Figure 3.7: Scatter Plots of Lift Forces for Ramp Service

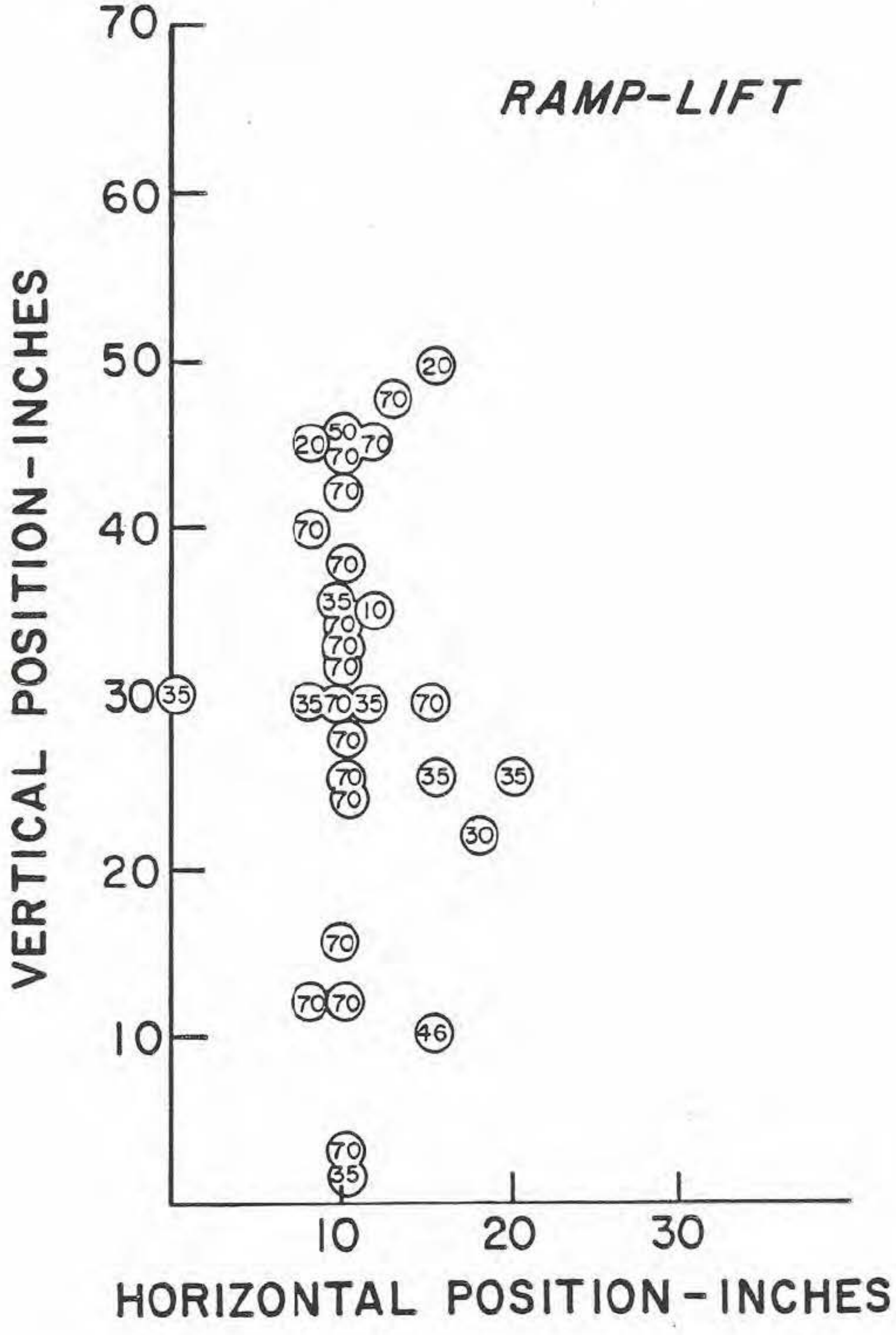
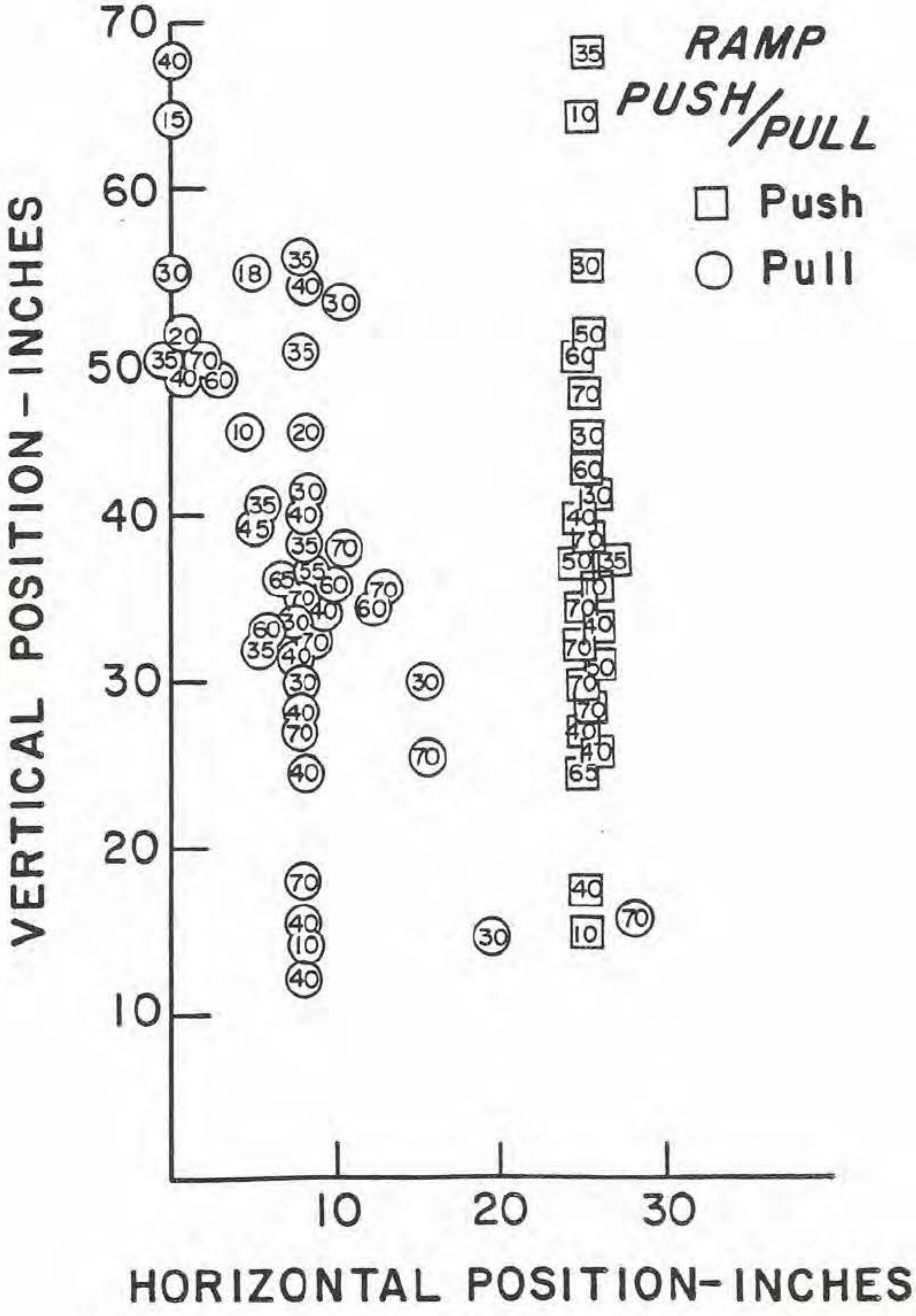


Figure 3.8: Scatter Plot of Push/Pull Forces for Ramp Service



E. Incumbent Strength Test Results

A total of 285 employees at the Denver facility volunteered for the incumbent strength testing program. Each employee was tested during his normal shift according to the protocol and procedures discussed in Appendix B. All pertinent data were reported on the form shown in Figure 3.9. A signed informed consent form (Figure 3.10) was forwarded to the University of Michigan and the medical incidents relating to strength tested employees were monitored and recorded for contact, musculoskeletal and back injuries for a period of 3 years (1978-1980).

Descriptive statistics (means, ranges, and standard deviations) were computed for anthropologic measures of age, height and body weight for the strength tested employees as presented in Table 3.4. It is apparent from this table that the volunteers were very representative of the U.S. population with the possible exception of body weight. The UAL male volunteers were considerably heavier than their industrial counterparts. Females on the other hand were significantly lighter. It is unclear whether this is a reflection of differences between industries (UAL versus other industry) or if the sample is representative of the UAL population.

Figure 3.9: Strength Data Collection Form

PLEASE FILL IN THIS SIDE

No. ______________________
Test Date ______________________
Address Code ______________________
Job Title ______________________

Time in present job ______________________
If less than 2 years, previous job ______________________
____

HISTORY

Name ______________________
Age __________
Sex __________
Ht. __________
Wt. __________

Circle present activities:

Jog Swim Bicycle Calisthentics Other ______________________

Times per week __________ How long each time ______________________

Do you smoke? __________ Average daily amount ______ How many years? ______

List any physical restrictions ______________________

Circle any medical problems as listed below:

Back Joints Hands Feet Mescles Allergies Heart Lungs

Gastrointestinal Urinary Nervous Glandular Blood Pressure

Diabetes Psychiatric Surgery Other ______________________

____

____

____

____

TO BE COMPLETED BY UNIVERSITY OF MICHIGAN

INJURIES (past 2 years)

DATE	JOB CODE	BODY PART	DX	DAYS RESTRICTED	DAYS OFF WORK

MEASUREMENTS:

Mid Upper Arm ________
Chest (axilla) Insp. ______ Exp. ______
Umb. Exp. ______
Mid Thigh ______

STRENGTH TEST RESULTS

TESTS		Trial 1 M	Trial 1 A	Trial 2 M	Trial 2 A	Trial 3 M	Trial 3 A	Trial 4 M	Trial 4 A	Trial 5 M	Trial 5 A
Hi Pull	U										
	M										
Hi Push	M										
Lo Pull	U										
	M										
Hi Lift	U										
	M										
Mid Lift	U										
	M										
Lo Lift	U										
	M										

Figure 3.10: Subject Informed Consent

The University of Michigan

COLLEGE OF ENGINEERING • DEPARTMENT OF INDUSTRIAL & OPERATIONS ENGINEERING
2260 G. G. BROWN LABORATORY ANN ARBOR, MICHIGAN 48109

Human Performance and Safety Laboratory

STRENGTH MEASUREMENT STUDY

EMPLOYEE INFORMATION AND CONSENT FORM

I understand that I am being asked to participate in a study to determine the strength capabilities of the U.S. working population which is being conducted by researchers at the University of Michigan. The results of my strength tests, the physical demands of my job, and my past and future medical records will be compared with employees in other industries across the country to provide a statistical validation of strength requirements for jobs such as mine.

