	0.05
Stair	4.26	0.05
Direction	5.40	0.02
Load	0.27	not significant
Stair*Direction	5.53	0.05
Stair*Load	10.66	0.01
Direction*Load	9.53	0.01
Stair*Direction*Load	5.51	0.02

Thus, the Lapeyre Stair is advantageous or equal to the conventional ship's ladder depending on the circumstances; in no case is the Lapeyre Stair less safe than the conventional ladder as measured by misstpes.

Overall Rankings

Subjects provided an overall ranking for the stairs on the final two items OF the comparison questionnaire. The mean overall ranks (1 to 10 ranking) for the alternating tread stair and the conventional ladder were 7.33 and 5.71, respectively. A Sign test on the overall stair rankings showed that the ranking for the alternating tread stair was significantly higher than that of the conventional ladder ($p < 0.00014$). Table 4 presents the number of subjects assigning the indicated ranks to each stair.

Comments

No specific statistical analyses were performed on the subjects' comments. However, Appendix VIII presents a tally of subjects' comments about each experimental condition (8 conditions in total) and their general comments about the stairs.

Table 4

Frequency of Each Rank Assigned to the Alternating Tread and Conventional Stairs.

LAPEYRE STAIR		CONVENTIONAL STAIR	
Rank	Number of Subjects Assigning This Rank	Rank	Number of Subjects Assigning This Rank
1	1	1	1
2	3	2	4
3	2	3	5
4	3	4	11
5	3	5	14
6	8	6	14
7	17	7	16
8	22	8	12
9	17	9	2
10	4	10	1
	80		80
	Avg. Rank = 7.33		Avg. Rank = 5.71

DISCUSSION AND CONCLUSIONS

Results from both the objective and subjective measures suggest that the Lapeyre Stair is safer and more comfortable than the conventional ship's ladder. The questionnaires and overall rankings clearly indicate that the alternating tread stair is perceived to be significantly safer and more comfortable than the conventional ship's ladder. In addition, the misstep data provide objective evidence that the alternating tread stair is in fact safer (fewer missteps on the alternating tread stair), particularly when carrying a load or descending the strairs. Further, comments made by subjects (see Appendix VIII) show that in general they perceive the Lapeyre Stair to be safer and more comfortable. For example, one may compare actual missteps during descent for the two stairs, and the responses to question 37 of the comparison questionnaire. Missteps were significanlty fewer on the Lapeyre Stair, and about 80% of the subjects preferred this stair for descent (i.e., question 37).

The small (7 percent) travel time difference in favor of the conventional ship's ladder was not unexpected. Most subjects had many years of experience with this type of ladder, but only 15 minutes with the alternating tread stair. Additionally, most subjects were forced to descend the conventional ladder more rapidly than they desired because the conventional stair forced the subjects' bodies forward. In effect, the subjects had to move their feet more rapidly to maintain their balance. This condition was especially severe during descent with a load.

In summary, the users' subjective data and the objectively measured frequency of missteps consistently and clearly demonstrate the comfort and safety advantage of the Lapeyre alternating tread stair over the conventional ship's ladder. The small increase in travel time for the Lapeyre stair, considered to be due to lack of experience with that stair,

is considered unimportant and likely to diminish to zero with even modest experience with the stair.

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APPENDICES

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Appendix I

Time and Misstep Data Recording sheet

		Stair _____		Stair _____	
		Ascent	**Descent**	**Ascent**	**Descent**
NO-LOAD	**Trial 1**				
	Misstep				
	Trial 2				
	Misstep				
	Trial 3				
	Misstep				
	Trial 4				
	Misstep				
	Trial 5				
	Misstep				
LOAD	**Trial 1**				
	Misstep				
	Trial 2				
	Misstep				
	Trial 3				
	Misstep				
	Trial 4				
	Misstep				
	Trial 5				
	Misstep				

Appendix II

Questionnaires Used in the Experiment

QUESTIONNAIRE 1

This questionnaire deals with SAFETY issues of the stair systems. Please read each question carefully, and indicate your response on the "Opscan" sheet provided. Note that the response scale may be different for some questions. Please answer ALL questions and do not mark up the questionnaires.

1. You could **safely** begin the ascent (initial foot placement) on the stair;

1	2	3	4	5	6	7
strongly disagree						strongly agree

2. You could **safely** begin the descent (initial foot placement) on the stair;

1	2	3	4	5	6	7
strongly disagree						strongly agree

3. The step width (i.e. the dimension of a single step from left to right as you face the stair) was **safe** for ascent on the stair;

1	2	3	4	5	6	7
strongly disagree						strongly agree

4. The step width (i.e. the dimension of a single step from left to right as you face the stair) was **safe** for descent on the stair;

1	2	3	4	5	6	7
strongly disagree						strongly agree

5. For **safety** of ascent, the distance between consecutively used steps was;

1	2	3	4	5	6	7
too small			just right			too large

6. For **safety** of descent, the distance between consecutively used steps was;

1	2	3	4	5	6	7
too small			just right			too large

7. The likelihood of foot slippage and twists during ascent was;

1	2	3	4	5	6	7
very unlikely						very likely

8. The likelihood of foot slippage and twists during descent was;

1	2	3	4	5	6	7
very unlikely						very likely

9. The likelihood of tripping during ascent was;

1	2	3	4	5	6	7
very unlikely						very likely

10. The likelihood of tripping during descent was;

1	2	3	4	5	6	7
very unlikely						very likely

11. The depth of each step (i.e. front to back dimension as you face the stair) on the stair was;

1	2	3	4	5	6	7
too shallow			just right			too deep

12. During ascent the steps adequately supported your foot;

1	2	3	4	5	6	7
strongly disagree						strongly agree

13. During descent the steps adequately supported your foot;

1	2	3	4	5	6	7
strongly disagree						strongly agree

14. During ascent you had secure footing;

1	2	3	4	5	6	7
strongly disagree						strongly agree

15. During descent you had secure footing;

1	2	3	4	5	6	7
strongly disagree						strongly agree

16. Knee movement was not impaired during ascent;

1	2	3	4	5	6	7
strongly disagree						strongly agree

17. Knee movement was not impaired during descent;

1	2	3	4	5	6	7
strongly disagree						strongly agree

18. Overall, you could **safely** ascend the stair ;

1	2	3	4	5	6	7
strongly disagree						strongly agree

19. Overall, you could **safely** descend the stair ;

1	2	3	4	5	6	7
strongly disagree						strongly agree

QUESTIONNAIRE 2

This questionnaire deals with **COMFORT** issues of the stair systems. Please read each question carefully, and indicate your response on the "Opscan" sheet provided. Note that the response scale may be different for some questions. Please answer **ALL** questions.

20. You could **comfortably** begin the ascent (initial foot placement) on the stair;

1	2	3	4	5	6	7
strongly disagree						strongly agree

21. You could **comfortably** begin the descent (initial foot placement) on the stair;

1	2	3	4	5	6	7
strongly disagree						strongly agree

22 The step width (i.e. the dimension of a single step from left to right as you face the stair) was **comfortable** for ascent on the stair;

1	2	3	4	5	6	7
strongly disagree						strongly agree

23. For **comfort** the width of the stair (i.e. the distance from the left to the right hand rail) was;

1	2	3	4	5	6	7
too small			just right			too large

24. The step width was **comfortable** for <u>ascent</u> on the stair;

1	2	3	4	5	6	7
strongly disagree						strongly agree

25. The step width was **comfortable** for <u>descent</u> on the stair;

1	2	3	4	5	6	7
strongly disagree						strongly agree

26. For <u>ascent</u>, there was a **comfortable** distance between consecutive steps;

1	2	3	4	5	6	7
strongly disagree						strongly agree

27. For <u>descent</u>, there was a **comfortable** distance between consecutive steps;

1	2	3	4	5	6	7
strongly disagree						strongly agree

28. The depth of the steps on the stair was **comfortable**;

1	2	3	4	5	6	7
strongly disagree						strongly agree

29. Overall, you could **comfortably** ascend the stair ;

1	2	3	4	5	6	7
strongly disagree						strongly agree

30. Overall, you could **comfortably** descend the stair ;

1	2	3	4	5	6	7
strongly disagree						strongly agree

COMPARISON QUESTIONNAIRE

These questions ask you to compare the two stair systems. Please read each question carefully, and select the appropriate response (i.e. stair color). Please respond to **ALL** questions and select **ONLY** one answer. To indicate BLUE or YELLOW mark **1 or 2** , respectively, on the "Opscan" sheet.

1. Beginning the ascent (initial foot placement) on the stair was safer for;

   BLUE YELLOW

2. Beginning the descent (initial foot placement) on the stair was safer for;

   BLUE YELLOW

3. For ascent, the steepness of the stair (i.e. the angle of the stair with respect to the horizontal) was safer for;

   BLUE YELLOW

4. For descent, the steepness of the stair (i.e. the angle of the stair with respect to the horizontal) was safer for;

   BLUE YELLOW

5. The step width was safer for ascent on the;

BLUE YELLOW

6. The step width was safer for descent on the;

BLUE YELLOW

7. For ascent, the distance between consecutive steps was safer for;

BLUE YELLOW

8. For descent, the distance between consecutive steps was safer for;

BLUE YELLOW

9. The likelihood of foot slippage and twists during ascent was higher for;

BLUE YELLOW

10. The likelihood of foot slippage and twists during descent was higher for;

BLUE YELLOW

11. The likelihood of tripping during ascent was higher for;

BLUE YELLOW

12. The likelihood of tripping during descent was higher for;

BLUE YELLOW

13. The depth of the steps on the stair was safer for;

BLUE YELLOW

14. During ascent the steps better supported your foot on the;

BLUE YELLOW

15. During descent the steps better supported your foot on the;

BLUE YELLOW

16. During ascent you had more secure footing on the;

BLUE YELLOW

17. During descent you had more secure footing on the;

BLUE YELLOW

18. During ascent, knee movement was more impaired on the;

BLUE YELLOW

19. During descent, knee movement was more impaired on the;

BLUE YELLOW

20. Overall, you could more safely ascend the stair on the;

BLUE YELLOW

21. Overall, you could more safely descend the stair on the;

BLUE YELLOW

22. You could more comfortably begin the ascent (initial foot placement) on the;

BLUE YELLOW

23. You could more comfortably begin the descent (initial foot placement) on the;

BLUE YELLOW

24. For ascent, the steepness of the stair (i.e. the angle of the stair with respect to the horizontal) was more comfortable for the;

BLUE YELLOW

25. For descent, the steepness of the stair (i.e. the angle of the stair with respect to the horizontal) was more comfortable for the;

BLUE YELLOW

26. The width of the stair (i.e. the distance from the left to the right hand rail) was more comfortable for the;

BLUE YELLOW

27. The step width was more comfortable for ascent on the;

BLUE YELLOW

28. The step width was more comfortable for descent on the;

BLUE YELLOW

29. For ascent, the distance between consecutive steps was more comfortable for the;

BLUE YELLOW

30. For descent, the distance between consecutive steps was more comfortable for the;

BLUE YELLOW

31. The depth of the steps on the stairs was more comfortable for the;

BLUE YELLOW

32. Overall, you could more comfortably ascend the;

BLUE YELLOW

33. Overall, you could more comfortably descend the;

BLUE YELLOW

34. Overall, the load was easier to carry on the;

BLUE YELLOW

35. Overall, for ascent, you had better balance on the;

BLUE YELLOW

36. Overall, for descent, you had better balance on the;

BLUE YELLOW

37. Which would you select for ascending;

BLUE YELLOW

38. Which would you select for descending;

BLUE YELLOW

39. Overall, which would you select;

BLUE YELLOW

40. On a scale of 1 to 10, (with 1 being lowest and 10 being highest), how would you rate the BLUE stair;

PLEASE INDICATE YOUR ANSWER ON THE OPSCAN SHEET

41. On a scale of 1 to 10, (with 1 being lowest and 10 being highest), how would you rate the YELLOW stair;

PLEASE INDICATE YOUR ANSWER ON THE OPSCAN SHEET

Appendix III

Subject Comment Sheet

COMMENT SHEET

Please use this sheet for making any comments with regard to the listed items.

1. Ascending the BLUE stair without a load

2. Ascending the YELLOW stair without a load.

3. Descending the BLUE stair without a load.

4. Descending the YELLOW stair without a load.

5. Ascending the BLUE stair with a load.

6. Ascending the YELLOW stair with a load.

7. Descending the BLUE stair with a load.

8. Descending the YELLOW stair with a load.

9. Other comments.

Appendix IV

Participants' Informed Consent Form

PARTICIPANT'S INFORMED CONSENT

The purpose of this study is to examine two stair systems with respect to ease of use, perceived comfort of use, perceived safety of use, and performance during ascending and descending activities. In this study you will be asked to ascend and descend the stair systems both at an angle of 68 degrees. Let us emphasize that the stairs are the objects under investigation, **NOT** you. You will be helping us evaluate the stairs.

You will be timed during your ascent from the ground to the platform, and during the descent from the platform to the ground. The rate of ascent and descent should be a safe, comfortable, normal pace. You will perform this task five times for each ladder system under two conditions: no-load and load. In the no-load condition you will ascend and descend the stairs without carrying anything. Under the load condition you will carry a 20 lb. tool box (with handle). If, for any reason, you cannot carry a 20 lb. load please notify the researchers. During the ascent and descent of the ladders you will be visually monitored by video-cameras.

Upon completion of these performance tasks, you will be asked to complete a questionnaire rating each ladder system on the perceived comfort of use and the perceived safety of use. You will also be required to make a relative preference between the two ladder systems for both ascending and descending.

After completing these tasks you will have the opportunity to comment with respect to any opinions, preferences, and/or particular

thoughts regarding characteristics of the ladder systems which may be of help to the study.

You are asked to ascend and descend the ladders with caution, and if an accident occurs, a first-aid kit will be available as well as the Virginia Tech Rescue Squad. In case of an accident, you are obligated to undergo immediate medical examination.

If you consent to participate, you will be paid $5.00 per hour for your participation. The entire study is expected to last no more than one hour.

The research team consists of:

1. Gerard C. Jorna, Graduate Student, Human Factors Dept.

2. Michael Mohageg, Graduate Student, Human Factors Dept.

3. Dr. Harry Snyder, Faculty Member, Human Factors Dept.

A member of the research team will answer any questions you may have. However, in cases that may affect the outcome of the study, the team member may delay a detailed answer until you have completed your runs.

You are requested to refrain from discussing the study with other persons who may become participants. We expect all data to be taken by February 20, 1988. Following that date, feel free to discuss the experiment with anyone you wish.

Finally, we'd like to point out that your data will be treated with anonymity, and that:

1. You have the right to withdraw from this study at any time, if you feel that it is not agreeable to you. Should you terminate the experiment, you will be paid only for the time you actually participated.

2. If you have any problem with or questions about the study itself, you may contact Dr. Harry Snyder at the phone number given on the following page. If you have questions about your rights as a participant, you may contact Mr. Charles D. Waring, Chairman of the Institutional Review Board at Virginia Tech (703) 961-5284. If you wish to receive a summary of the results of the research, please include your address with your signature below.

3. There are some risks to which you expose yourself in volunteering for this research. The risks are:

a. The risk of falling or slipping from the stairway or the platform. Such a fall could result in an injury to you. The platform is 10' 6" above the ground. We have taken precautions to minimize the likelihood and severity of a fall while you participate, but the risk can not be totally eliminated.

b. The risk associated with overexertion. Since you will be climbing stairways, you will be exerting yourself to some degree. If you are a healthy person, the risk due to overexertion is minimal.

4. You should not volunteer for participation in this research if you are under 18 years of age, if you are not in good health, or if you have taken any drug, alcoholic beverage, or medication within the last 24 hours. It is your responsibility to inform the experimenters of any additional condition which might interfere with your ability to ascend or descend stairways. Such condition would include inadequate sleep, hunger, hangover, headache, cold symptoms, depression, allergies, emphysema, emotional upset, visual impairment,

dizziness, seizures, nerve, muscle,or bone disorders, heart or breathing disorders, or other similar conditions.

The faculty and graduate students involved in this study greatly appreciate your help as a participant.

Your signature below indicates that you have read this document in its entirety, that all of your questions have been answered, and that you consent to participate in the study described. If you include your printed name and address below, a summary of the experimental results will be sent to you.