Like all other medical data, my strength test results will be treated in a confidential manner. The results of the test will not be disclosed in a personally identifiable form to me or to any other person other than the medical department. Any questions I have concerning my participation will be answered by the undersigned witness.

Risk of injuring myself during the strength test has been minimized by first having the Medical Department assess my ability to perform the test. Furthermore, the test itself requires me to slowly exert force on the test handles until I have reached what I believe to be a maximum exertion. This effort should be what I believe I am capable of exerting if given a heavy object to handle on my job. If I feel excessive discomfort while increasing the forces against the handle, I am to stop my exertion. Several such tests will be performed. I may terminate my participation at any time.

Participation in the strength testing program is strictly voluntary. Whether I choose to participate or not will not jeopardize my job assignment in any way.

I fully understand that above and after review, voluntarily choose to participate and hereby consent and agree to the release of the results to the above researchers.

____________________________ __________

Signature of Employee Date

____________________________ __________

Signature of Witness Date

TABLE 3.4

DESCRIPTIVE STATISTICS FOR INCUMBENT STUDY POPULATION

	MALE					FEMALE				
	No.	Min	Max	Mean	S.Dev.	No.	Min	Max	Mean	S.Dev.
AGE	209	21	65	39.5	9.3	74	20	64	35.7	9.4
HGT.	209	51	83	70.2	3.6	74	55	70	64.1	2.7
WGT.	209	125	250	175.6	22.7	74	90	200	124.6	16.9

U.S. Population Norms*

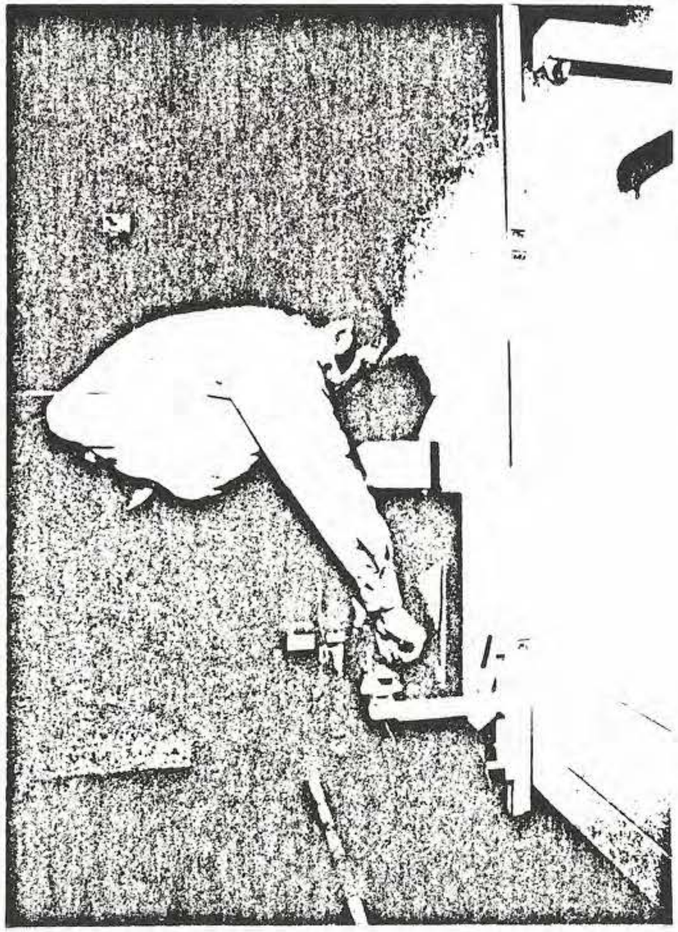
	MALE		FEMALE	
	Mean	SD	Mean	SD
AGE	37.9	14.7	37.0	14.5
HGT.	68.2	2.7	63.1	2.4
WGT.	167.3	26.9	142.2	28.4

*Population statistics based upon National Health Survey (1960-62) and Bureau of Labor Statistics (1974). SD = Standard Deviation

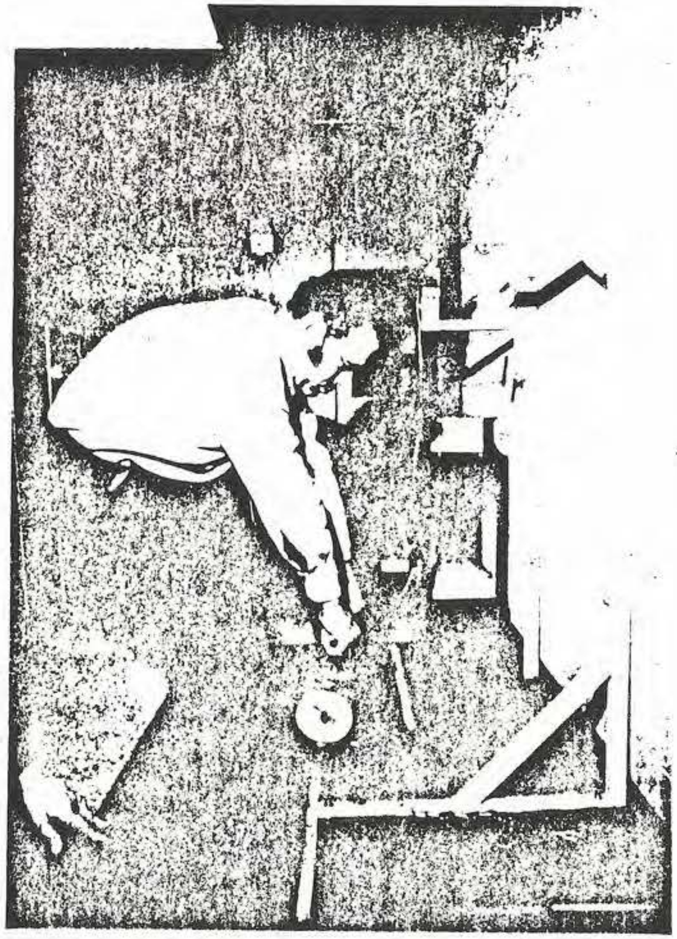
The injury experiences of the volunteers for the years 1975 to 1980 are summarized in Table 3.5. In comparing this table with the general Denver population (see Table 3.2) it is apparent that the volunteers experienced fewer injuries (retrospectively) than their counterparts. This is not uncommon in studies such as this due to the perceived threat of testing and the survivor phenomenon (indeed, injured workers are not among the survivors tested). Also, those volunteers with a documented history of recent musculoskeletal disorders were advised not to participate.

Two similar fixtures were employed in the incumbent strength measurement study (denoted as M and U on the data collection form, Figure 3.9). Figures 3.11 through 3.16 show the fixture configurations for each of the six tests conducted. Detailed descriptions are provided in Appendices C and D. The "M" fixture and equipment were developed by Dr. Chaffin and his associates at the University of Michigan. This equipment was used in much of the research reported in Chapter 1 and was used here for comparison with this study with other industry norms and the biomechanical model predictions.

The second fixture (denoted as "U") was developed at United Airlines by Dr. Scott and his associates. This simplified fixture used a "Dillon dynomometer" for recording forces and a flexible chain interface. This fixture was included in the study to determine whether a more simplified, lower maintenance and cost system would produce comparable results.

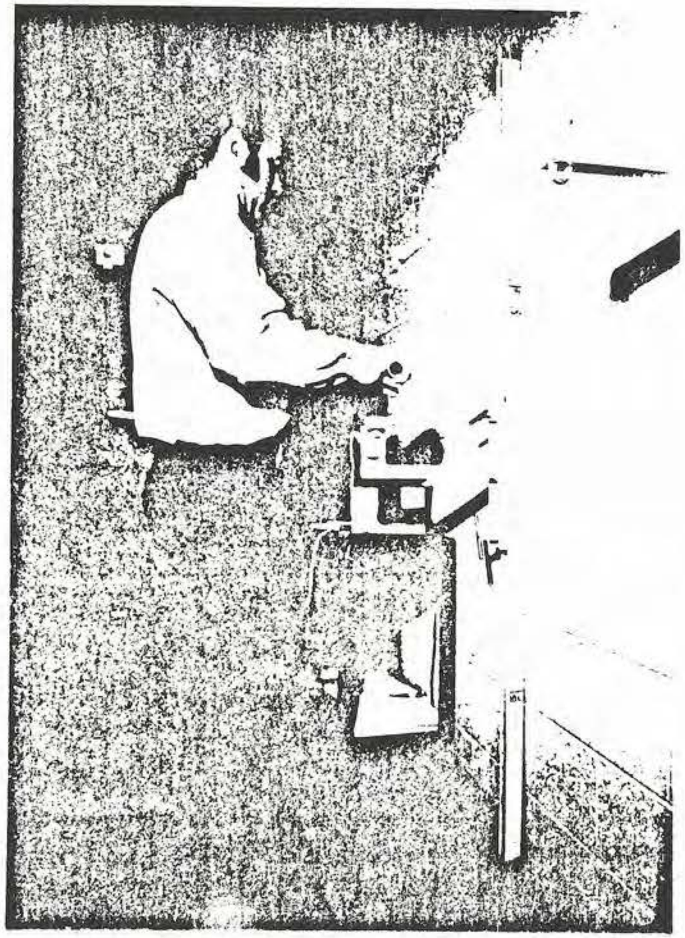


University "M" Fixture

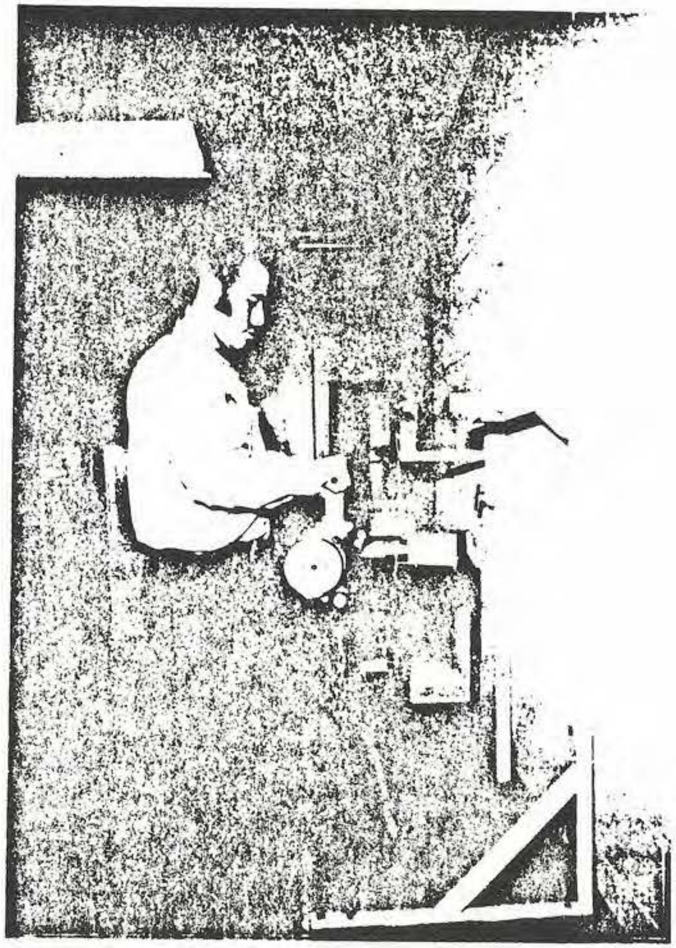


United "U" Fixture

Figure 3.11: Low Lift Test Fixtures

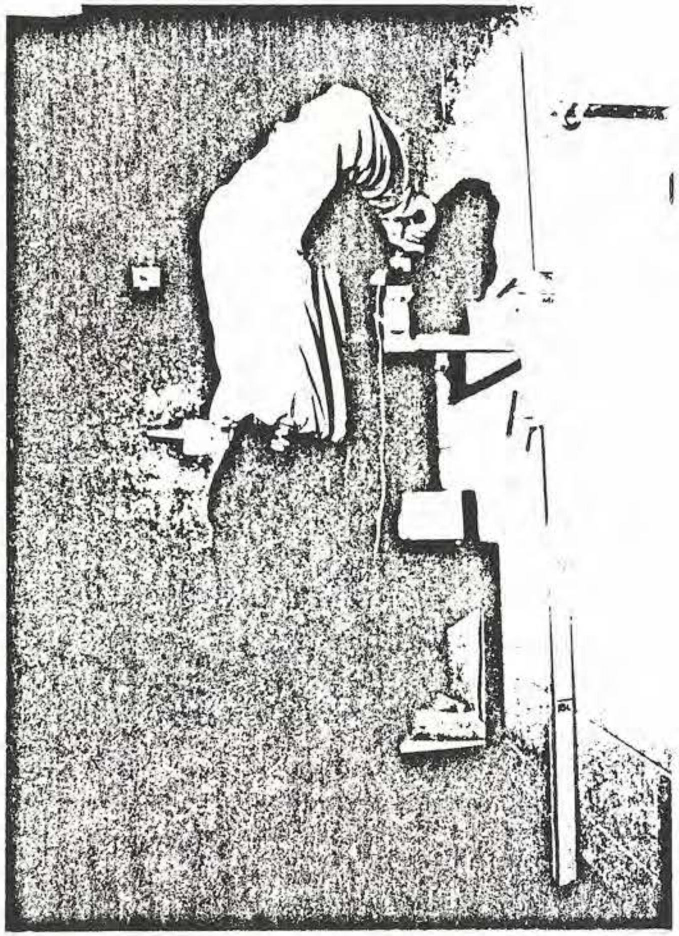


University "M" Fixture

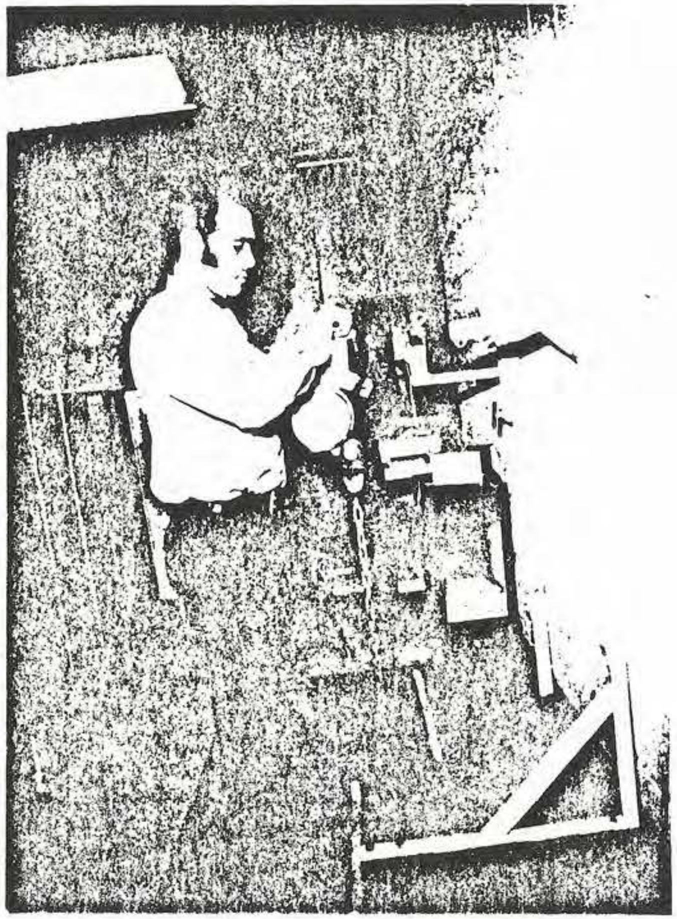


United "U" Fixture

Figure 3.12: Mid Lift Test Fixtures

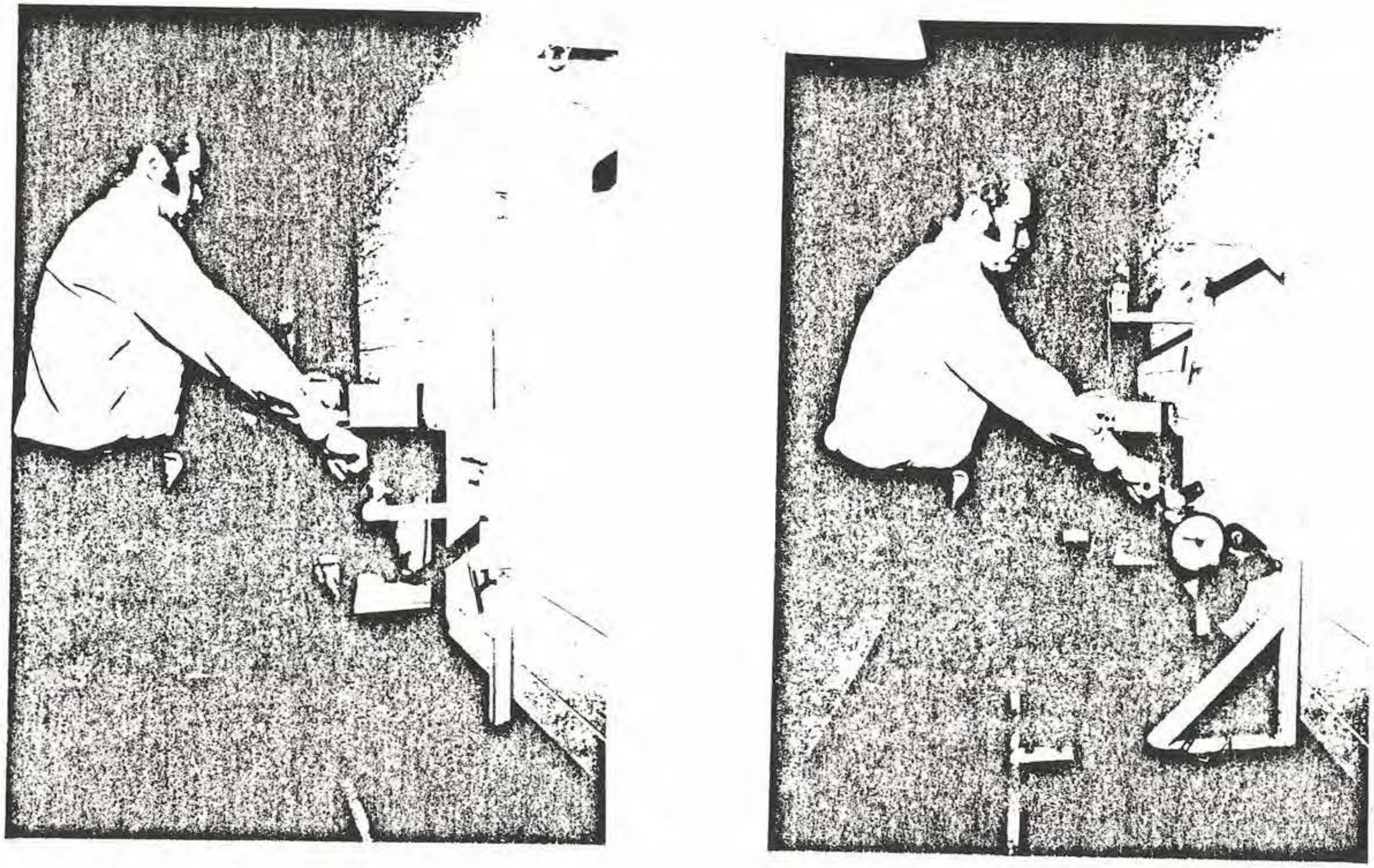


University "M" Fixture



United "U" Fixture

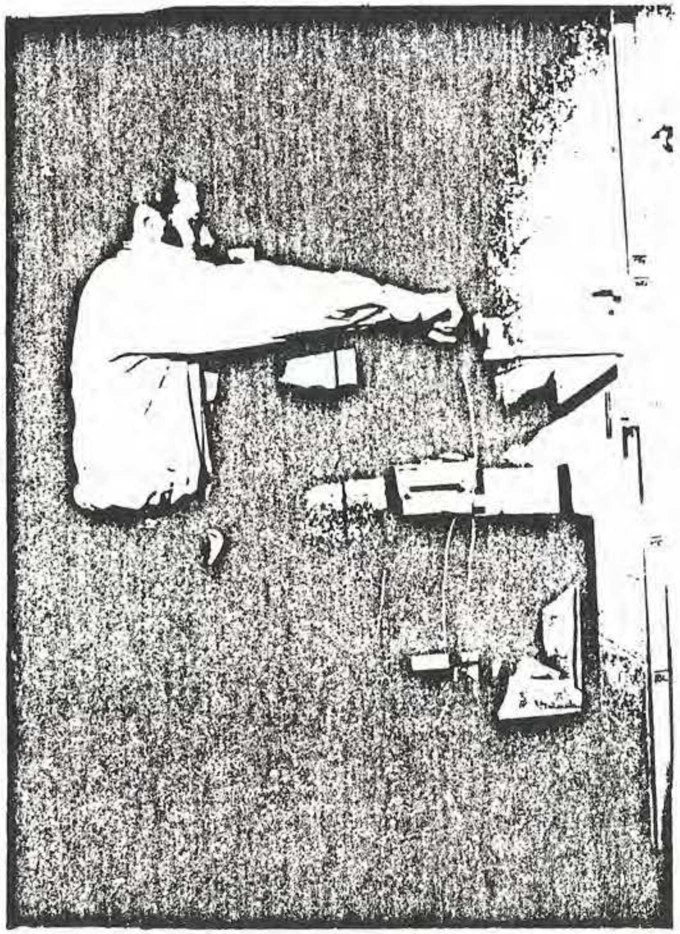
Figure 3.13: High Lift Test Fixtures



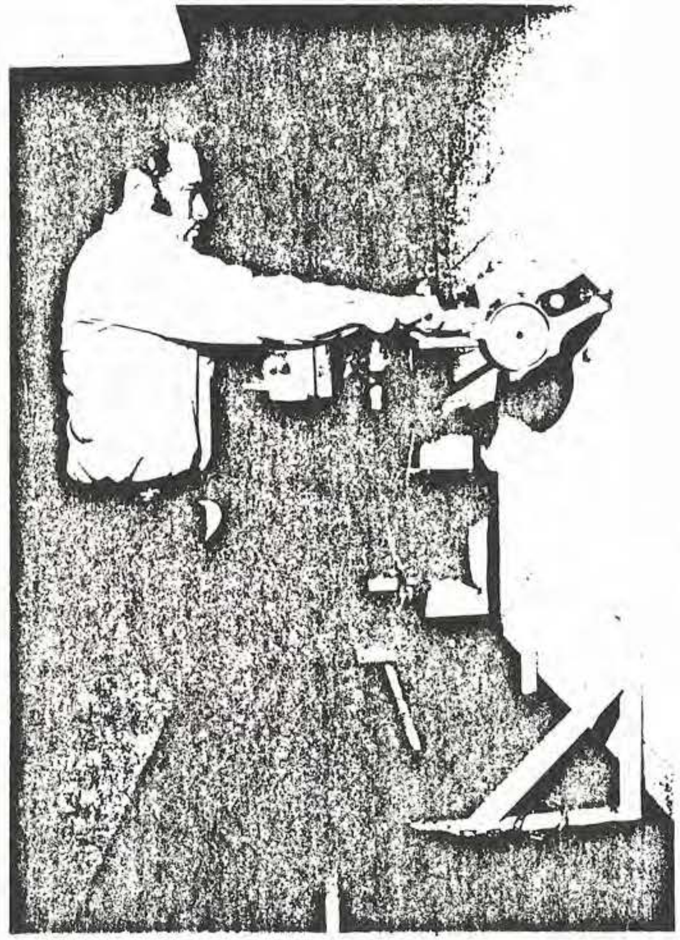
University "M" Fixture

United "U" Fixture

Figure 3.14: Low Pull Test Fixtures

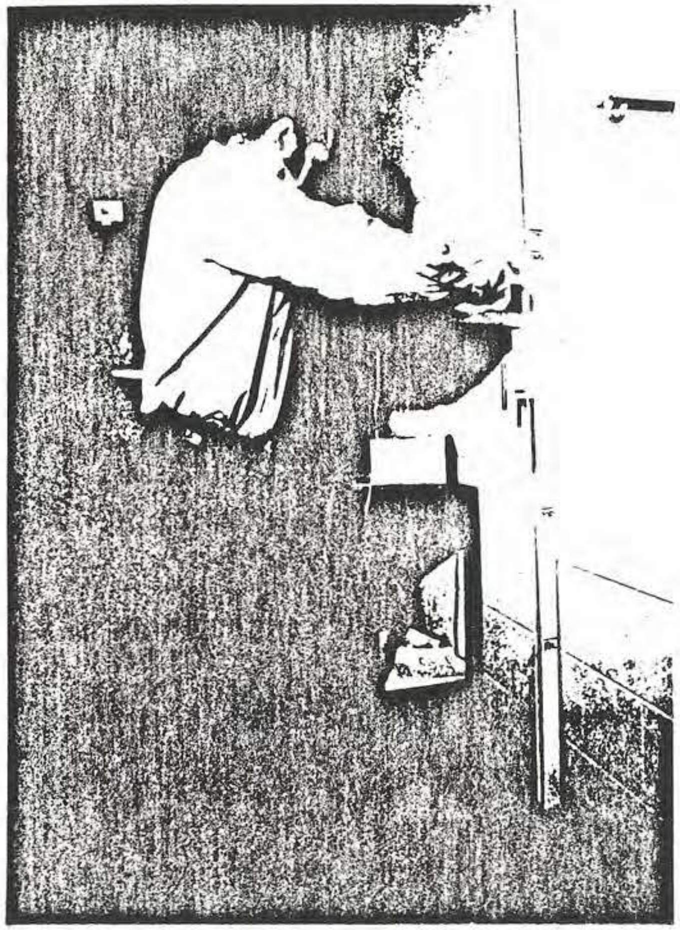


University "M" Fixture



United "U" Fixture

Figure 3.15: High Pull Test Fixtures



University "M" Fixture

Figure 3.16: High Push Test Fixtures

Tables 3.6 and 3.7 summarize the incumbent strength data using the University of Michigan testing Fixture. Table 3.6 compares the United volunteers results with the other industry norms (based on the studies of Keyserling (1979) and Stobbe (1982) and Frievalds (1980)). It also provides a comparison with the biomechanical model predictions. It is apparent that the male volunteers were somewhat weaker in the lifting tasks and stronger in the push/pull tasks than their industrial counterparts. The observed differences are probably an artifact of the testing procedure. During some periods inadequate rest between trials was observed (a steady deterioration in strength was observed over the 30-45 minute testing sessions). There was also a question of where the feet were to be placed during testing and what postures were allowed.

TABLE 3.5

ALL OCCUPATIONAL INJURIES SUMMARY (1/1/75-3/31/80)

UNITED AIRLINES
STRENGTH STUDY VOLUNTEERS

NUMBER M	NUMBER F	JOB TITLE	EXPOSURE (Man-Years)	INCIDENCE (Incidents per 100 Man-Years) MMH	OTHER	TOTAL	SEVERITY (Days Lost + Days Restricted Per Man-Years) TOTAL
7	33	1) Flight Attndnt	200.811	.996	2.489	3.486	.120
24	14	2) Food Service	146.092	2.738	3.423	6.161	.130
7	0	3) Fueler	36.724	2.723	5.446	8.169	.300
32	0	4) Mechanic	163.184	1.838	11.030	12.869	.435
36	19	5) Passngr Service	263.831	1.895	1.895	3.790	.027
85	0	6) Ramp Service	436.596	8.247	11.681	19.927	1.289
10	0	7) Storekeeper	52.393	0	0	0	0
		TOTAL	1299.631				

*MMH = Injury Attributed to Lift/Push/Pull

TABLE 3.6

STRENGTH COMPARISON WITH
OTHER DATA BASES: MEAN (STD. DEV.)

TASK	UNITED MALE	UNITED FEMALE	INDUSTRY MALE	INDUSTRY FEMALE	BIOMECHANICAL MODEL MALE	BIOMECHANICAL MODEL FEMALE
LOW LIFT	97.96 (31.44)	60.43 (21.43)	108.00 (46.13)	60.98 (28.13)	111.94 (42.13)	61.50 (22.12)
MED LIFT	70.69 (28.71)	43.31 (4.17)	86.18 (20.93)	48.15 (20.93)	115.89 (35.05)	59.68 (18.92)
HI LIFT	71.64 (26.77)	40.87 (5.09)	122.75 (35.10)	63.00 (22.95)	139.22 (28.01)	52.16 (18.40)
LOW PULL	141.28 (63.77)	80.50 (33.32)	*	*	162.44 (48.78)	97.44 (32.05)
HI PULL	69.59 (18.44)	43.03 (10.29)	59.15 (13.95)	47.03 (13.95)	77.93 (17.24)	50.25 (8.23)
HI PUSH	81.06 (26.38)	46.66 (11.84)	71.10 (17.10)	49.95 (11.03)	98.94 (21.19)	59.21 (22.46)

* Data Not Available

TABLE 3.7

STRENGTH TEST SUMMARY BY JOB CLASSIFICATION
MEANS AND (STANDARD DEVIATIONS)

TASK	FLIGHT ATTENDENT N=7 MALE	FLIGHT ATTENDENT N=33 FEMALE	FOOD SERVICE N=24 MALE	FOOD SERVICE N=14 FEMALE	FUELER N=7 MALE	FUELER N=0 FEMALE	MECHANIC N=32 MALE	MECHANIC N=0 FEMALE