_____ _____

Signature

_____ _____

Date

_____

Printed Name and Address

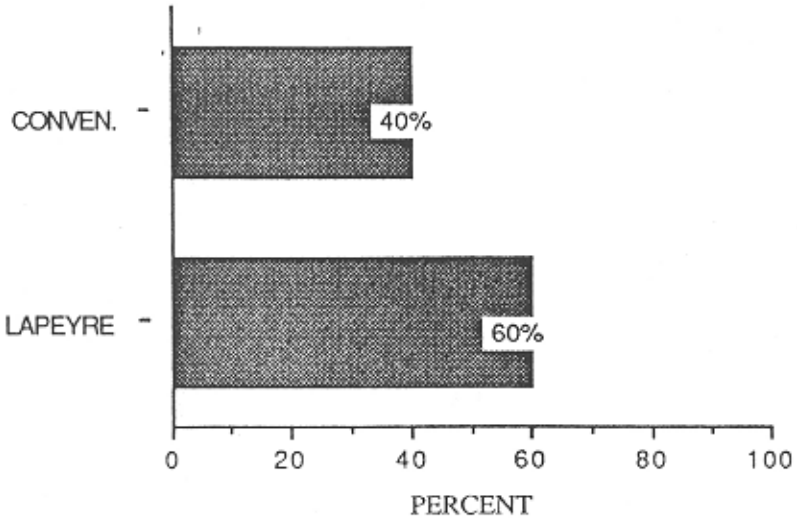
Visual Displays Lab.
IEOR Department
Virginia Tech
Blacksburg, Virginia 24061
961-7527

Appendix V

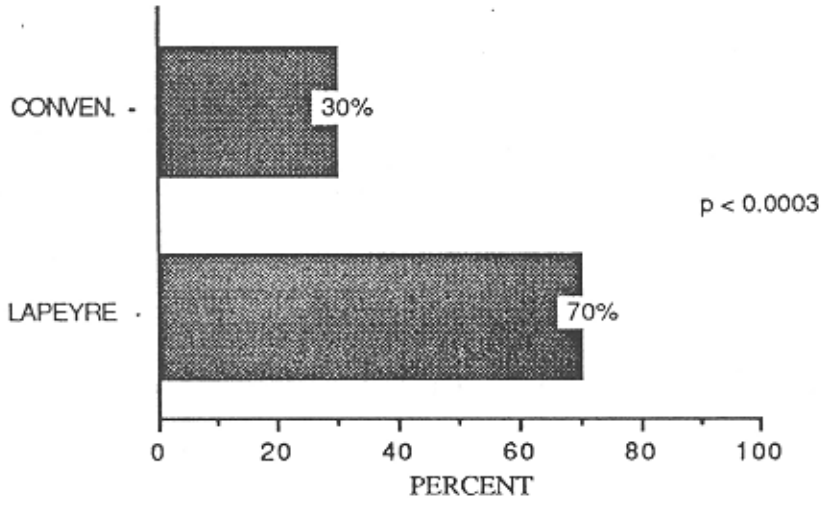
Data From Comparison Questionnaire

This appendix contains a graphical representation of the answers to the Comparison Questionnaire. Results are in percentages (n = 80) and p values are presented if percentages were statistically different.

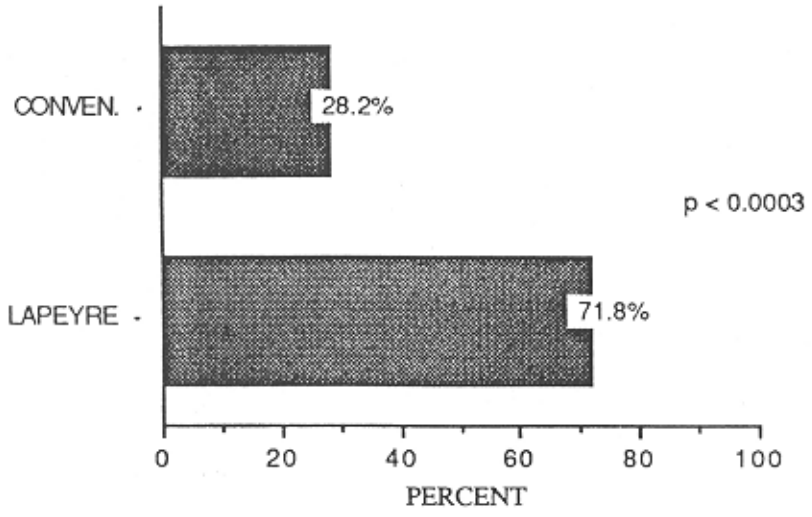
1. BEGINNING THE ASCENT WAS SAFER FOR:



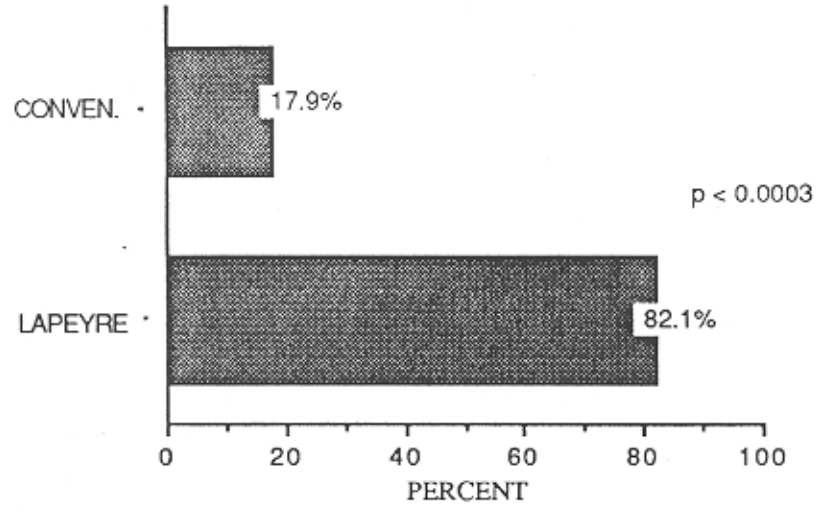
2. BEGINNING THE DESCENT WAS SAFER FOR:



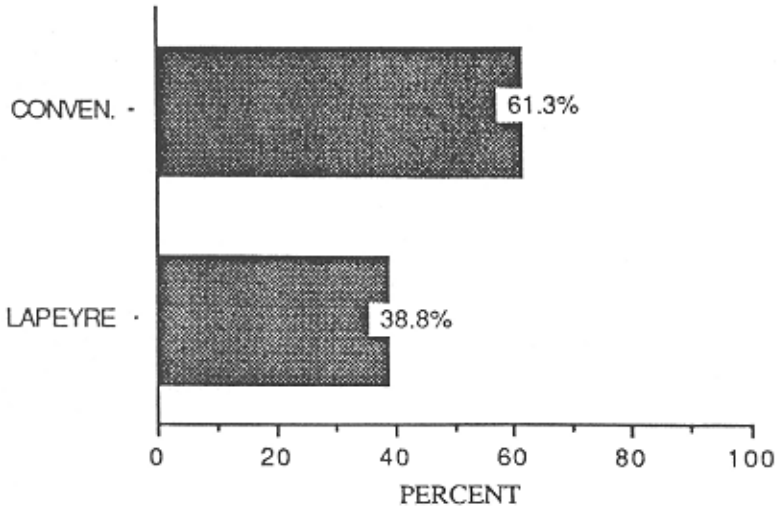
3. FOR ASCENT, STEEPNESS WAS SAFER FOR:



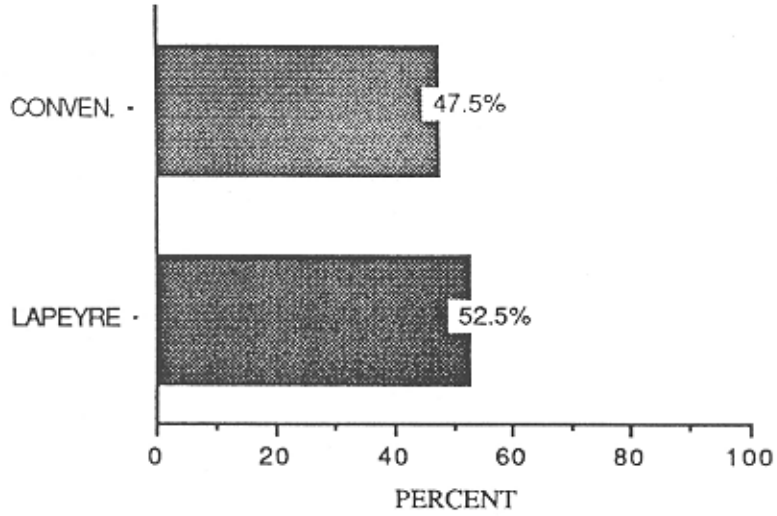
4. FOR DESCENT, STEEPNESS WAS SAFER FOR:



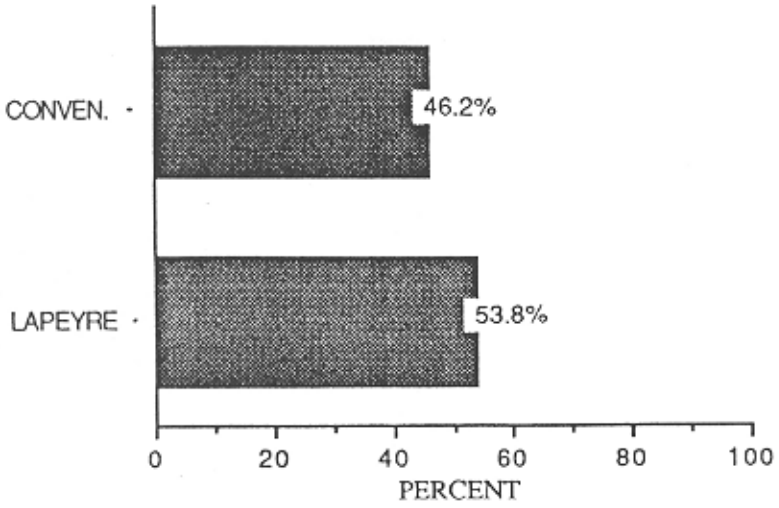
5. STEP WIDTH WAS SAFER FOR ASCENT 0N:



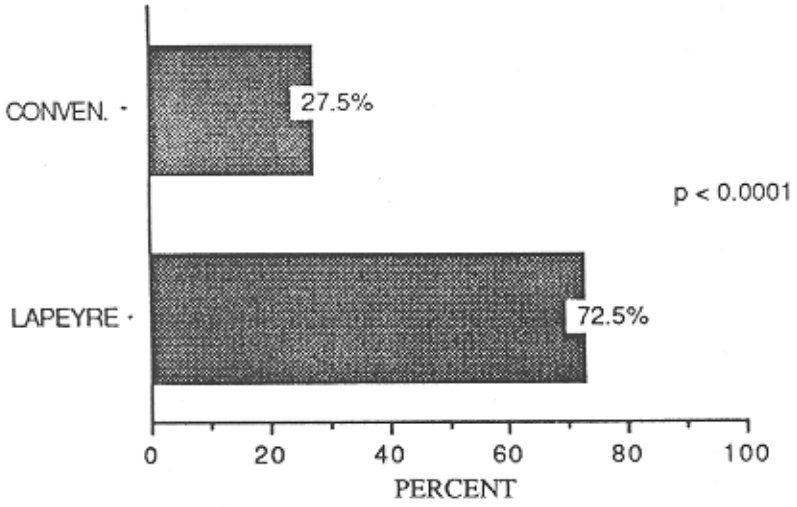
6. STEP WIDTH WAS SAFER FOR DESCENT ON:



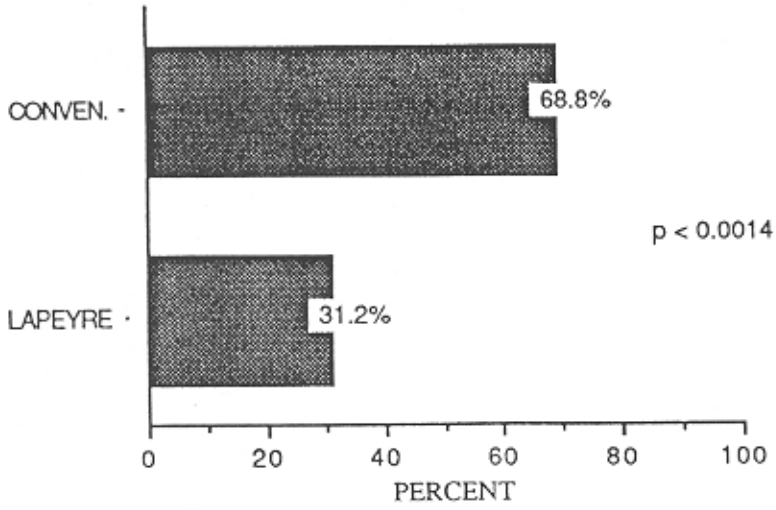
7. FOR ASCENT, CONSECUTIVE STEP DISTANCE WAS SAFER FOR:



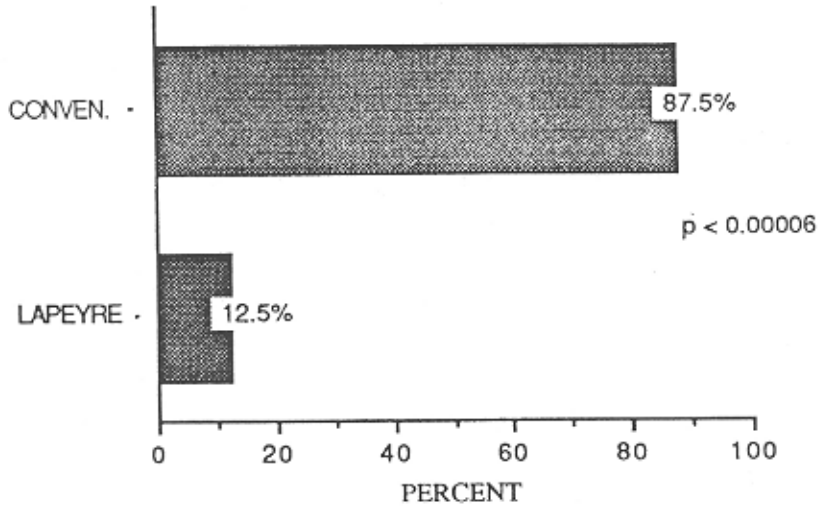
8. FOR DESCENT, CONSECUTIVE STEP DISTANCE WAS SAFER FOR:



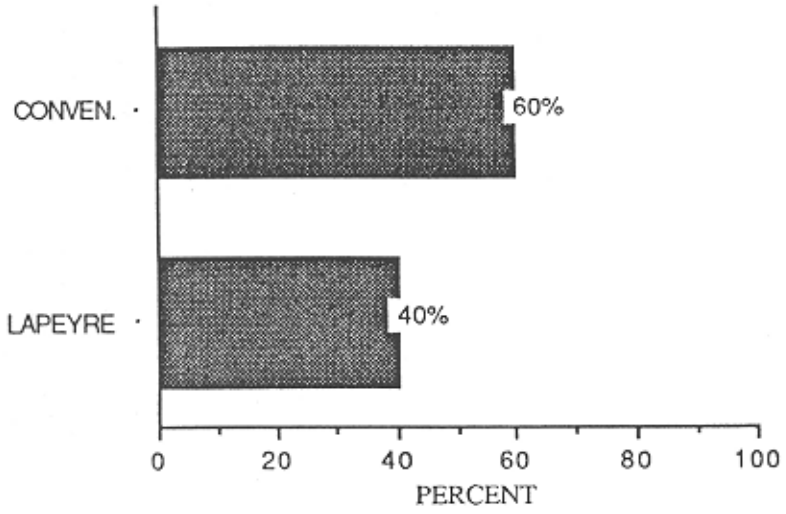
9. LIKELIHOOD OF FOOT SLIP/TWIST DURING ASCENT HIGHER FOR:



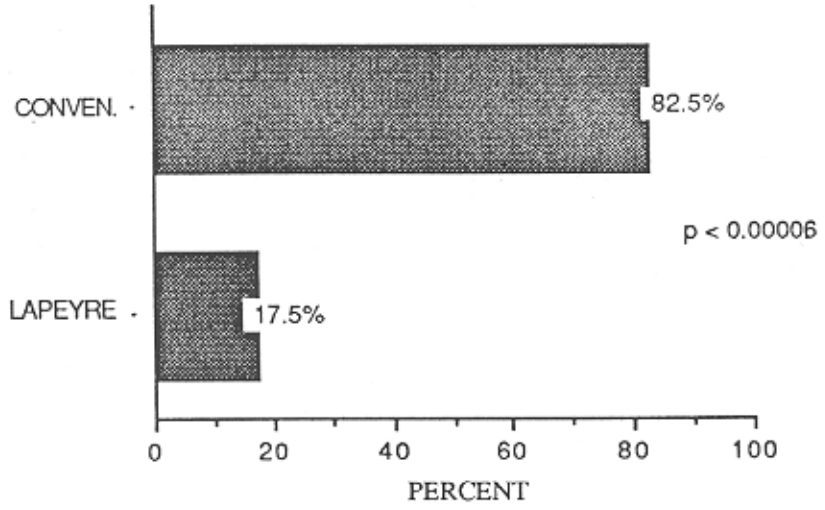
10. LIKELIHOOD SLIP/TWISTS DURING DESCENT HIGHER FOR:



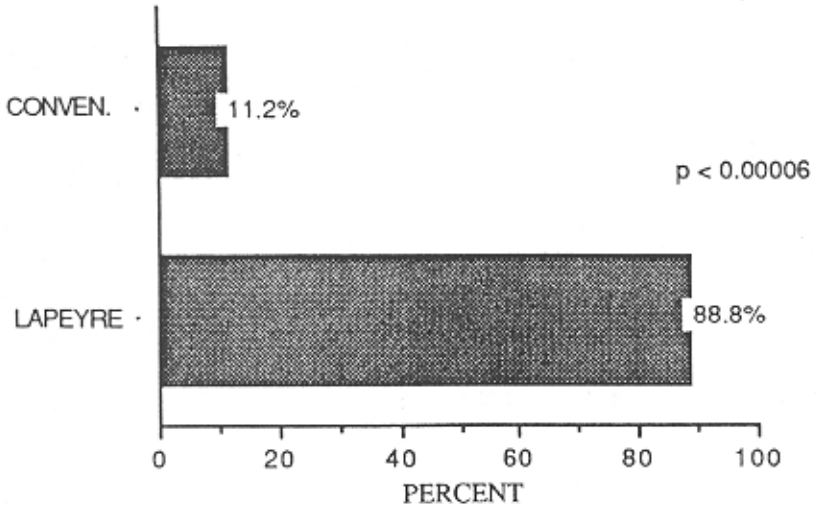
11. LIKELIHOOD TRIPPING DURING ASCENT HIGHER FOR:



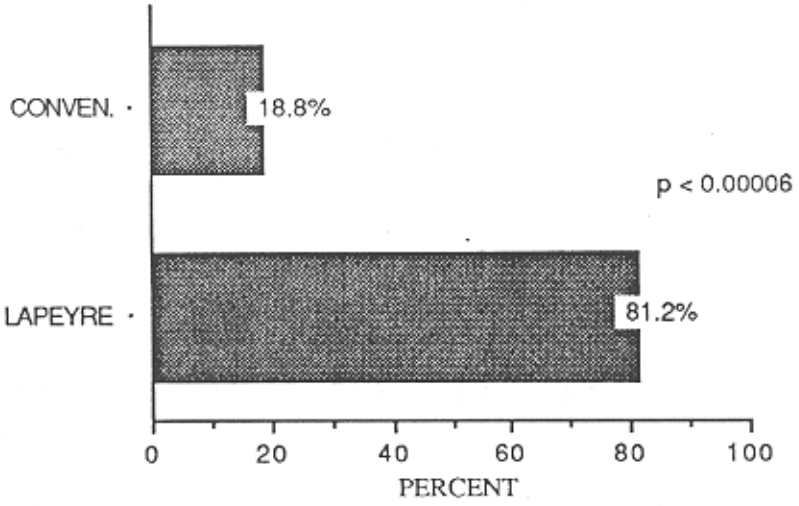
12. LIKELIHOOD TRIPPING DURING DESCENT HIGHER FOR:



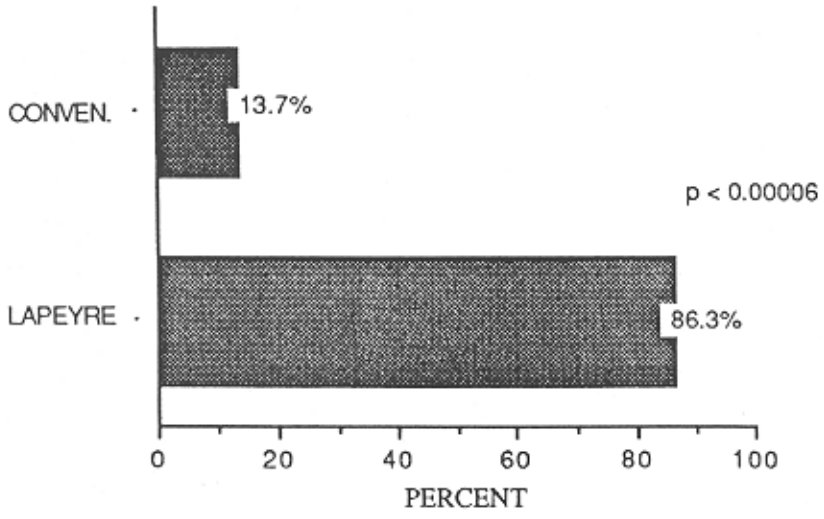
13. DEPTH OF STEPS ON STAIR WAS SAFER FOR:



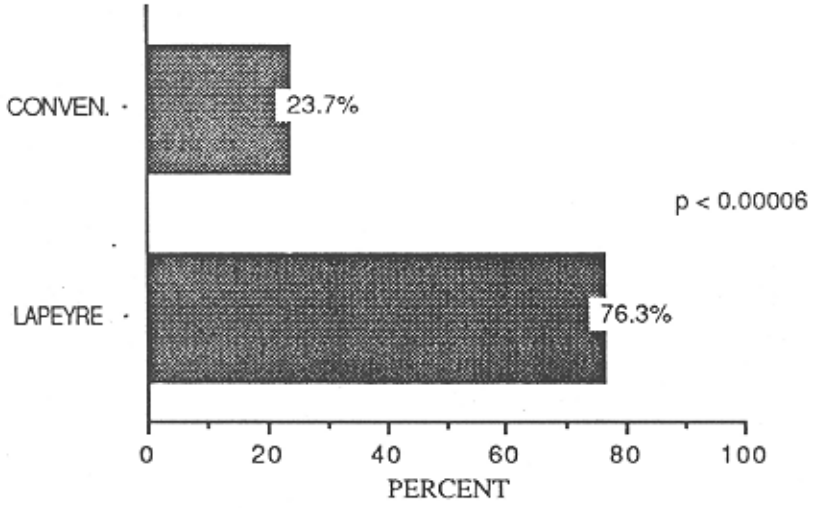
14. BETTER FOOT SUPPORT DURING ASCENT FOR:



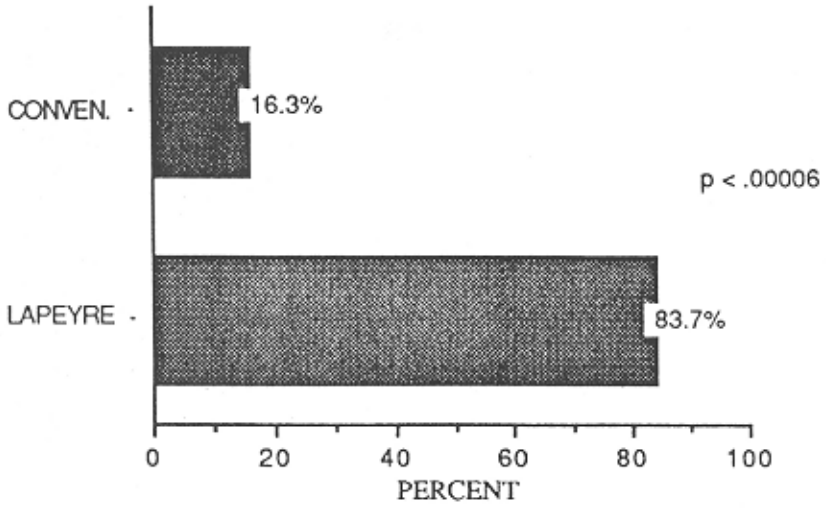
15. BETTER FOOT SUPPORT DURING DESCENT FOR:



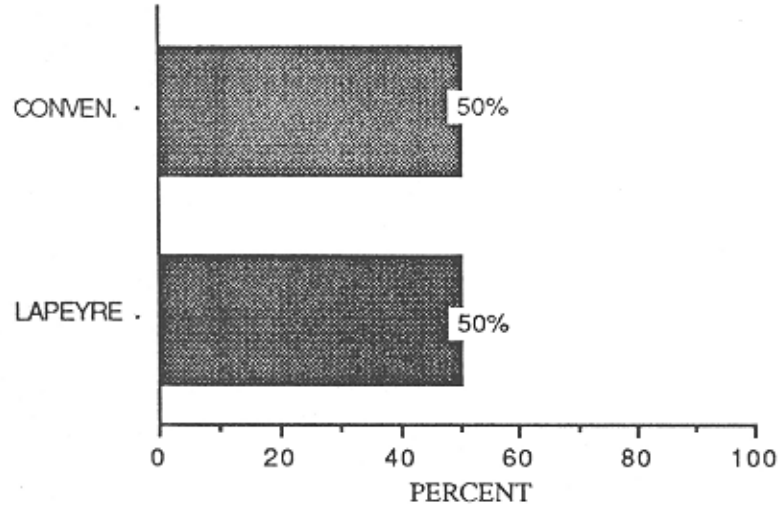
16. MORE SECURE FOOTING DURING ASCENT ON:



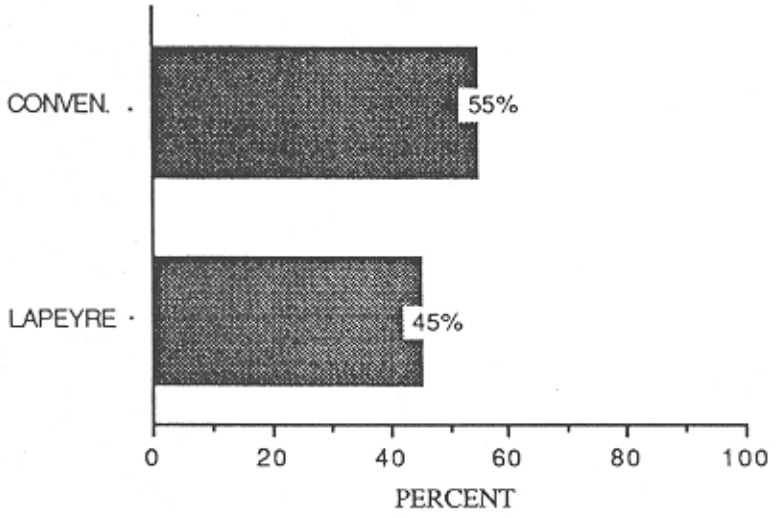
17. MORE SECURE FOOTING DURING DESCENT ON:



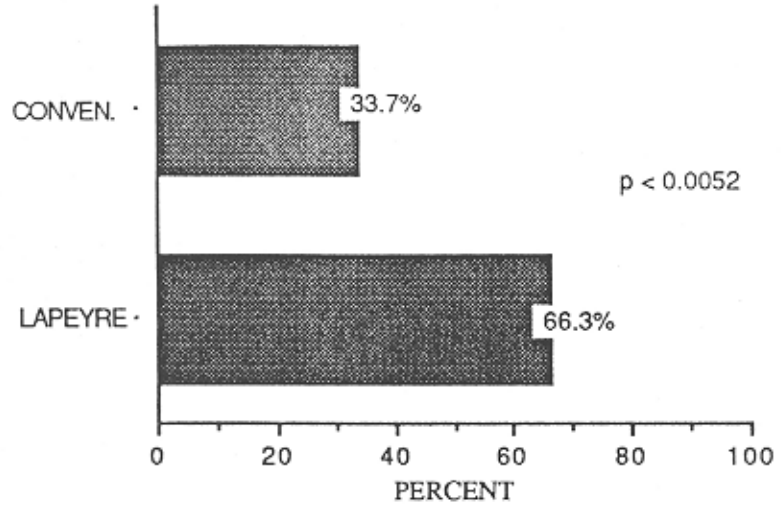
18. MORE IMPAIRED KNEE MOVEMENT DURING ASCENT ON:



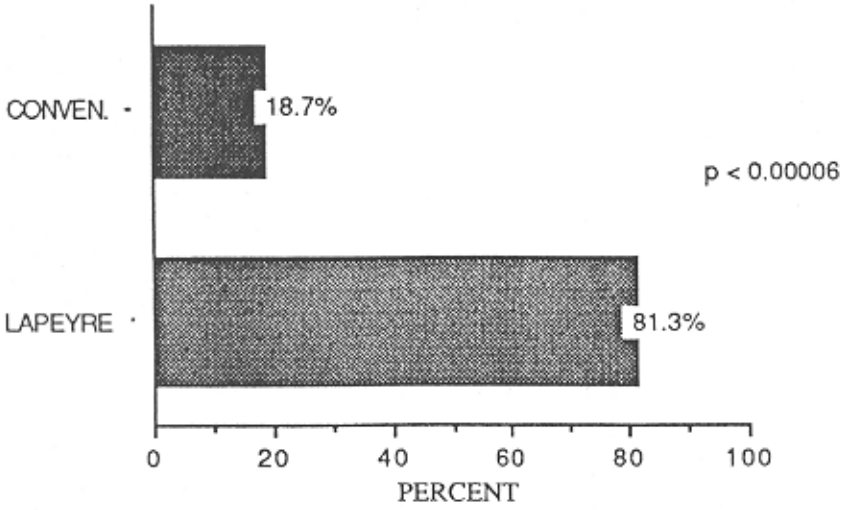
19. MORE IMPAIRED KNEE MOVEMENT DURING DESCENT ON:



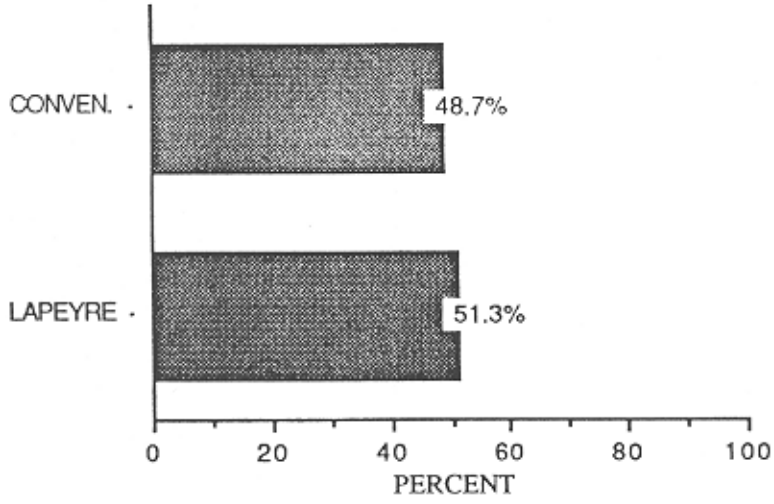
20. OVERALL, COULD MORE SAFELY ASCEND ON:



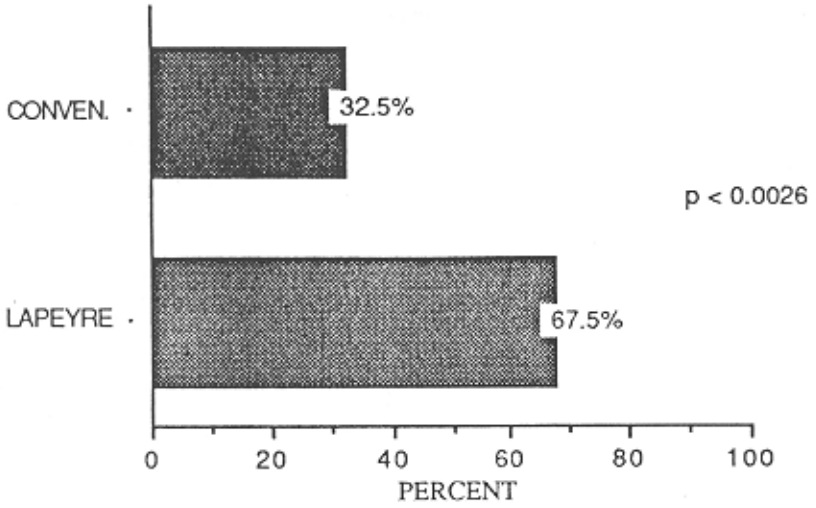
21. OVERALL, COULD MORE SAFELY DESCEND ON:



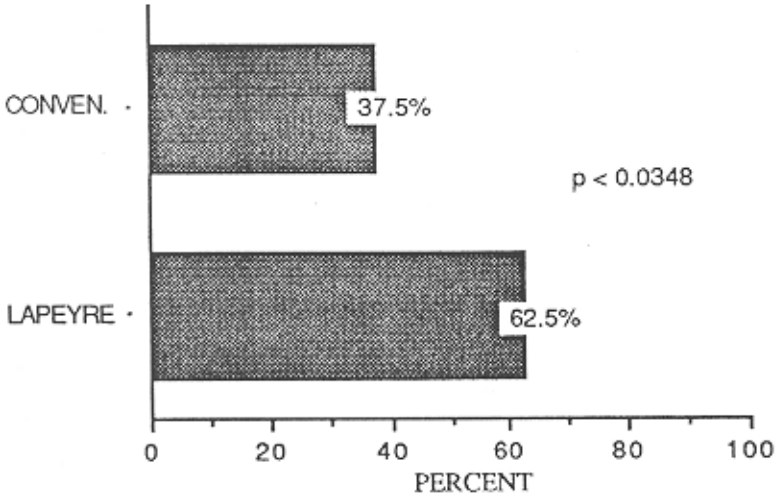
22. COULD MORE COMFORTABLY BEGIN ASCENT ON:



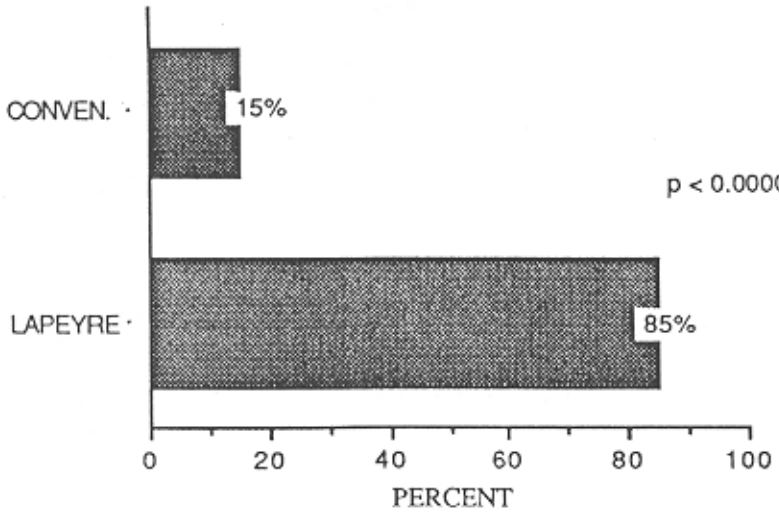
23. COULD MORE COMFORTABLY BEGIN DESCENT ON:



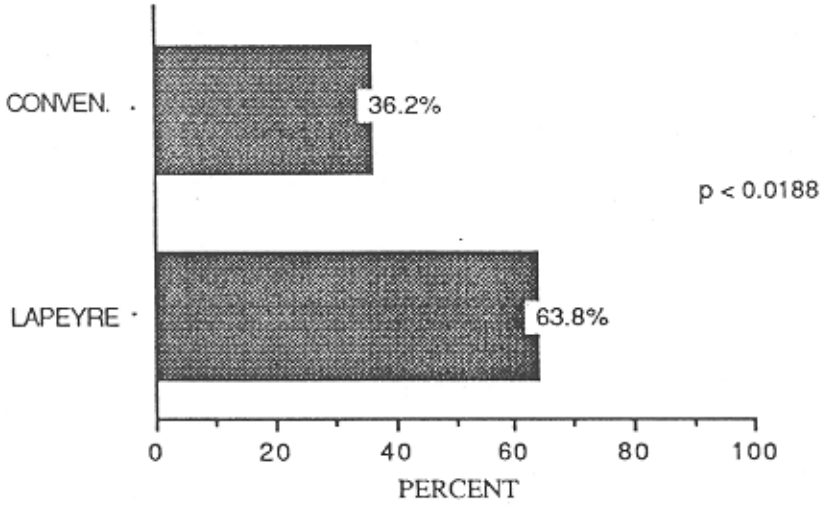
24. FOR ASCENT, STEEPNESS WAS MORE COMFORTABLE ON:



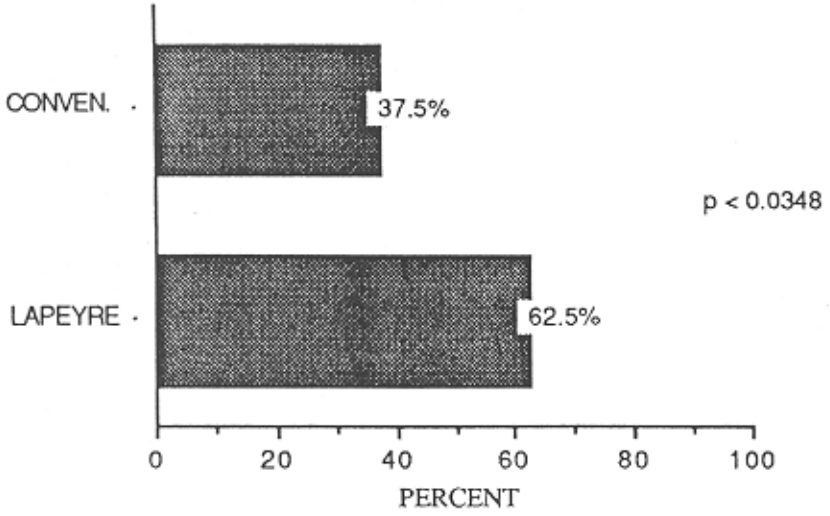
25. FOR DESCENT, STEEPNESS WAS MORE COMFORTABLE ON:



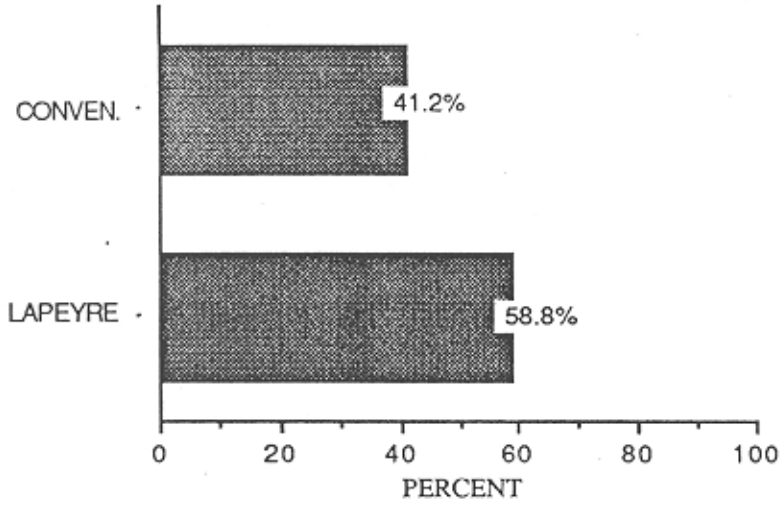
26. WIDTH OF THE STAIR WAS MORE COMFORTABLE ON THE:



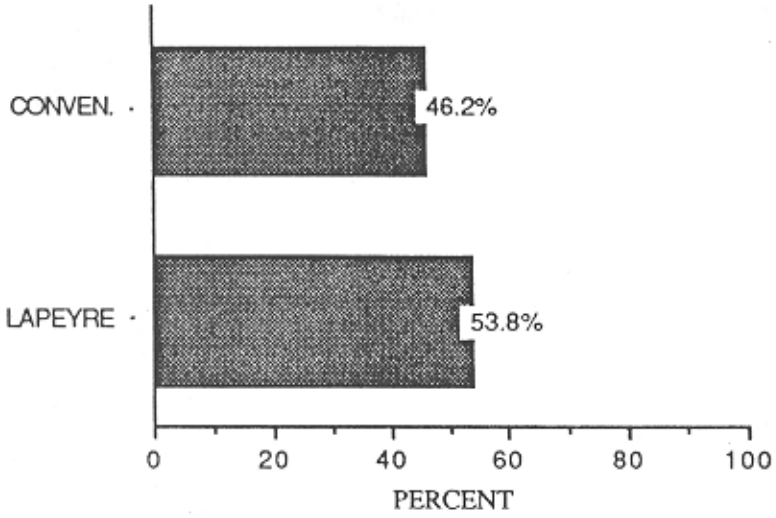
27. STEP WIDTH, DURING ASCENT, WAS MORE COMFORTABLE ON:



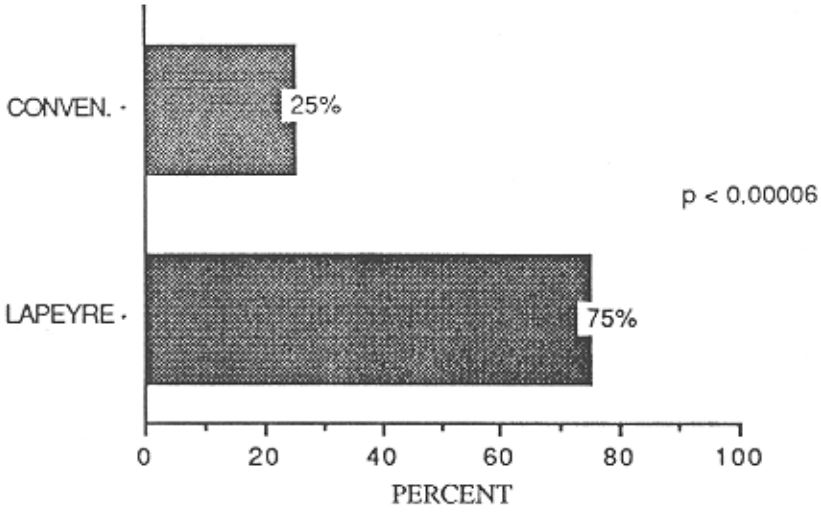
28. STEP WIDTH, DURING DESCENT, WAS MORE COMFORTABLE ON:



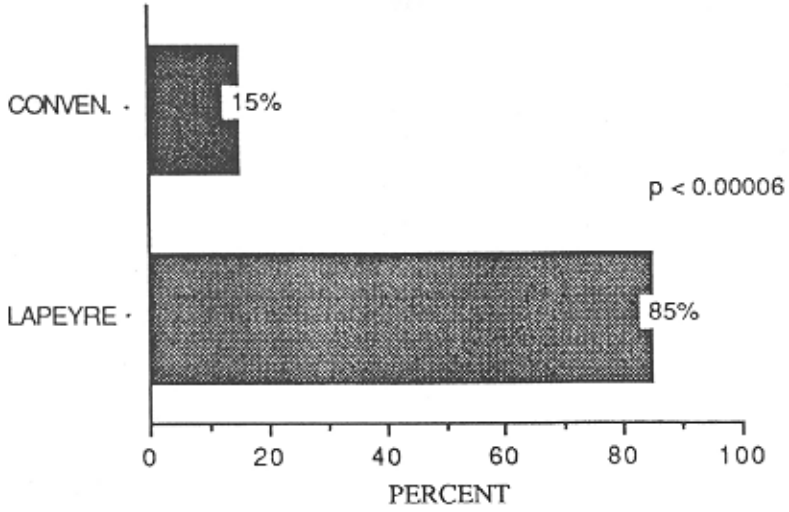
29. FOR ASCENT, CONSECUTIVE STEP DISTANCE WAS MORE COMFORTABLE ON:



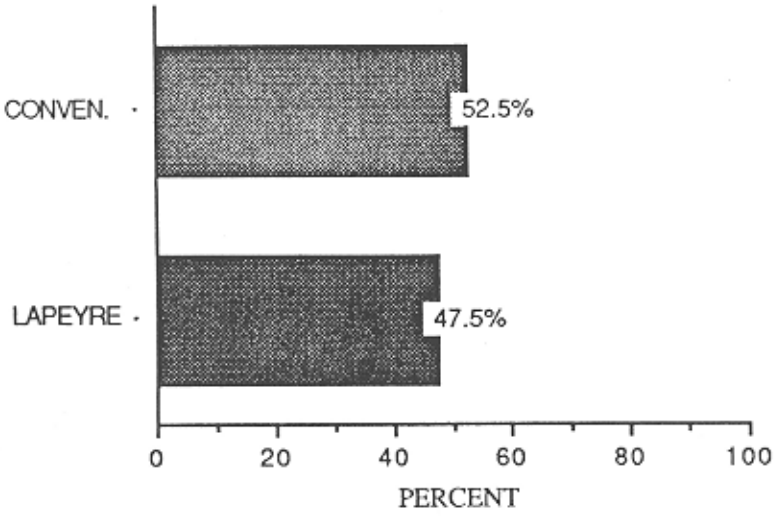
30. FOR DESCENT, CONSECUTIVE STEP DISTANCE WAS MORE COMFORTABLE ON:



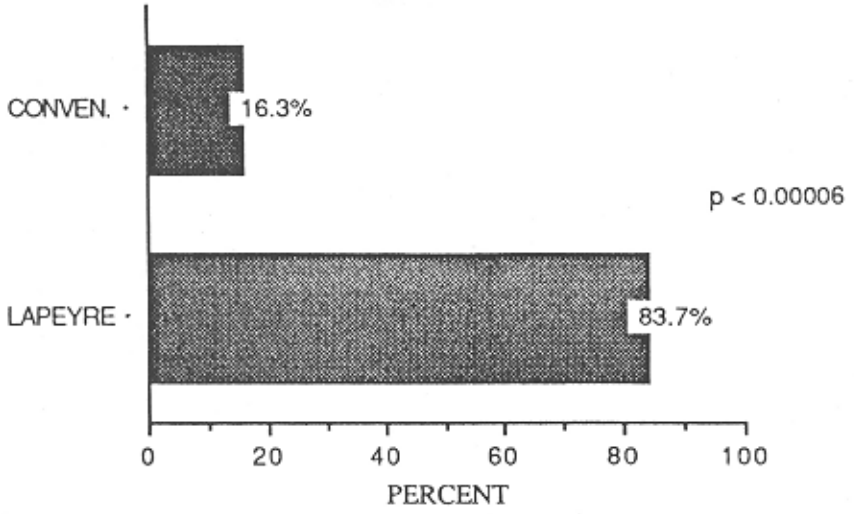
31. DEPTH OF STEPS MORE WAS COMFORTABLE ON:



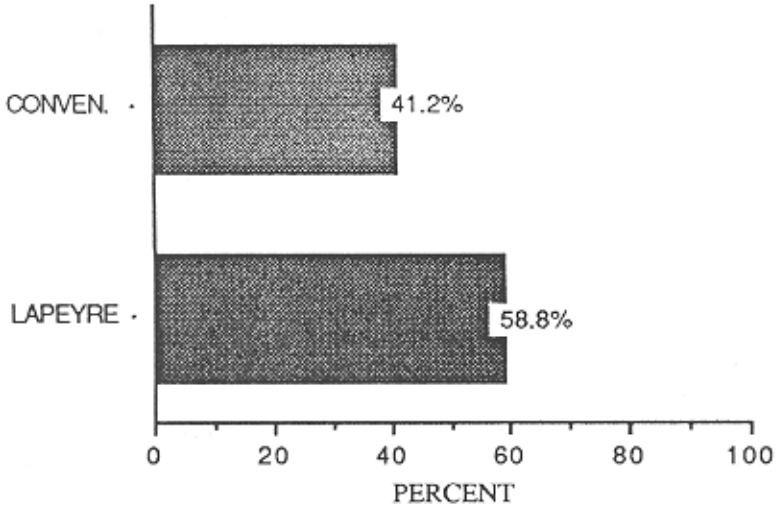
32. OVERALL, COULD ASCEND MORE COMFORTABLY ON:



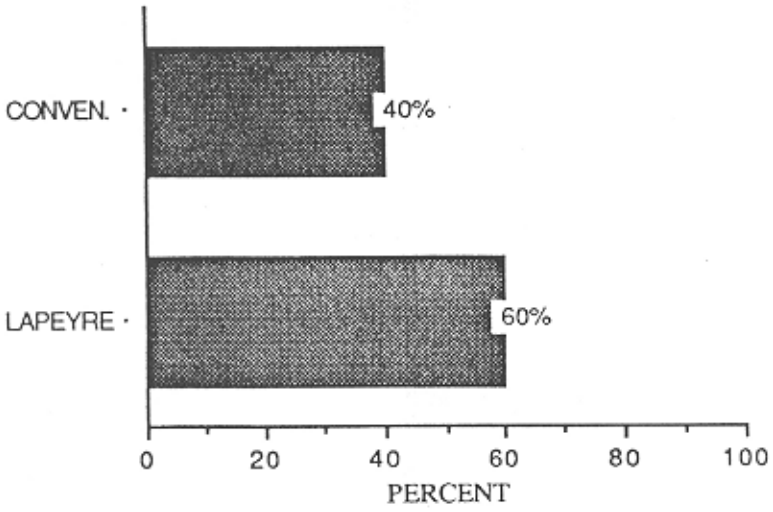
33. OVERALL, COULD DESCEND MORE COMFORTABLY ON:



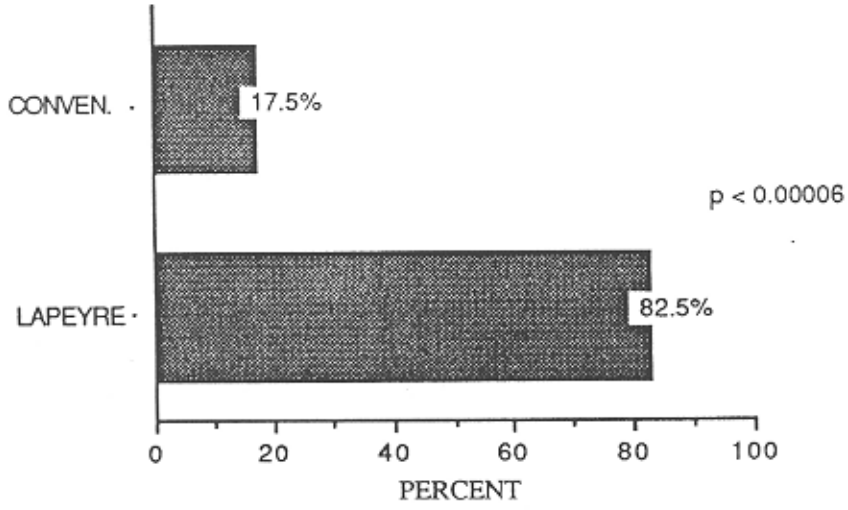
34. OVERALL, LOAD WAS EASIER TO CARRY ON:



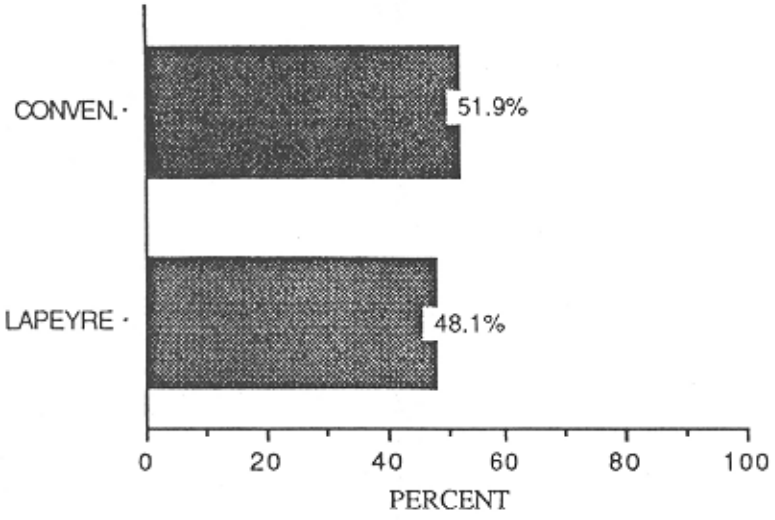
35. OVERALL, BETTER BALANCE FOR ASCENT ON:



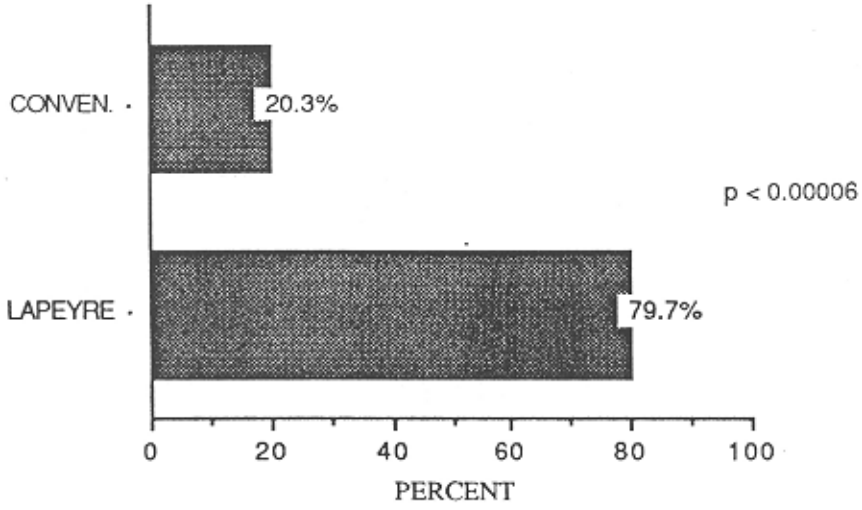
36. OVERALL, BETTER BALANCE FOR DESCENT ON:



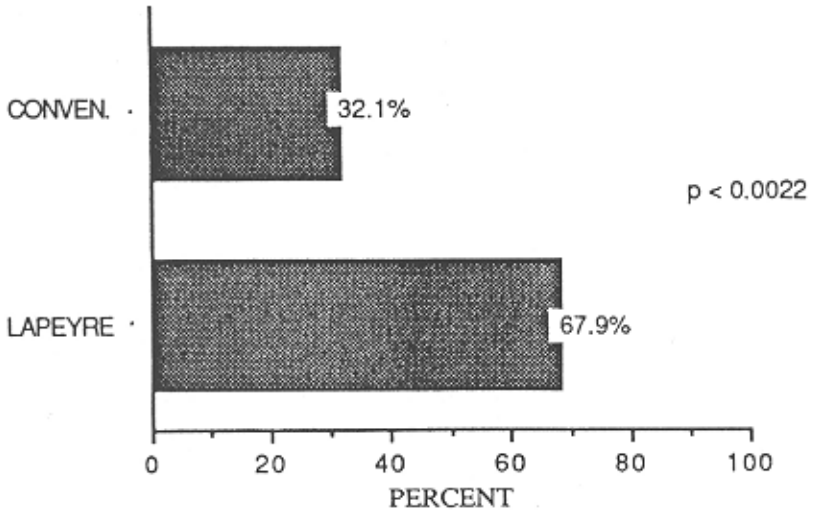
37. WHICH WOULD YOU SELECT FOR ASCENDING:



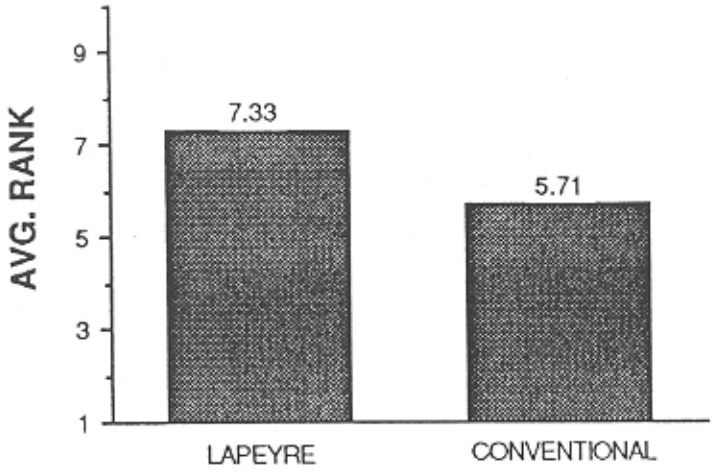
38. WHICH WOULD YOU SELECT FOR DESCENDING:



39. OVERALL, WHICH WOULD YOU SELECT:



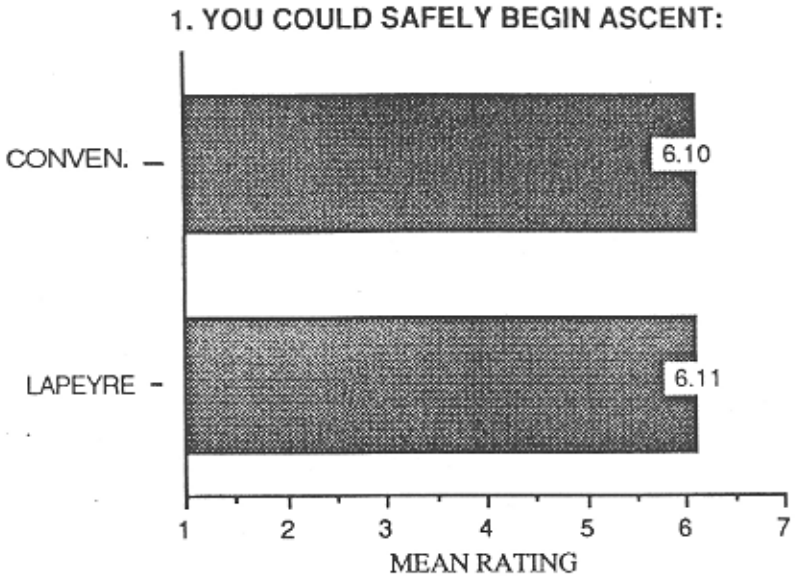
40-41. SCALE 1-10, HOW WOULD YOU RATE STAIRS:



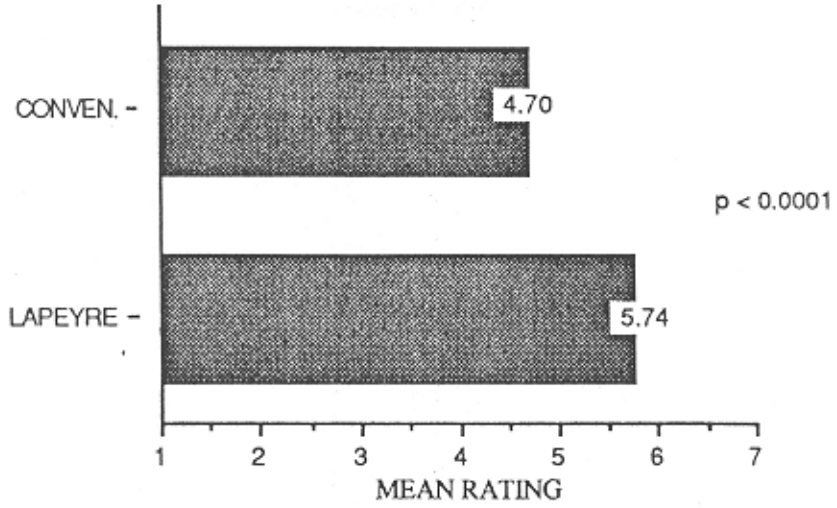
Appendix VI

Data From Absolute Rating Questionnaires (1 and 2)

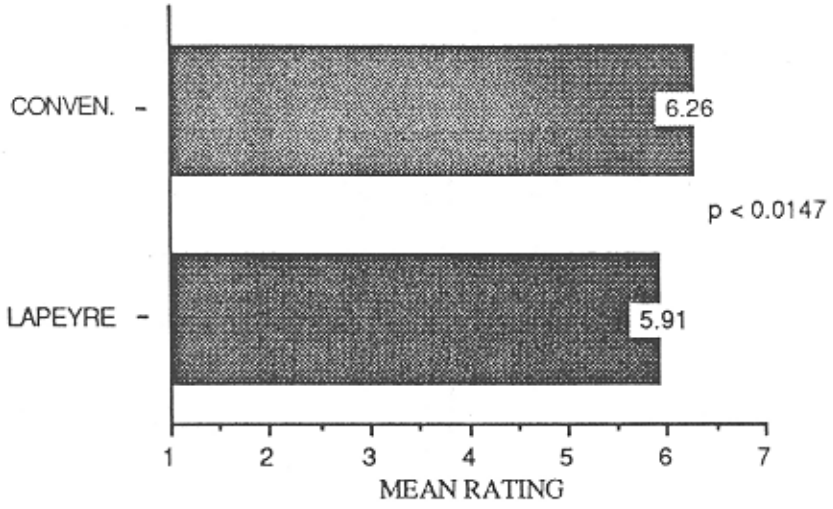
This appendix contains graphical representations of the results from the Absolute Rating Questionnaire. Graphs show the mean rating (n = 80) of each stair for each question. p values are given if means were statistically different from each other. Subjects rated the stairs on a scale of 1 to 7, with 1 representing "strongly disagree" and 7 representing "strongly agree". Indications are given in the graphs if 1 and 7 represented other answers like "too small" and "too large."



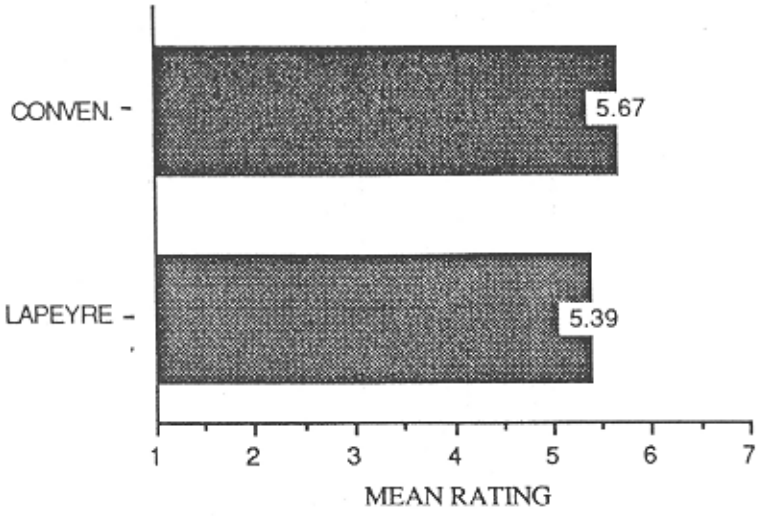
2. YOU COULD SAFELY BEGIN DESCENT:



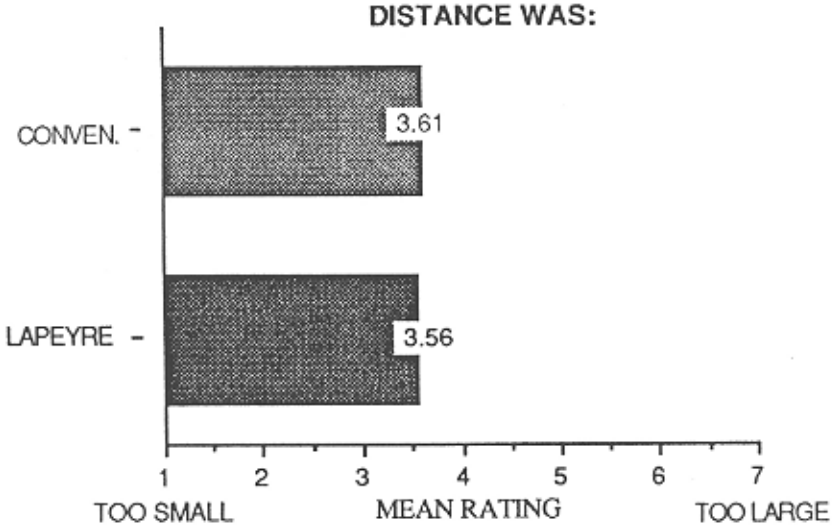
3. FOR ASCENT, STEP WIDTH WAS SAFE:



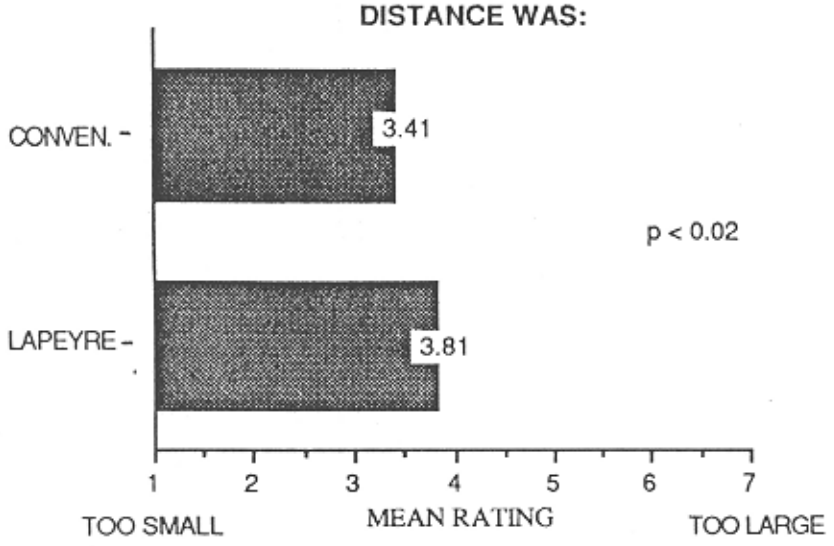
4. FOR DESCENT, STEP WIDTH WAS SAFE:



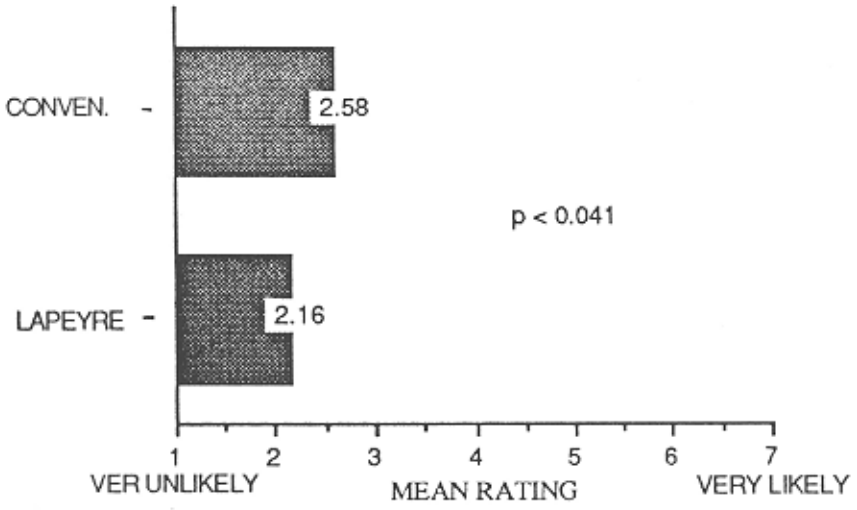
5. FOR SAFETY OF ASCENT, CONSECUTIVE STEP DISTANCE WAS:



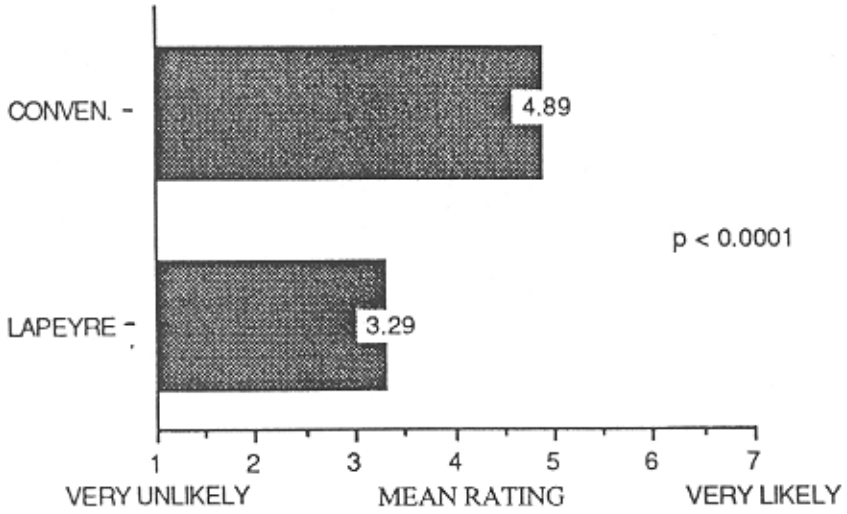
6. FOR SAFETY OF DESCENT, CONSECUTIVE STEP DISTANCE WAS:



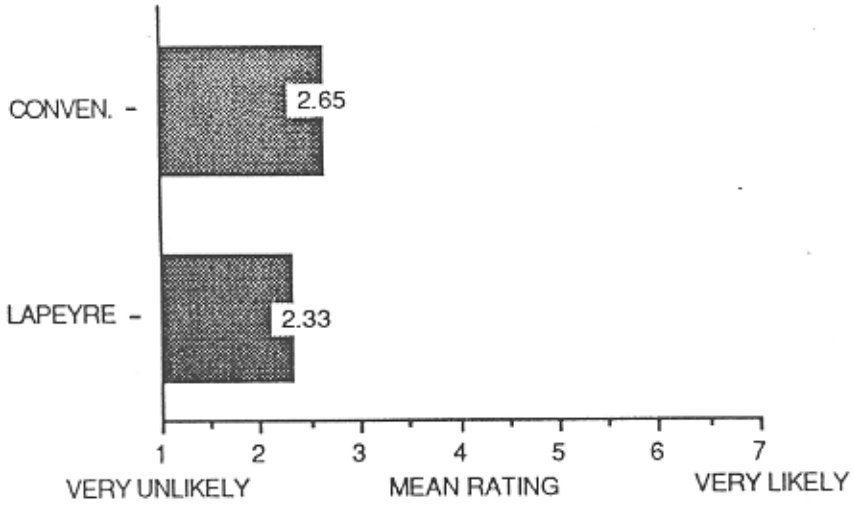
7. LIKELIHOOD OF SLIP/TWIST DURING ASCENT WAS:



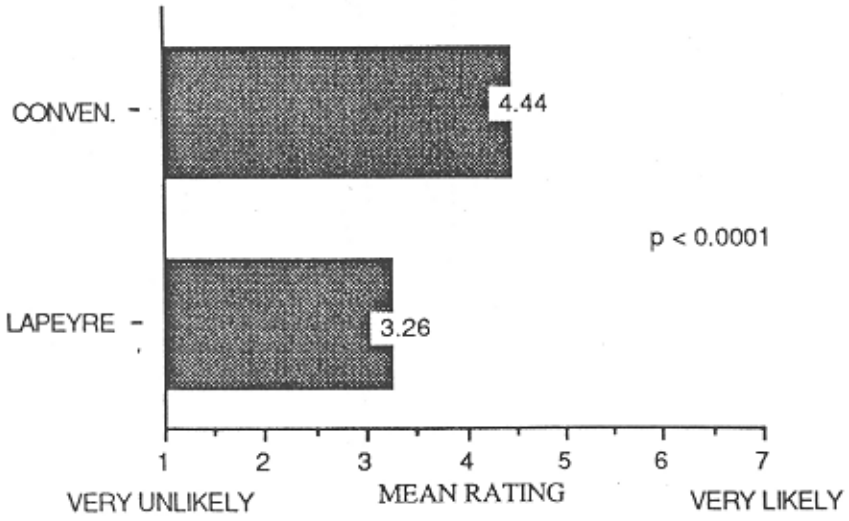
8. LIKELIHOOD OF SLIP/TWIST DURING DESCENT WAS:



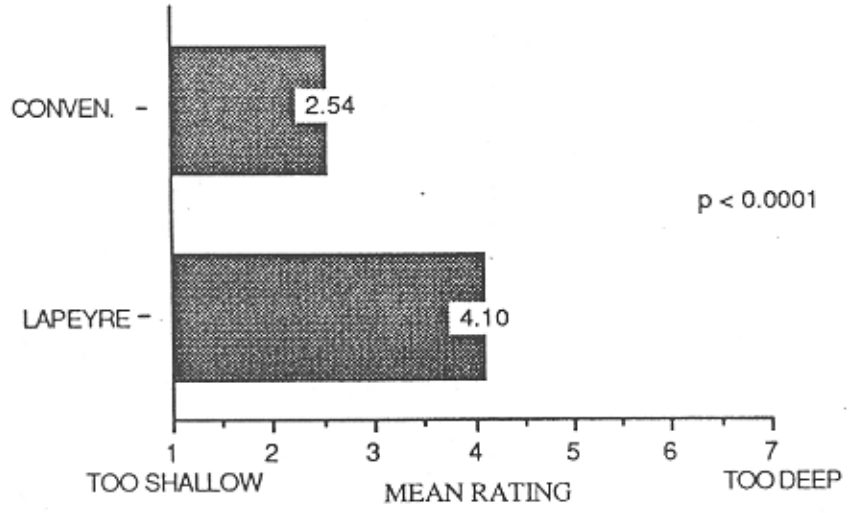
9. LIKELIHOOD OF TRIPPING DURING ASCENT WAS:



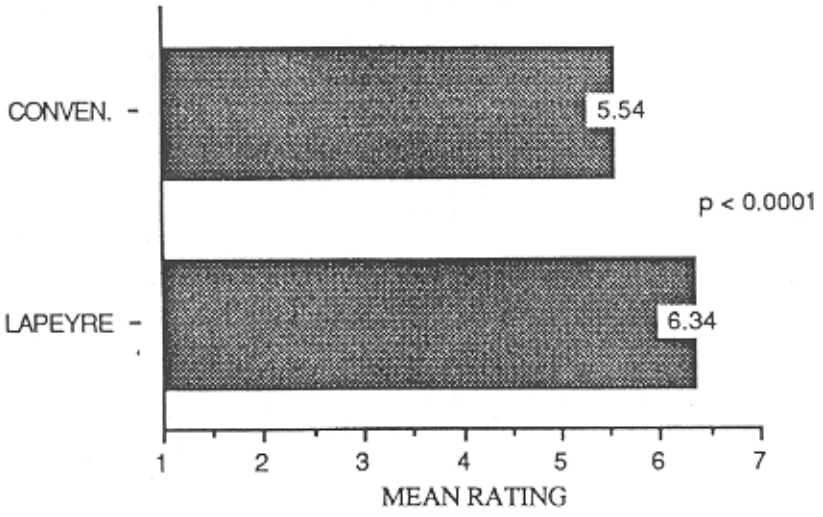
10. LIKELIHOOD OF TRIPPING DURING DESCENT WAS:



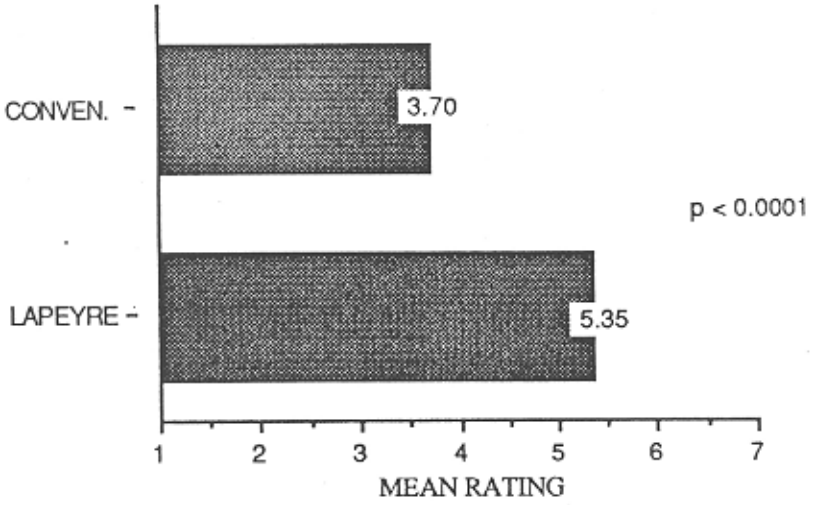
11. DEPTH OF EACH STEP WAS:



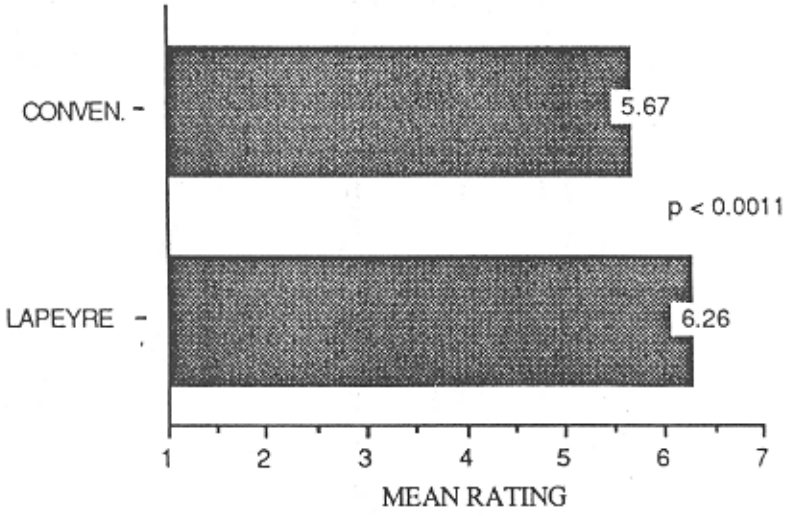
12. DURING ASCENT, STEPS SUPPORTED FOOT ADEQUATELY:



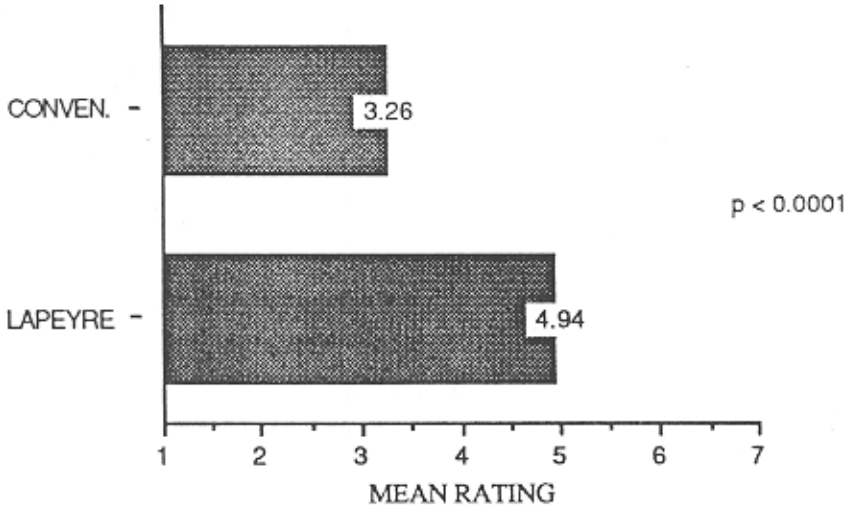
13. DURING DESCENT, STEPS SUPPORT FOOT ADEQUATELY:



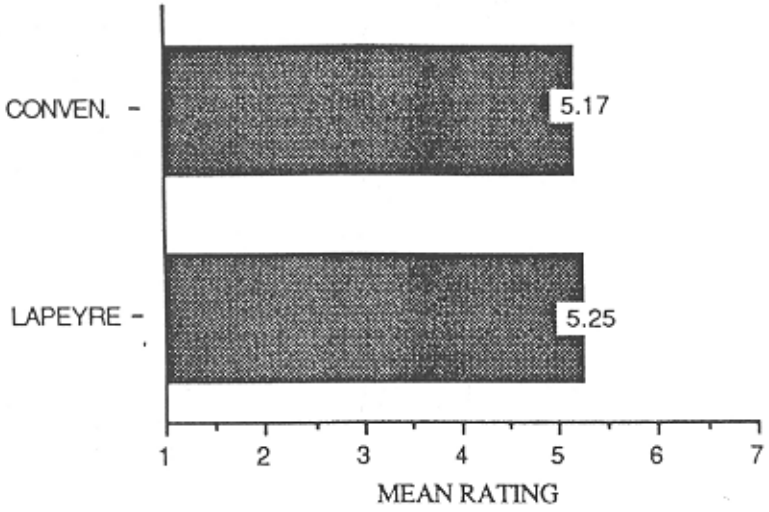
14. DURING ASCENT YOU HAD SECURE FOOTING:



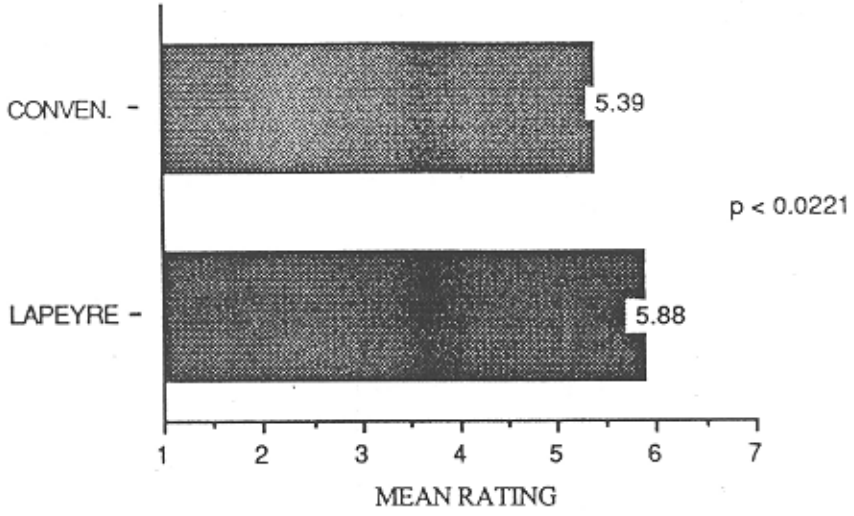
15. DURING DESCENT YOU HAD SECURE FOOTING:



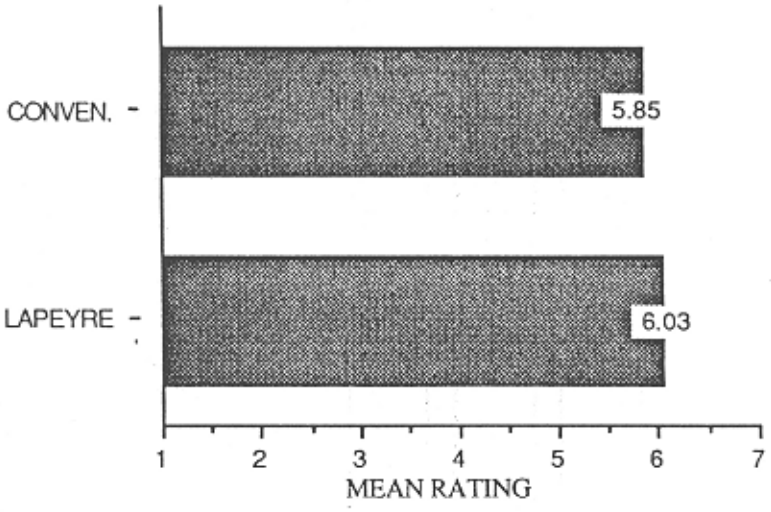
16. KNEE MOVEMENT WAS NOT IMPAIRED DURING ASCENT:



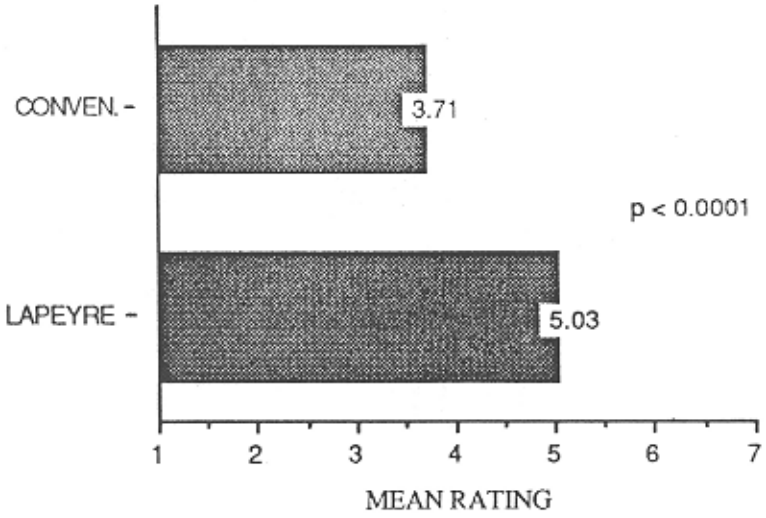
17. KNEE MOVEMENT WAS NOT IMPAIRED DURING DESCENT:



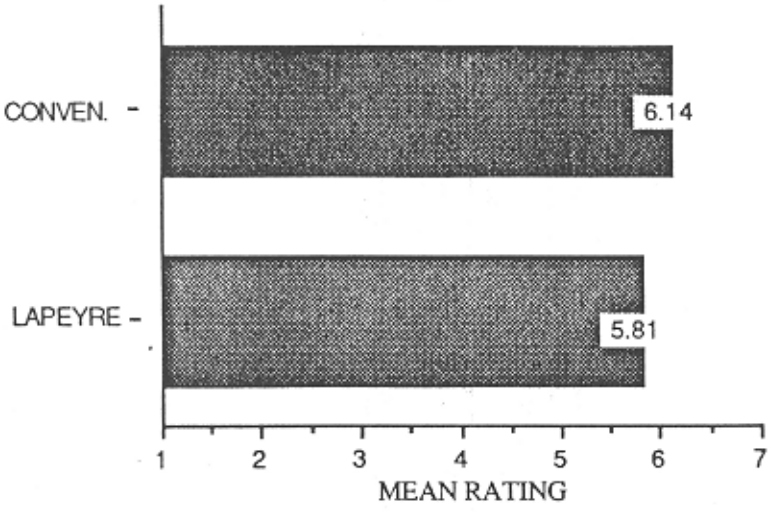
18. OVERALL, YOU COULD SAFELY ASCEND STAIR:



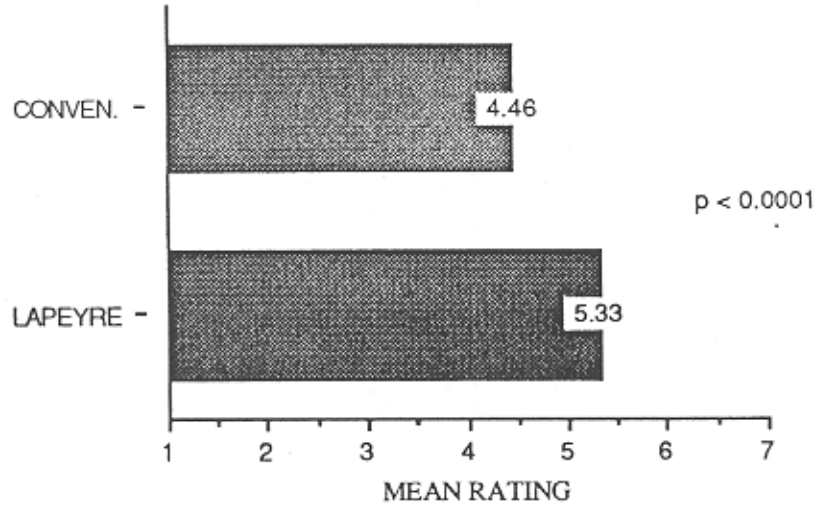
19. OVERALL, YOU COULD SAFELY DESCEND STAIR:



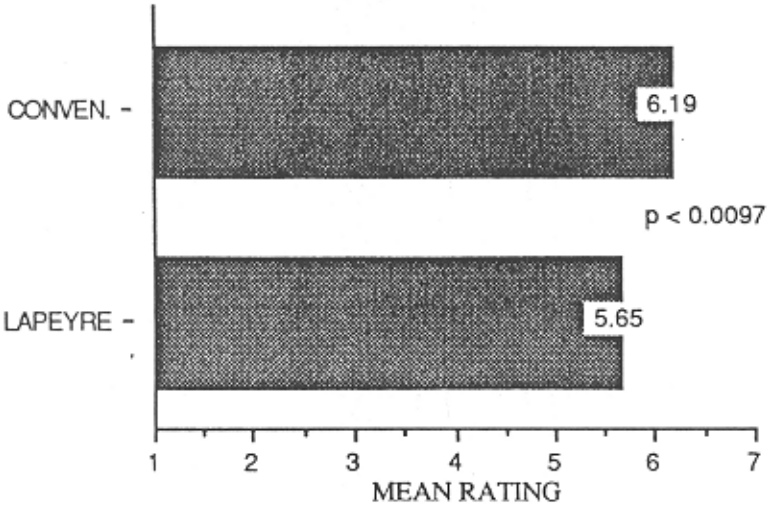
20. YOU COULD COMFORTABLY BEGIN ASCENT:



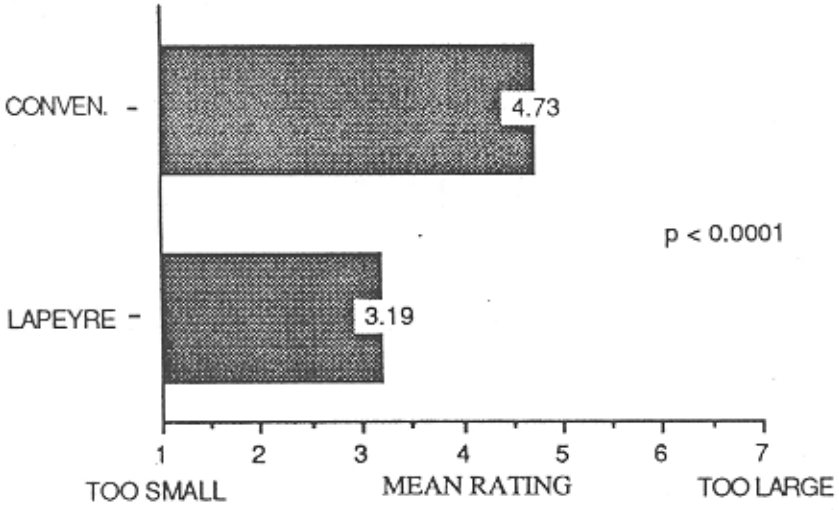
21. YOU COULD COMFORTABLY BEGIN DESCENT:



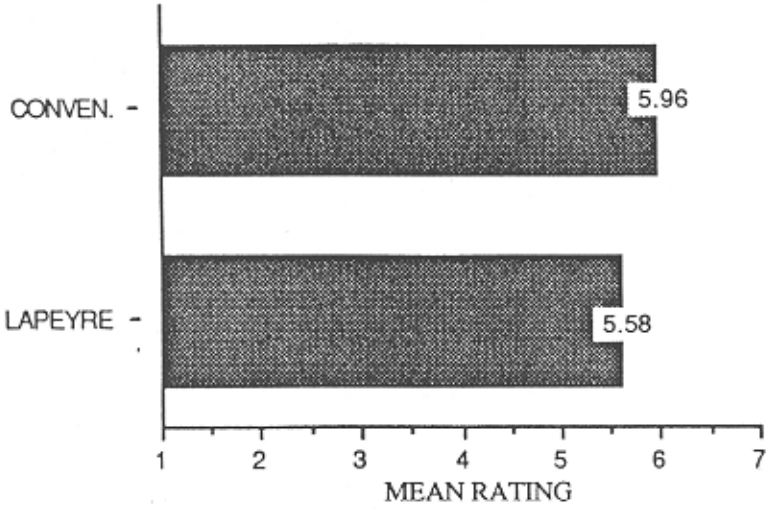
22. STEP WIDTH WAS COMFORTABLE FOR ASCENT:



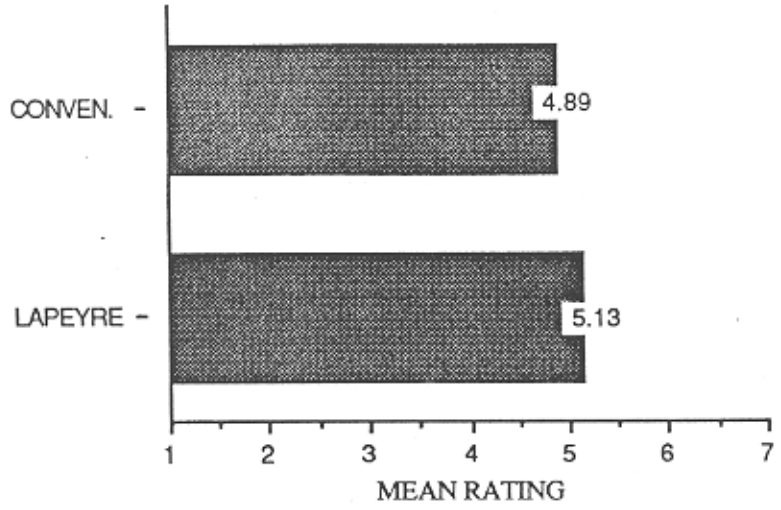
23. FOR COMFORT, THE WIDTH OF THE STAIR WAS:



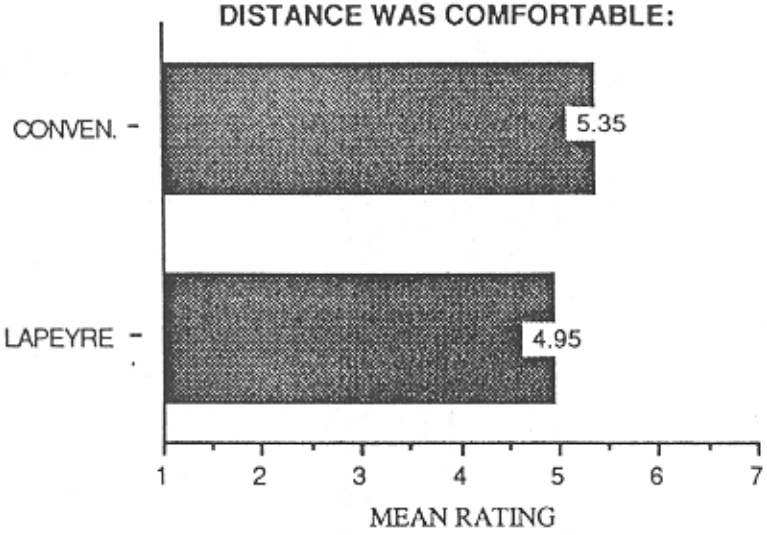
24. STEP WIDTH WAS COMFORTABLE FOR ASCENT:



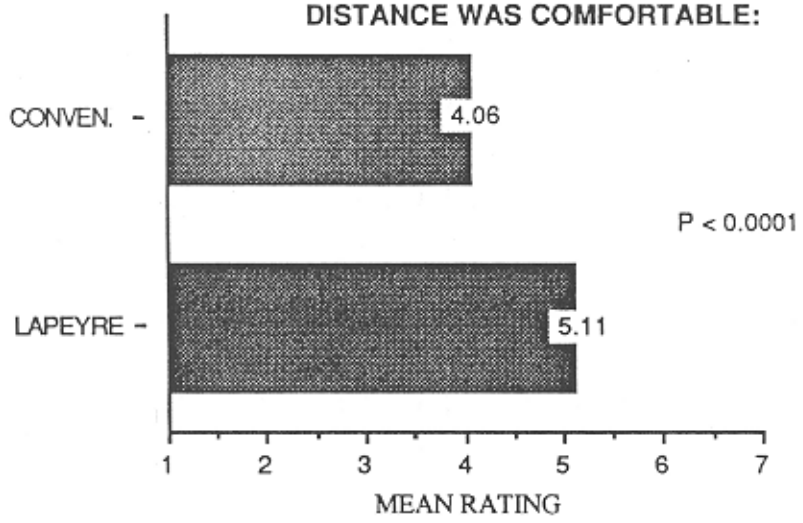
25. STEP WIDTH WAS COMFORTABLE FOR DESCENT:



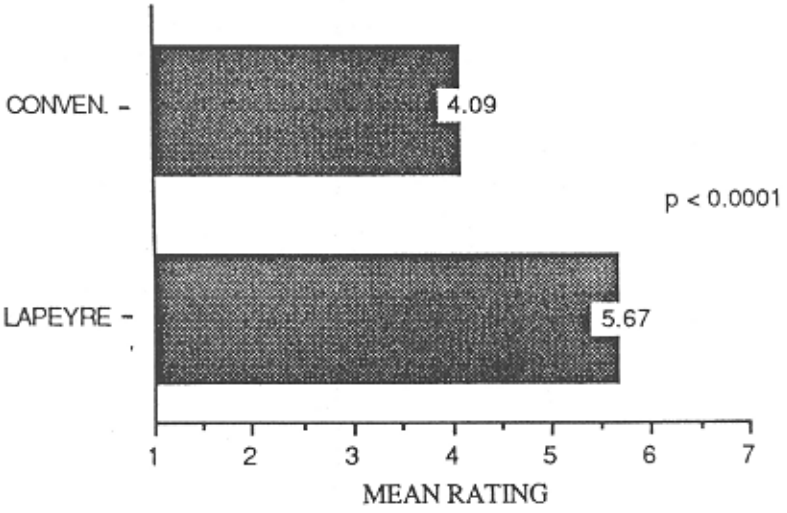
26. FOR ASCENT, CONSECUTIVE STEP DISTANCE WAS COMFORTABLE:



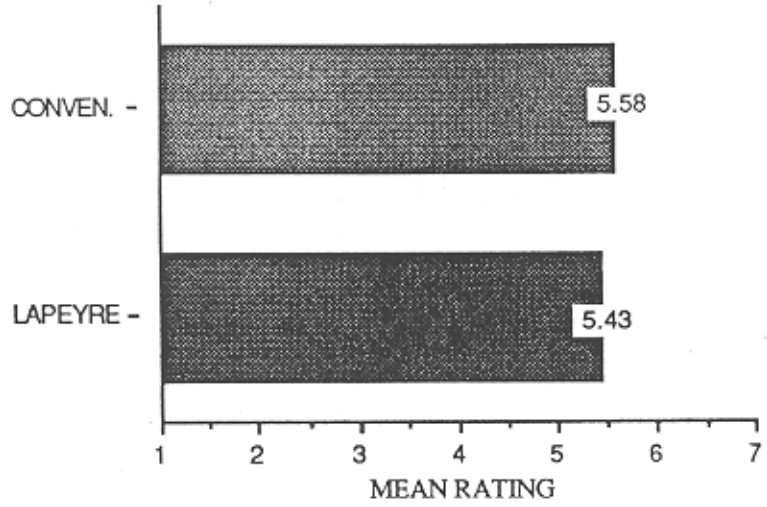
27. FOR DESCENT, CONSECUTIVE STEP DISTANCE WAS COMFORTABLE:



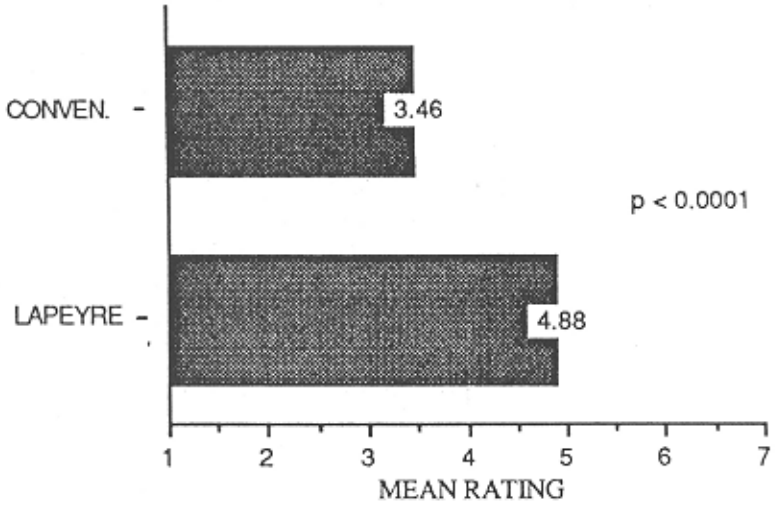
28. THE DEPTH OF THE STEPS WAS COMFORTABLE:



29. OVERALL, YOU COULD COMFORTABLY ASCEND:



30. OVERALL, YOU COULD COMFORTABLY DESCEND:



Appendix VII

Graphs for Misstep Data

This appendix presents graphical illustrations of the points made in the "Misstpes" portion of the "Results" section.

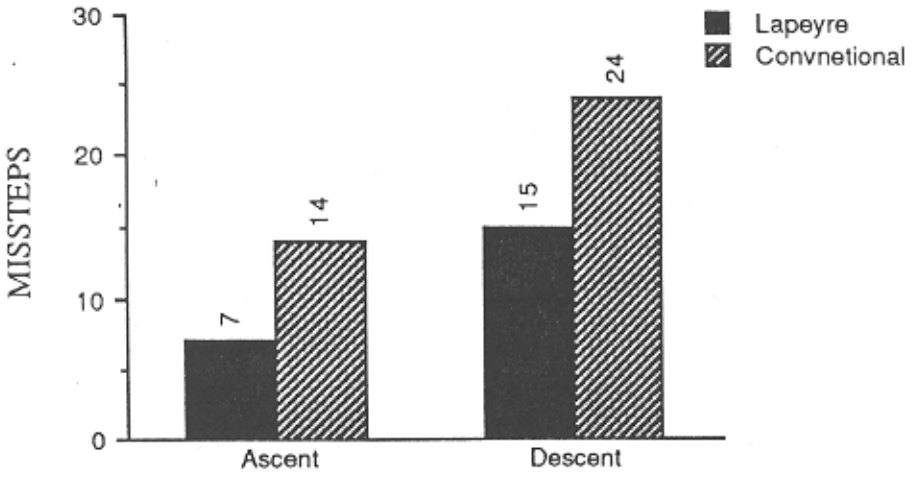


Figure A. The Stair-by-Direction interaction.

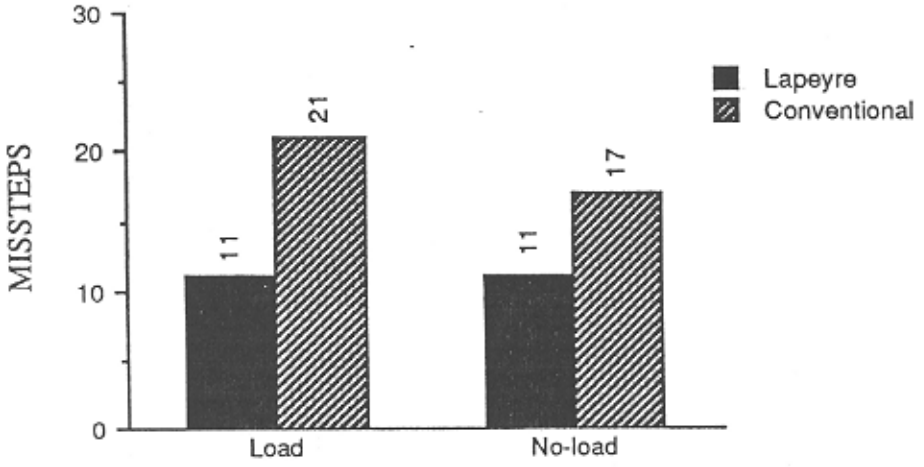


Figure B. The Stair-by-Load interaction.

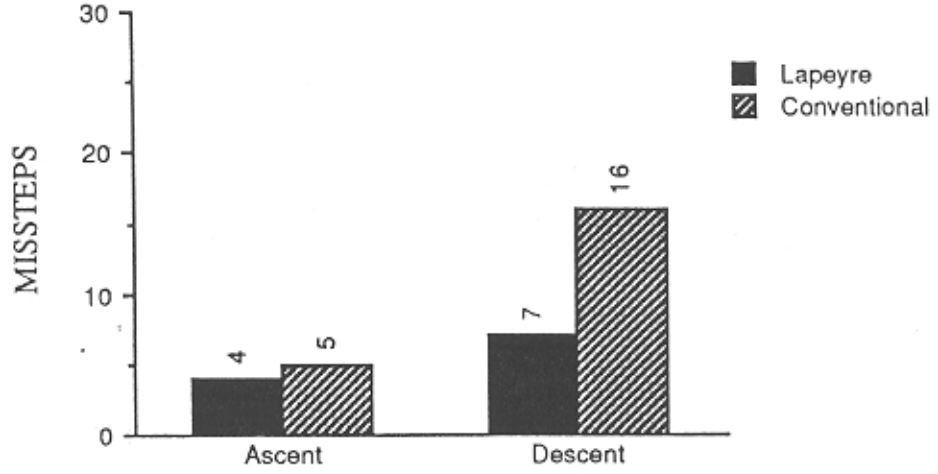


Figure C. The Stair-by-Direction interaction for **only** the No-load condition.

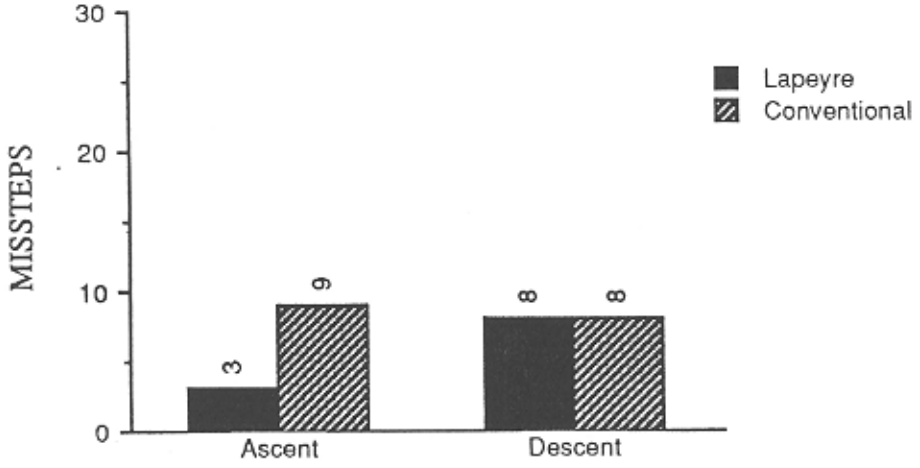


Figure D. The Stair-by-Direction interaction for **only** the Load condition.

Appendix VIII

Tally of Subjects' Comments

Upon finishing the Comparison Questionnaire, participants made comments on both the BLUE and YELLOW stair with respect to all the stair-load conditions and any other comments they had regarding the study. The responses given for each question are tallied and presented below. Similar responses were grouped together.

COMMENTS MADE BY SUBJECTS

Please use this sheet for making any comments with regard to the listed items.

Question and Comments	# of responses if not 1
1. Ascending the BLUE (alternating tread stair) without a load.	
- was easy	16
- steps too close together (vertical)	15
- very comfortable	9
- rails were too narrow	4
- awkward to start with a certain foot	4
- footing was deep but not wide enough	3
- safer	3
- awkward	3
- secure feeling	2
- stair was too narrow	2
- tricky in the beginning, later comfortable	2
- knees kept hitting step above	2
- tend to pick up a rocking motion due to alternating steps	2
- steps felt tilted slightly down	2
- quick	2
- very uncomfortable	
- more comfortable than yellow	
- uncomfortable but safer	

- restricted movement
- not as easy as yellow
- felt weird, not used to it
- quicker than yellow
- well supported
- distance between the steps was just right
- not used to it-biased somewhat since never used before
- stair was arranged unnatural- all stairs that I have climbed were like yellow
- easier than with load
- easier to raise/ lower foot to next step
- knew where steps were
- required less effort than yellow
- like those close handrails
- slow because distance between the steps on each side was a bit high and the divider made my normal step width a bit too large
- confined, cramped
- natural feeling
- no problem
- felt like running up a flight of stairs
- tedious
- middle bar separated legs unnaturally
- more depth to place foot
- perfect
- liked hand rail supports being flat and inside
- could hold on to hand rail
- had to look at steps
- almost like walking due to the placement of the steps
- interesting but turning around is hindered by step width

2. Ascending the YELLOW (conventional ship's ladder) without a load.

- easy	12
- comfortable	11
- steps too close together	8

- shallow depth	8
- felt normal, am used to it	6
- faster than blue	6
- easier to slip on	4
- restricted knee movement	4
- great width between hand rails	4
- too steep	3
- not as secure as blue	3
- was able to half step with feet and half pull with hands	2
- normal initial foot placement	2
- width too small of steps	2
- safe	2
- okay	2
- steps at comfortable distance	2
- used to it	2
- more comfortable but dangerous	2
- perfect	
- less comfortable than blue	
- steps too far apart	
- good width of steps	
- no restricted foot placement	
- like walking the stairs at home, comfortable	
- confident feeling	
- easy slippage if in swag situation on a ship	
- can climb two people at one time	
- hand rail too low	
- hand rails too wide	

3. Descending the BLUE (alternating tread stair) without a load.

- very comfortable	10
- very safe	9
- great safe rail support, helped in placement foot	7

- better footing	7
- easy	6
- more comfortable than yellow	5
- slow because of small distance between hand rails	3
- safer but uncomfortable	3
- easier and safer than yellow	3
- distance between steps too small	3
- perfect	2
- very uncomfortable	2
- had to think more about what you are doing, unfamiliarity	2
- distance between steps too far apart	2
- start a little tricky but very comfortable after a while	2
- uncomfortable with hand rails	
- good as long as you use hand rail	
- prefer continuous step-width	
- distance between steps seemed greater than yellow	
- step width too small	
- slipped more because of wear on the edge rounding it off	
- not used to it	
- descending forward was a bit unsafe	
- good secure pace	
- fast but not to safe	
- less steep	
- unnatural because of start with specific foot	
- effortless	
- tendency to catch heel on last step	
- awkward	

4. Descending the Yellow (conventional ship's ladder).

- too small depth width	22
- hits heels and back of leg, scraping with steps	16
- uncomfortable	9

- easy to slip of, fall down 9
- too steep 8

- difficult, impossible without hand rail 6
- steps too close 5
- unsafe 5
- had to turn feet sideways to get secure footing 4
- awkward 4
- too wide between hand rails 4
- was more natural, put weight body on hand rail went faster 3
- dangerous 3
- faster, more comfortable but more dangerous 2

- very fast because of distance between steps and hand rail 2
- steeper than blue
- tripped more than on BLUE
- bad foothold
- did not like it at all
- rails wobbled
- rely mostly on arms to slide down
- terrible, hard to descent
- needs to have hatch above it to swing down on
- too cramped and confined
- would get out of control
- easier than on blue
- comfortable
- better due to freedom of foot placement
- safe
- okay

5. Ascending the BLUE (alternating tread stair) with a load

- could easily put load outside of hand rail 13
- easier than on yellow 9
- rough, carried box outside hand rail 8

- too narrow	7
- easy, inward railing was great	4
- comfortable	3
- step placement was very comfortable	3
- hand rail got in the way	3
- better foot support than yellow, relied less on railing	2
- safer than yellow	2
- safe, secure footing but slow	2
- very hard	2
- awkward	2
- uncomfortable	2
- more difficult than on yellow	2
- impaired knee movement	2
- very well supported	
- strange until I got used to it	
- less steep	
- save but uncomfortable	
- height of the railing was good, did not have to hang down	
- impractical	

6. Ascending the YELLOW (conventional ship's ladder) with a load.

- easy	11
- carried load inside, bad knee movement, bump into steps	11
- moved to one side to put box outside rail, other rail out reach	6
- more comfortable than blue	5
- like distance between rails	5
- tiring, walked at angle	4
- less comfortable than blue	4
- no problem	3

- less safe	3
- less foot support	3
- harder than blue	2
- fair	2
- steps too close together	2
- steps too far apart	2
- okay	2

- difficult due to rail
- steps too shallow
- steps too wide
- pain

7. Descending the BLUE (alternating tread stair) with a load.

- easier than yellow	10
- one arm outside rail, box, helped balance, good railing	9
- safe	7
- comfortable	6
- more secure footing	4
- dangerous, hand rail too close, got in the way	4
- slightly difficult	4
- easy	3
- uncomfortable	3
- unsafe	2
- no free knee movement	2
- did not like load outside railing	2
- less steep	
- get rocking movement	
- lousy	
- little slippage	
- impractical	
- okay	
- perfect	

8. Descending the YELLOW (conventional ship's ladder) without a load.

- easy to slip	9
- dangerous	8
- shallow depth steps, less foot support	7
- very insecure, very scary	7
- difficult	6
- steps too close	5
- hurt ankles	5
- awkward	3

- okay 3
- easy, easier 3

- less comfortable than blue 3
- unsafe 2
- continuous fear of falling 2
- steps too narrow 2
- railing too far apart 2
- too steep

- horrible
- hazardous
- most difficult of all, very unsafe
- load carried outside railing, better balance
- load closer to body, therefore better balance
- prefer not to do it because of safety reason
- quick

9. Any other comments.

- blue definitely better and safer overall 11
- yellow easier up, blue easier down 4
- yellow fastest, blue safer especially descending 2
- blue hand rail needs to be wider 2
- blue superior in all except in initial start of ascend, descend 2

- pick blue
- preferred the blue
- wished had used blue more often
- yellow excellent ascend, blue excellent descend
- yellow faster, blue more convenient
- go blue, put grip tape on steps
- blue best except for hitting knees on ascend
- like blue design

- even partial to yellow, blue I liked better
- awkward at beginning but great at the end, blue of course
- step start bad for blue
- blue for depth steps, yellow for width
- strange feeling due to unfamiliarity stair
- do not like middle bar in blue
- blue too narrow
- blue handrail too close, yellow steps too shallow
- both better if greater distance between steps
- railing hatches need to be evaluated, hurt legs
- yellow hurts heels
- yellow should be narrower
- yellow seemed steeper
- hand rails yellow need to be higher
- yellow more slippery
- yellow similar to Navy ships ladder, I am used to those
- yellow safer and more comfortable