LO LIFT	118.43 (55.46)	64.97 (25.56)	102.38 (28.68)	56.57 (13.42)	87.57 (14.19)	----	96.09 (18.66)	----
MID LIFT	85.00 (30.06)	46.33 (14.92)	79.42 (32.39)	39.43 (10.10)	69.00 (12.12)	----	63.28 (19.33)	----
HI LIFT	82.43 (55.46)	42.36 (25.56)	76.75 (28.68)	39.86 (13.42)	65.43 (14.19)	----	72.38 (18.66)	----
LO PULL	180.71 (83.12)	89.70 (36.00)	157.13 (60.85)	72.14 (19.78)	118.29 (48.86)	----	152.47 (62.93)	----
HI PULL	65.71 (21.56)	44.52 (8.92)	72.83 (14.63)	41.50 (6.59)	66.00 (16.49)	----	73.53 (20.89)	----
HI PUSH	82.00 (28.48)	49.76 (10.51)	90.96 (27.04)	46.00 (10.82)	79.86 (18.52)	----	82.31 (30.83)	----

TABLE 3.7 (continued)

STRENGTH TEST SUMMARY BY JOB CLASSIFICATION
MEANS AND (STANDARD DEVIATIONS)

TASK	PASSENGER SERVICE N=36 MALE	PASSENGER SERVICE N=19 FEMALE	RAMP SERVICE N=85 MALE	RAMP SERVICE N=0 FEMALE	STOREKEEPER N=10 MALE	STOREKEEPER N=0 FEMALE
LO LIFT	101.44 (37.86)	55.26 (15.45)	95.09 (31.86)	----	104.20 (33.99)	----
MID LIFT	76.39 (36.39)	42.26 (14.38)	68.34 (28.17)	----	70.70 (24.12)	----
HI LIFT	76.08 (37.86)	40.00 (15.45)	67.19 (31.86	----	70.00 (23.18)	----
LO PULL	132.02 (58.45)	75.47 (35.41)	134.68 (65.24)	----	170.90 (71.32)	----
HI PULL	67.67 (18.47)	40.74 (12.49)	68.91 (18.52)	----	75.20 (16.31)	----
HI PUSH	76.25 (21.33)	42.74 (12.68)	79.95 (27.42)	----	89.90 (24.60)	----

* Data Not Available

Table 3.6 also shows the biomechanical model predictions for these tests. The model reflects a slightly younger and more motivated population (a blend of new hires and incumbents) and consequently higher strength scores.

Table 3.7 partitions the incumbent tests by occupation. It is apparent from this table that ramp service volunteers were significantly weaker than anticipated. Apparently some negative concerns were circulated among these volunteers prior to testing that low scores would be interpreted as the ramp jobs are excessively stressful for incumbent ramp servicers; an unfounded and unfortunate rumor. Male flight attendants on the other hand demonstrated higher scores than predicted. Presumably a "macho" attitude could be attributed to these differences.

It should be apparent to the reader now that strength is a psychophysical measurement. It is a person's perception of his capability rather than "tissue tolerance". This is an important consideration in interpreting strength scores of incumbents versus new hires. It is also important that criteria for selection be based on job requirements as well as incumbent performance.

The repeatability or test-retest precision is also an important measure of the reliability of any testing procedure. Strength test scores were obtained over a minimum of two and maximum of five trials for each of eleven test procedures; the six standardized (M) tests and the five additional (U) tests using a Dillon Dynomometer. The total variance of the data with each Fixture was separated into the following components:

$$\sigma^2_{T_i} = \sigma^2_{A_i} + \sigma^2_{W_i}$$

where $\sigma^2_{T_i}$ = total variance on test i

$\sigma^2_{A_i}$ = variance due to differences among subjects on test i

$\sigma^2_{W_i}$ = variance due to test-retest changes within a subject on test i

$i = 1, 2, \ldots, 11$, tests.

The average coefficient of variation (CV) was computed for each set of strength test data as follows:

$$CV_i = \frac{S_{W_i}}{\bar{X}_i} \times 100$$

where

S_{W_i} = within subject sample standard deviation on test i.

$\bar{X}_i$ = sample mean on test i.

$i = 1, 2, ..., 11$

Coefficients of variation and the between subject sample standard deviations of the CV's for all tests are summarized in Table 3.8. The values indicate that strength test scores were quite repeatable and precise. Values of 8-12 percent are typical for field testing, however, CV's of 5 percent are generally attainable only using a well controlled laboratory testing protocol and rest periods of over 2 minutes between exertions.

TABLE 3.8

TEST/RETEST COEFFICIENT OF VARIATIONS

Strength Test	Michigan (M) Tests		United (U) Tests	
	C.V.	Std.Dev.C.V.	C.V.	Std.Dev.C.V.
HI PULL	.061	(.048)	.076	(.062)
HI PUSH	.075	(.061)	*	*
LO PULL	.092	(.089)	.056	(.047)
HI LIFT	.085	(.095)	.087	(.072)
MED LIFT	.072	(.059)	.092	(.078)
LO LIFT	.068	(.066)	.073	(.059)

*Push test not applicable.

It is apparent from Table 3.8 that the standardized tests were slightly less variable than the simplified tests in general. The simplified procedure only recorded maximal exertions. Averages were estimated by visually inspecting the guage over the period of the test. This error, though of nominal bias, did introduce test/retest variability. The one exception (low-pull) was attributable to a lack of standardization in foot placement.

Figures 3.17 through 3.21 show the comparative strength scores between the two test fixtures and equipment. The axes for strength have been log transformed due to the heteroscedasticity of the variance (increasing variance with mean values). A regression analysis revealed "statistically significant" prediction biases as noted on the figures ranging in magnitude between 0.4 and 6.4 percent error. In general, the M fixture results were nominally higher than the corresponding U fixture results. While "statistically" significant ($p > .999$) the errors were less than the sampling "test/retest" variability inherent to either testing process and thus of no practical difference. A complete listing of the incumbent strength test results is provided in Appendix D.

Figure 3.17: Comparison of Low Lift Strengths Between Fixtures

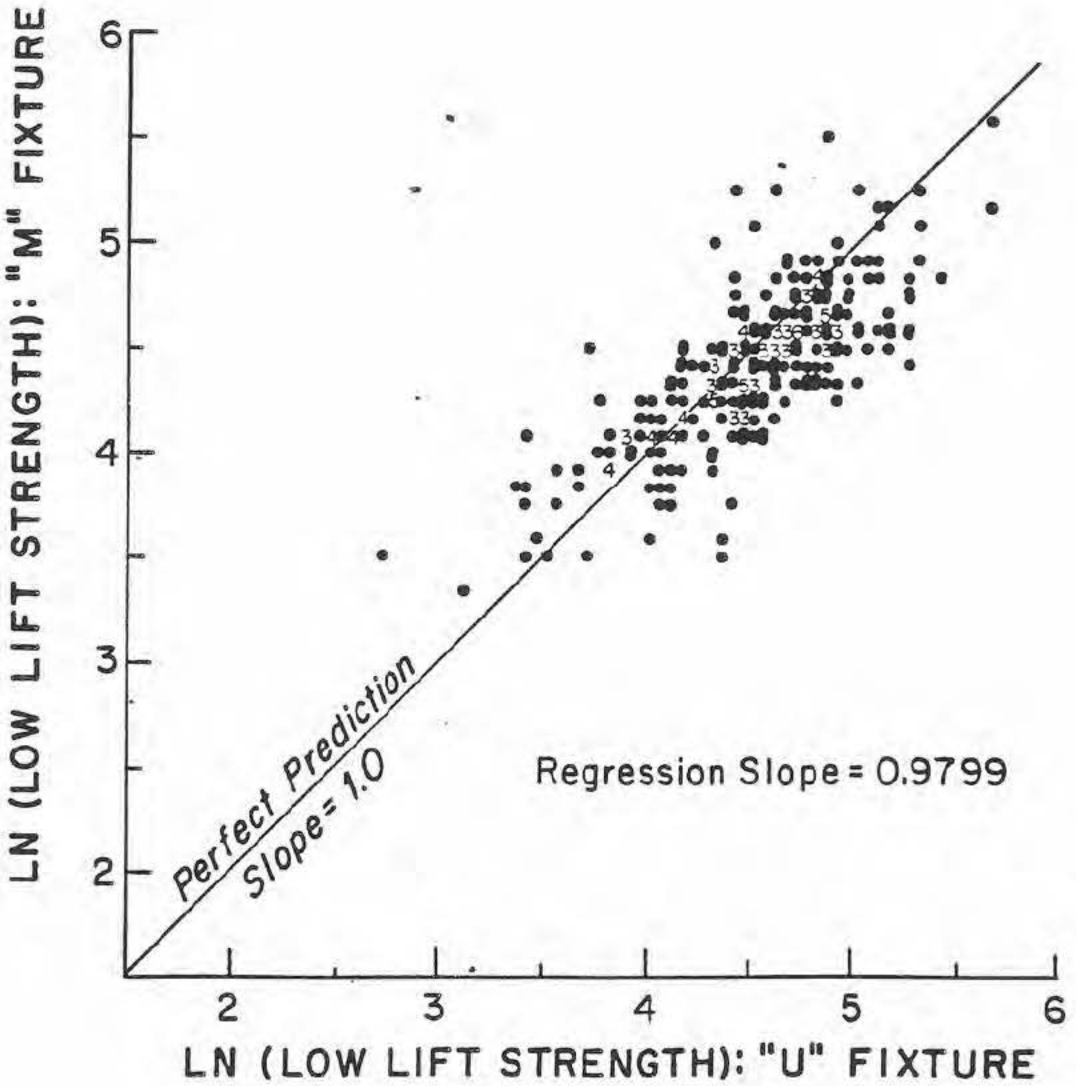


Figure 3.18: Comparison of Mid Lift Strengths Between Fixtures

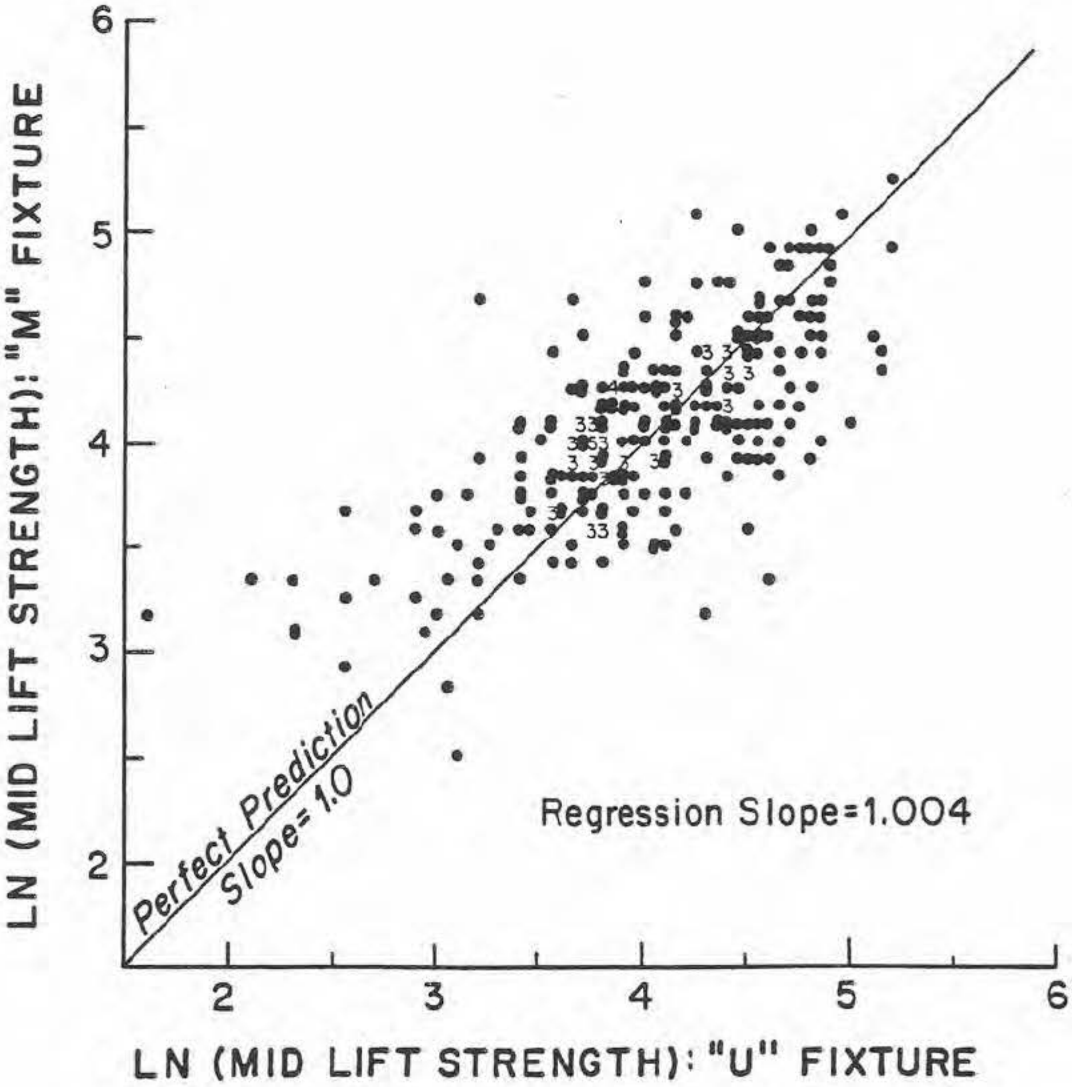


Figure 3.19: Comparison of High Lift Strengths Between Fixtures

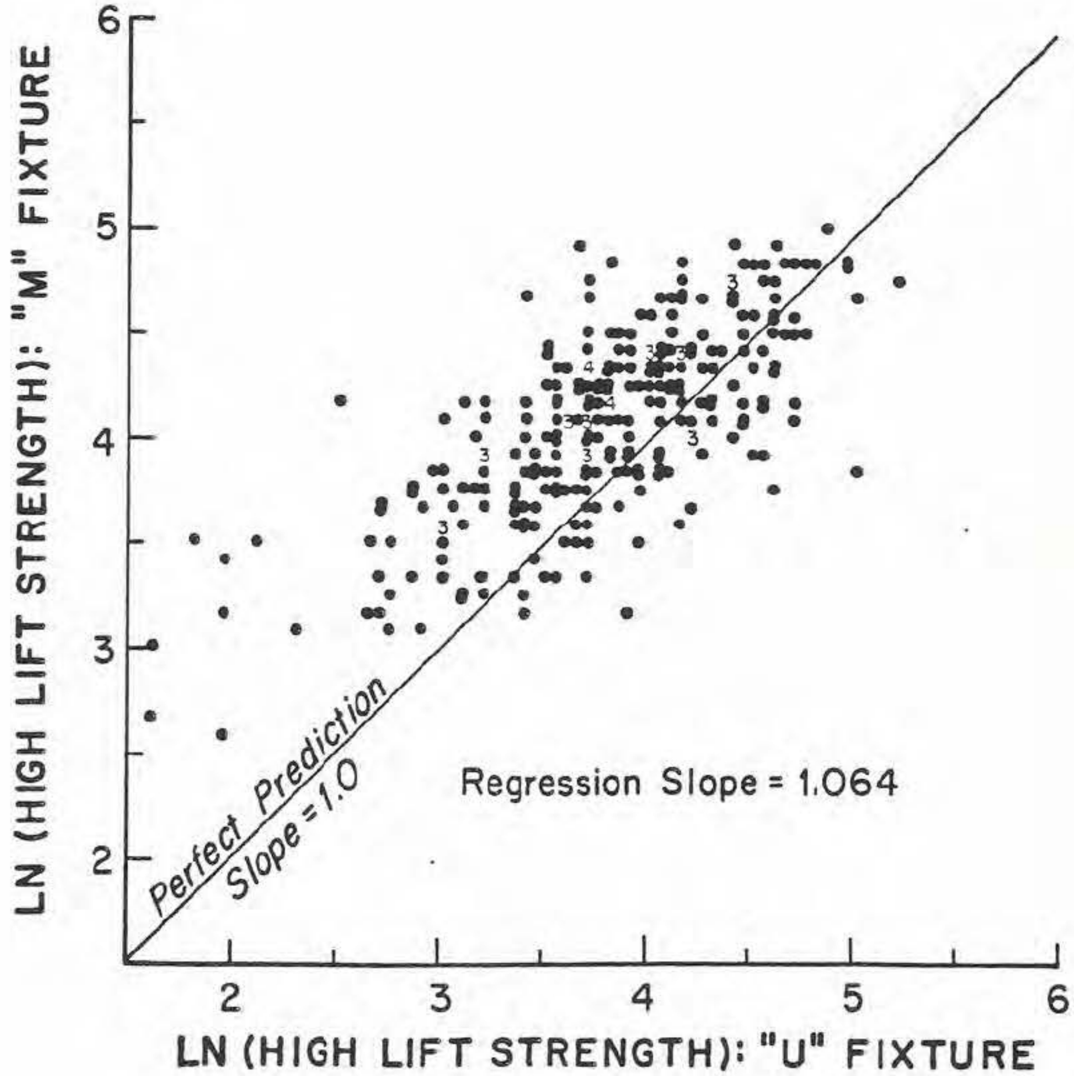


Figure 3.20: Comparison of Low Pull Strengths Between Fixtures

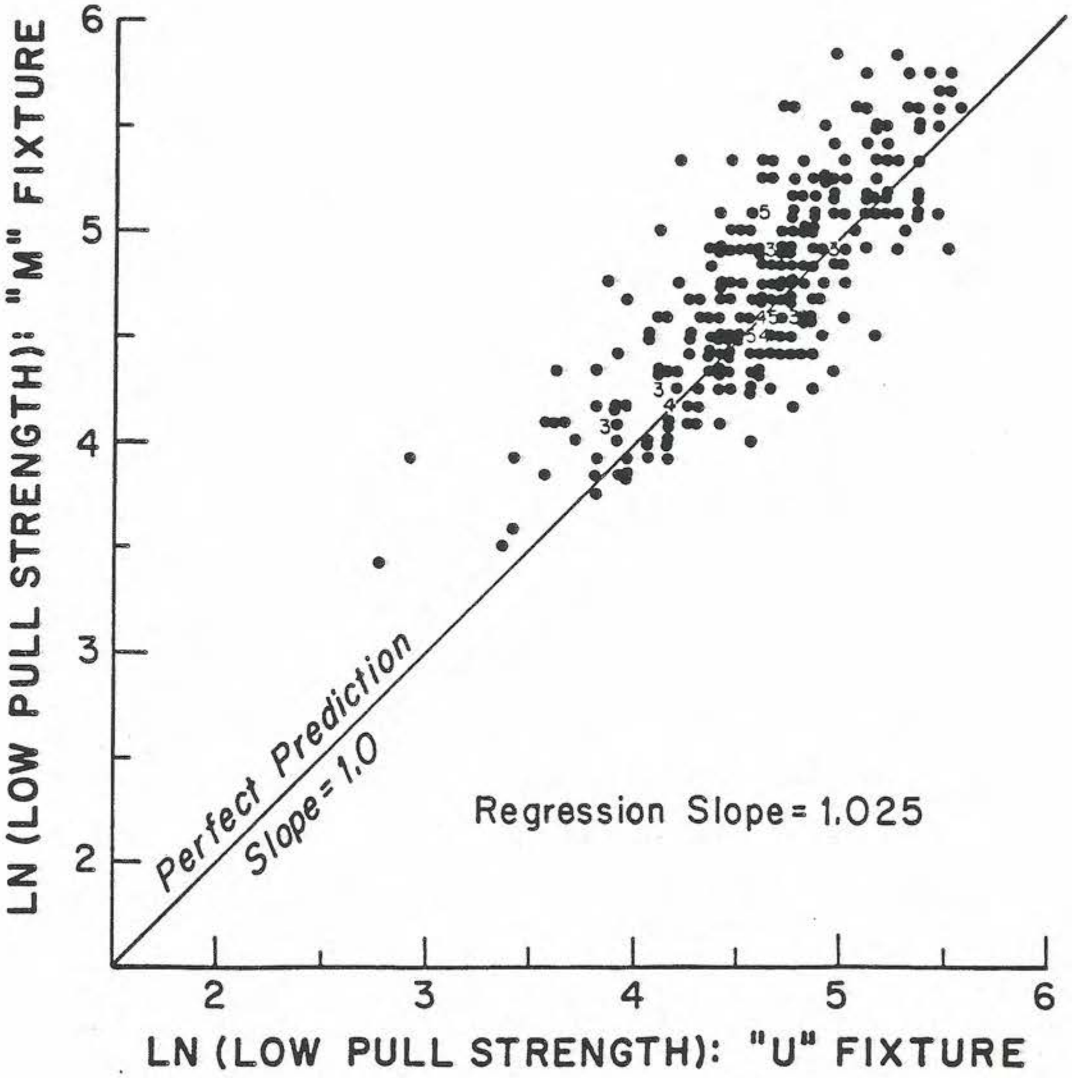
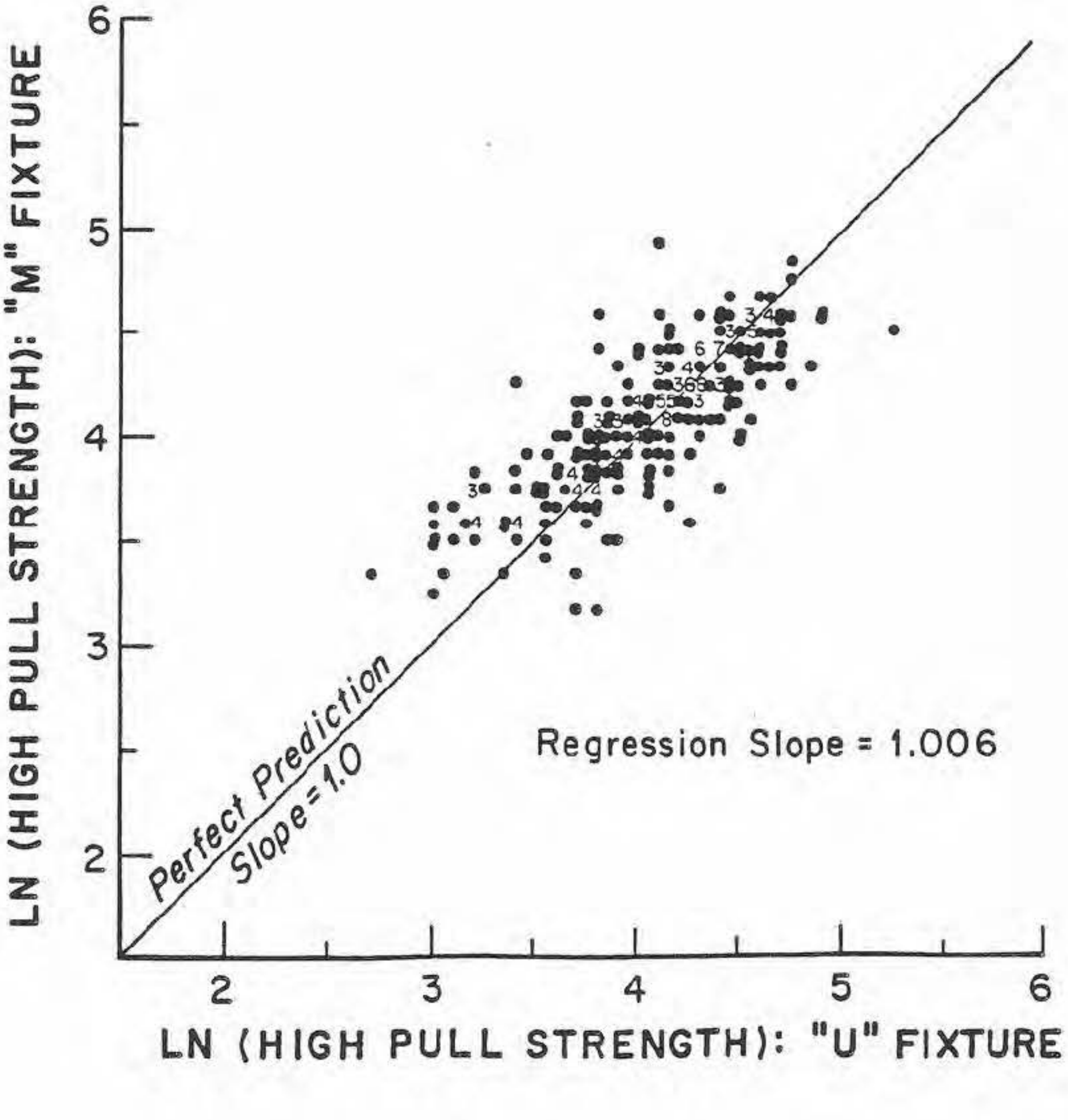


Figure 3.21: Comparison of High Pull Strengths Between Fixtures



A general conclusion drawn from the above is that the study sample was reasonably representative of the UAL workforce and US workforce in general. Further, there appeared to be no practical differences between the test fixtures for assessing maximal isometric strength. The incumbent testing program also allowed a number of refinements in testing protocol and most importantly provided training of medical personnel (under Dr. V. Scott's supervision) in strength test administration.

F. Development of Qualification Scores

The matching of standardized strength scores with job requirements requires standardization in terms of matching percentiles. For each task (within each job) the most limiting muscle group was identified via biomechanical modeling. The corresponding percentile capability was determined. This percentile was carried to the appropriate standardized test (eg. a task requiring lifting between knuckle and shoulder high, say, reflects standardized elbow flexion strength) and based on the required percentile, the corresponding standard force or strength requirement was determined. An example of this procedure was shown in Chapter 2.

The results of a first analysis of these derived qualification scores is presented in Table 3.9. To examine the accuracy (validity) of these requirements, the incumbent strengths were examined. In applying these criteria to the incumbents it was observed that a large number could not meet all 6 criteria simultaneously. Further examination revealed two major factors contributing to this fact:

1. A number of the tasks simulated, exceeded maximum permissible criteria (discussed earlier)
2. The requirement to simultaneously achieve certain levels on multiple capacity tests is overly restrictive.

Through a process of re-evaluation of the jobs and redesign of the work practices involved the first factor was eliminated. The second issue, however, remains unresolved. Most simply put, the problem is as follows: Suppose a qualified person will pass any test with probability .90 (recall the test/retest CV is on the order of 5 to 10%). If six, independent tests are administered, the odds of simultaneously meeting all criteria is $(.90)^6 = .53$. The fact that the tests are, in fact, positively correlated alleviates some of this problem. However, with multiple tests the false rejection problem will always be present. To minimize this effect, the allowance of retests would be recommended as would reducing the criteria for "passing". Both alternatives would, of course, increase the number of false acceptances.

Table 3.10 provides revised qualification scores based on most recent job analyses and incumbent strength results. The reader may note that these scores are, in general, lower than those displayed in Table 3.9.

TABLE 3.9

PRELIMINARY STRENGTH TEST QUALIFICATION SCORES
(in pounds)

Group	Lifting Low 18"	Lifting Mid 26-40"	Lifting High 37-45"	Pulling Low 21"	Pulling High 48"	Pushing
Air Freight Agent	108	85	74	92	92	96
Cleaner	66	58	54	35	30	30
Flight Attendant	65	52	46	42	54	72
Food Service	82	81	50	82	70	78
Fueler	25	25	35	50	25	30
Mechanics	94	86	64	72	77	77
Ramp Service	108	85	74	92	92	96
Passenger Serv (Line)	108	85	74	92	92	96
Passenger Serv (TM)	94	56	51	72	--	--
Skycap	99	85	86	74	68	72
Storekeeper	112	85	74	106	81	84

TABLE 3.10
STRENGTH TEST QUALIFICATION SCORES (in pounds)

Group	Lifting Low 18"	Lifting Mid 26-40"	Lifting High 37-45"	Pulling Low 21"	Pulling High 48"	Pushing
Air Freight Agent	125	--	70	80	80	50
Cleaner	66	58	54	35	30	30
Flight Attendant	51	36	48	10	35	25
Food Service	85	67	--	80	65	32
Fueler	25	30	--	20	50	30
Mechanics	137	88	--	--	73	108
Ramp Service	101	70	25	95	74	40
Passenger Serv (Line)	--	--	--	--	35	20
Passenger Serv (TM)	73	68	--	--	46	20
Skycap	80	--	20	75	--	38
Storekeeper	110	--	67	--	92	110

In order to determine the predictive effectiveness of isometric strength testing on the occurrence of overexertion injuries, injury rates were computed for employees whose demonstrated strengths exceeded the job requirements (see Table 3.10) and for those whose did not. The results are tabulated in Tables 3.11-3.17 for each strength test, each job classification, and a summary across all jobs and all tests. The reader will note that the Air Freight job classification does not appear in Tables 3.11 through 3.17 since no workers in the classification were tested. Furthermore, medical experience for the two sub-classifications of Passenger Service Agent (Terminal (TM) versus Line) could not be separated, so all employees were rated by the maximum of the two sets of criteria and combined in the analyses summarized in Tables 3.11 through 3.17. A careful analysis of these results shows that incumbents who were either unwilling or unable to demonstrate strengths in excess of those required on the job had greater injury rates than their counterparts (with sufficient strength). The magnitude of the differences is less than would be expected from earlier studies due to the inherent problems with incumbent studies. In particular, the survivor phenomenon (high injury rate populations do not volunteer) and the lack of sufficient motivation. Recognizing the limitations of an incumbent study it was decided to evaluate the procedures with a new hire population. The results of this effort are discussed in the next chapter.

TABLE 3.11

MEDICAL INCIDENCE RATE COMPARISONS FOR LOW LIFT TEST

Job Classification	Force Required	Qualified N	Qualified Contact Rate	Qualified Musc. Rate	Qualified Back Rate	Qualified Total Rate	Not Qualified N	Not Qualified Contact Rate	Not Qualified Musc. Rate	Not Qualified Back Rate	Not Qualified Total Rate
Flight Attendent	51	33	1.39	1.39	1.39	4.17	7	12.48	6.24	6.24	24.96
Food Service	85	12	0.00	1.98	0.00	1.98	24	7.38	4.92	1.23	13.53
Fueler	25	7	5.44	2.72	2.72	10.88	-	-	-	-	-
Mechanic	137	0	-	-	-	-	32	9.15	3.66	1.22	14.03
Pagssenger Service	73	32	0.66	2.64	1.32	4.62	21	1.94	1.94	0.97	4.85
Ramp Service	101	29	6.90	8.97	3.45	19.32	56	8.05	12.95	5.25	16.25
Skycap	80	2	9.51	0.00	0.00	9.51	-	-	-	-	-
Storekeeper	110	2	0.00	0.00	0.00	0.00	8	0.00	0.00	0.00	0.00
ALL JOBS		117	3.15	4.20	1.89	9.24	148	6.72	7.00	2.80	16.52

TABLE 3.12

MEDICAL INCIDENCE RATE COMPARISONS FOR MID LIFT TEST

		Qualified					Not Qualified				
Job Classification	Force Required	N	Contact Rate	Musc. Rate	Back Rate	Total Rate	N	Contact Rate	Musc. Rate	Back Rate	Total Rate
Flight Attendent	36	31	4.47	1.49	1.49	7.45	9	0.00	4.85	4.85	9.70
Food Service	67	12	2.00	0.00	0.00	2.00	24	6.15	6.15	1.23	13.53
Fueler	30	7	5.44	2.72	2.72	10.88	-	-	-	-	-
Mechanic	88	5	3.81	3.81	0.00	7.62	27	10.22	3.65	1.46	15.33
Passenger Service	68	18	1.23	2.46	1.23	4.92	35	1.14	2.28	1.14	4.56
Ramp Service	70	33	10.62	10.03	3.54	24.19	52	5.85	12.87	5.46	24.18
Skycap	-	2	9.51	0.00	0.00	9.51	-	-	-	-	-
Storekeeper	-	10	0.00	0.00	0.00	0.00	-	-	-	-	-
ALL JOBS		118	5.40	4.40	1.80	11.60	147	5.04	6.72	2.80	14.56

TABLE 3.13

MEDICAL INCIDENCE RATE COMPARISONS FOR HIGH LIFT TEST

Job Classification	Force Required	Qualified N	Qualified Contact Rate	Qualified Musc. Rate	Qualified Back Rate	Qualified Total Rate	Not Qualified N	Not Qualified Contact Rate	Not Qualified Musc. Rate	Not Qualified Back Rate	Not Qualified Total Rate
Flight Attendent	48	19	7.59	2.53	2.53	12.65	21	0.00	2.07	2.07	4.14
Food Services	-	36	4.56	3.80	0.76	9.12	-	-	-	-	-
Fueler	-	7	5.44	2.72	2.72	10.88	-	-	-	-	-
Mechanic	-	32	9.15	3.66	1.22	14.03	-	-	-	-	-
Passenger Service	-	53	1.17	2.34	1.17	4.68	-	-	-	-	-
Ramp Service	25	84	7.36	11.04	4.37	22.77	1	20.12	40.24	20.12	80.48
Skycap	20	2	9.51	0.00	0.00	9.51	-	-	-	-	-
Storekeeper	67	5	0.00	0.00	0.00	0.00	5	0.00	0.00	0.00	0.00
ALL JOBS		238	5.58	6.03	2.43	14.04	27	1.26	3.78	2.52	7.56

TABLE 3.14

MEDICAL INCIDENCE RATE COMPARISONS FOR LOW PULL TEST

Job Classification	Force Required	Qualified N	Qualified Contact Rate	Qualified Musc. Rate	Qualified Back Rate	Qualified Total Rate	Not Qualified N	Not Qualified Contact Rate	Not Qualified Musc. Rate	Not Qualified Back Rate	Not Qualified Total Rate
Flight Attendent	10	40	3.42	2.28	2.28	7.98	-	-	-	-	-
Food Service	80	23	3.48	2.32	0.00	5.80	13	6.57	6.57	2.19	15.33
Fueler	20	7	5.44	2.72	2.72	10.88	-	-	-	-	-
Mechanic	-	32	9.15	3.66	1.22	14.03	-	-	-	-	-
Passenger Service	-	53	1.17	2.34	1.17	4.68	-	-	-	-	-
Ramp Service	95	55	8.64	11.16	4.68	24.48	30	5.94	12.54	4.62	23.10
Skycap	75	2	9.51	0.00	0.00	9.51	-	-	-	-	-
Storekeeper	-	10	0.00	0.00	0.00	0.00	-	-	-	-	-
ALL JOBS		222	5.10	4.80	2.10	12.00	43	6.00	11.00	4.00	21.00

TABLE 3.15

MEDICAL INCIDENCE RATE COMPARISONS FOR HIGH PULL TEST

		Qualified					Not Qualified				
Job Classification	Force Required	N	Contact Rate	Musc. Rate	Back Rate	Total Rate	N	Contact Rate	Musc. Rate	Back Rate	Total Rate
Flight Attendent	35	36	3.81	2.54	2.54	8.89	4	0.00	0.00	0.00	0.00
Food Service	65	12	3.52	1.76	0.00	5.28	24	5.36	5.36	1.34	12.06
Fueler	50	6	6.34	3.17	3.17	12.68	1	0.00	0.00	0.00	0.00
Mechanic	73	17	9.04	4.52	2.26	15.82	15	9.31	2.66	0.00	11.97
Passenger Service	46	37	0.56	2.24	1.68	4.28	16	2.64	2.64	0.00	5.28
Ramp Service	74	31	7.04	12.80	5.76	25.60	54	8.14	11.10	4.07	23.31
Skycap	-	2	9.51	0.00	0.00	9.51	-	-	-	-	-
Storekeeper	92	0	-	-	-	-	10	0.00	0.00	0.00	0.00
ALL JOBS		141	4.48	5.12	2.72	12.32	124	5.95	6.46	2.04	14.45

TABLE 3.16

MEDICAL INCIDENCE RATE COMPARISONS FOR PUSH TEST

Job Classification	Force Required	Qualified N	Qualified Contact Rate	Qualified Musc. Rate	Qualified Back Rate	Qualified Total Rate	Not Qualified N	Not Qualified Contact Rate	Not Qualified Musc. Rate	Not Qualified Back Rate	Not Qualified Total Rate
Flight Attendent	25	40	3.42	2.28	2.28	7.98	-	-	-	-	-
Food Services	32	35	3.95	3.95	0.79	8.69	1	19.03	0.00	0.00	19.03
Fueler	30	7	5.44	2.72	2.72	10.88	-	-	-	-	-
Mechanic	108	6	12.72	3.18	0.00	15.90	26	8.25	3.75	1.50	13.50
Passenger Service	20	53	1.17	2.34	1.17	4.68	-	-	-	-	-
Ramp Service	40	80	7.75	11.75	4.75	24.25	5	7.96	11.94	3.98	23.88
Skycap	38	2	9.51	0.00	0.00	9.51	-	-	-	-	-
Storekeeper	110	1	0.00	0.00	0.00	0.00	9	0.00	0.00	0.00	0.00
ALL JOBS		224	4.90	6.20	2.60	13.70	41	6.85	3.76	1.41	12.02

TABLE 3.17

MEDICAL INCIDENCE RATE COMPARISONS FOR ALL TESTS COMBINED

Job Classification	Force Required	Qualified N	Qualified Contact Rate	Qualified Musc. Rate	Qualified Back Rate	Qualified Total Rate	Not Qualified N	Not Qualified Contact Rate	Not Qualified Musc. Rate	Not Qualified Back Rate	Not Qualified Total Rate
Flight Attendant		17	2.87	2.87	2.87	8.61	23	3.78	1.89	1.89	7.56
Food Services		8	0.00	0.00	0.00	0.00	28	6.36	5.30	1.06	12.72
Fueler		6	6.34	3.17	3.17	12.68	1	0.00	0.00	0.00	0.00
Mechanic		0	-	-	-	-	32	9.15	3.66	1.22	14.03
Passenger Service		17	1.32	2.64	1.32	5.28	36	1.12	2.24	1.12	4.48
Ramp Service		11	3.56	10.68	3.56	17.80	74	8.37	11.88	4.86	25.11
Skycap		2	9.51	0.00	0.00	9.51	-	-	-	-	-
Storekeeper		0	-	-	-	-	10	0.00	0.00	0.00	0.00
ALL JOBS		61	2.80	4.00	2.00	8.80	204	5.60	6.00	2.40	14.00

IV. New Hire Study Results

A second longitudinal study of the impact of strength testing on new hires was also undertaken in 1978 (see steps G and H at beginning of chapter III). The population studied consisted of new hires in ten occupations. Injury data for 905 new hires, who would have passed strength testing criteria defined in Table 3.9 were compared to 2,925 new hires who were not strength tested.

Although strength testing was not instituted as a mandatory condition of employment it was conducted as part of the pre-employment physical exam for approximately one in four new hires for the years 1978 - 1981. The purpose of this study was to determine the potential new hire impact of strength testing on injury and days lost.

The qualified "new hire" sample sizes by occupational classification are presented in Table 4.1. In reviewing this table it is apparent that, the impact of strength testing cannot be assessed for air freight agent, cabin serviceman, fueler, or storekeeper. Thus, only the other five occupations form the basis for the analyses which follow (905 tested, 2,732 not tested). Further, only the flight attendant group would seem to have an adequate sample size for an analysis by occupation at this time. For the analyses which follow the data in Table 4.2 were used to determine exposure hours and injury costs (in terms of wages and medical costs).

In Table 4.3 injury, days lost, and the cost of injuries are documented by occupation. Of the 3,002 sprain/strain injuries, 92% (conservatively) were in the occupations of interest. The majority (63%) of the injuries were to the back. Total injuries resulted in an excess of 33,000 lost man days at a cost in excess of $5,000,000 (65% salary cost). The incidence of injury (per 200,000 exposure hours) was most frequent amongst flight attendants (6.7), ramp (4.7) and skycap (4.0) and least frequent in air freight (0.8) and stores (1.2).

Days lost per 100 man years (where one day equals eight working hours) was most severe amongst flight attendants (69.6), fueler (70.5) and ramp (51.6) and least severe amongst air freight agents (9.7), maintenance (15.2) and customer service agents (17.8).

TABLE 4.1

NEW HIRE SAMPLE SIZES

Occupation	Not Strength Tested N	%	Qualified N	%
Air Freight Agent	13	100.0	0	0.0
Cabin Service	191	100.0	0	0.0
Flight Attendant	927	60.1	615	39.9
Food Service	596	91.3	57	8.7
Fueler	3	100.0	0	0.0
Mechanic	203	92.7	16	7.3
Passngr Service Agent	318	81.3	73	18.7
Ramp Service	451	76.7	137	23.3
Skycap	30	81.1	7	19.9
Storekeeper	0	0.0	0	0.0
TOTAL	2732	75.1	905	24.9

TABLE 4.2

1980 FIGURES: HOURS WORKED, SALARY, AND COSTS

Occupation	Average Hours		Salary	
	Monthly	Daily	Hourly	Cost of Lost Day
Air Freight Agent	173.3	8.00	10.60	84.80
Cabin Service	169.9	7.84	9.50	74.48
Flight Attendant	76.0	5.00	$24.00	$120.00
Food Service	170.2	7.85	8.96	70.37
Fueler	178.1	8.23	10.79	88.80
Mechanic	174.5	8.05	12.80	103.04
Passenger Service	173.3	8.00	10.34	82.72
Ramp Service	174.6	8.06	11.02	88.82
Skycap	173.3	8.00	5.64	45.12
Storekeeper	174.7	8.06	10.69	86.16

Average Medical Costs by Part of Body:

Part of Body	Cost
Arm	$ 290
Back	700
Leg	830
Shoulder	360
Knee	670
Ankle	290
Elbow	460
Groin	660

* Hours worked for Passenger Service, Skycap, Air Freight Agent are estimates; 1980 figures are not available.

TABLE 4.3

OCCUPATIONAL INJURY (STRAIN/SPRAIN) BY OCCUPATION: 1978-1981

Occupation	Number	Average Man Year Worked	Injury Total	Injury Per 100 Man Years	Days Lost Total	Days Lost Per 100 Man Years	Days Lost Per Injury
Air Freight Agent	527	3.86	18	0.8	203	9.7	11.3
Cabin Service	1,070	3.57	70	1.7	787	20.6	11.2
Flight Attendent	9,102	1.63	1012	6.7	10,478	69.6	10.6
Food Service	2,447	3.55	152	2.0	2,425	29.1	15.9
Fueler	216	4.01	27	3.1	595	70.5	22.0
Mechanic	8,030	3.88	354	1.2	4.681	15.2	13.2
Passenger Service	3,604	3.25	270	2.4	2,078	17.8	7.7
Ramp Service	4,380	3.75	787	4.7	8,643	51.6	11.0
Skycap	261	3.43	34	4.0	216	23.7	6.3
Storekeeper	847	3.91	40	1.2	638	21.7	16.0
Unknown	-	-	238	-	2,680	-	11.3
TOTAL	30,821	3.08	3,002	3.6	33,424	38.7	11.1

Occupation	Arm	Back	Leg	Shld	Knee	Ank	Elb	Groin	Salary	Medical	Total
	Number of Injuries by Part of Body								Cost of Occup. Injury		
Air Freight Agt	0	14	2	1	1	0	0	0	17,214	12,490	29,704
Cabin Service	1	29	3	9	6	17	0	5	58,615	36,810	95,425
Flight Attndnt	71	647	17	92	75	88	10	12	1,257,360	571,700	1,829,060
Food Service	12	104	2	11	14	5	1	3	170,647	92,780	263,427
Fueler	0	16	1	2	2	6	0	0	52,835	15,830	68,665
Mechanic	15	217	12	23	47	29	0	11	482,330	218,590	700,000
Passngr Service	13	174	4	16	24	27	6	6	171,850	160,720	332,570
Ramp Service	39	492	21	71	73	59	11	21	767,671	499,810	1,217,481
Skycap	1	24	3	4	1	0	0	1	9,745	22,350	32,095
Storekeeper	2	29	1	1	1	3	0	3	54,970	24,890	79,860
Unknown	8	143	11	10	23	37	3	3	229,764	143,764	372,784
TOTAL	162	1889	77	240	267	271	31	65	3,272,005	1,748,990	5,021,995

In Table 4.4 an analysis of the impact of strength testing is presented for the total sample. Strength testing had an impact on both the incidence of injury ($F=3.03$, $P<.08$) and the days lost due to injury, ($F=7.2$, $P<.01$). When analyzed by part of body injured, strength testing was shown to significantly reduce the incidence and severity of non-back injuries (when grouped together) especially ankle injuries; and to significantly reduce the severity of back injuries.

In Table 4.5 the impact of strength testing is documented by occupation. It should be noted that only the flight attendant group has an adequate sample size. Strength testing was shown to significantly reduce the incidence of injuries for flight attendants by 50% and days lost by 75%. Strength testing was also shown to be equally effective in reducing injury and days lost for male and female flight attendants. The reader will also notice encouraging trends, though not statistically significant, for ramp service. The results for passenger service, food service and maintenance lack adequate sample size at this time.

TABLE 4.4

IMPACT OF STRENGTH TESTING BY BODY PART

Part of Body	Injury Per 100 Man Years			Lost Days Per 100 May Years		
	Qualified (N=905)	Not Strength Tested (N=2525)	Partial F	Qualified	Not Strength Tested	Partial F
Back	1.7	1.8	0.61	9.3	21.7	4.21**
Arm	0.2	0.2	0.51	1.9	1.3	1.17
Shoulder	0.4	0.3	0.44	2.2	4.3	1.08
Groin	0.0	0.0	0.02	0.0	0.1	0.02
Leg	0.1	0.1	0.05	1.2	0.3	1.39
Knee	0.1	0.1	0.66	2.5	1.9	0.00
Elbow	0.0	0.0	-	0.0	0.0	-
Ankle	0.1	0.4	5.20**	0.4	4.6	3.27*
All injuries but back	0.8	1.3	3.96**	7.7	13.1	3.27*
TOTAL INJURIES	2.6	3.2	3.03*	17.0	34.9	7.24***

*p<.10. **p<.05. ***p<.01.
(Note: Partial F= adjusted for age and occupation).

TABLE 4.5

IMPACT OF STRENGTH TESTING ON NEW HIRE INJURY AND DAYS LOST BY OCCUPATION

Occupation	Number		Injury Per 100 Man Years			Lost Days Per 100 Man Years		
	Qual	NT	Qualified	Not Strength Tested	F	Qualified	Not Strength Tested	F
Flight Attendant	615	927	2.6	5.0	5.28**	14.7	63.3	7.29***
Males	176	216	1.6	4.4	3.15*	15.4	64.1	2.87*
Females	439	711	2.9	5.2	2.85*	14.5	63.0	4.76*
Food Service	57	596	3.0	1.3	2.36	16.6	14.2	0.01
Mechanic	16	206	3.2	3.9	0.17	19.2	35.7	0.71
Passenger Service	73	318	1.1	1.1	0.00	30.8	5.9	2.79
Ramp Service	137	460	2.0	2.8	0.33	15.4	33.2	0.88

*p<.10. **p<.05. ***p<.01.
(Note: Qual = Qualified; NT = Not Tested).

Conclusion

Occupational strain/sprain injuries result in approximately 8,250 lost man days each year at a cost of $1.25 million a year at United Airlines. The majority of these injuries are back injuries (63%).

The use of static strength testing in preemployment selection will significantly reduce the incidence and severity (days lost) of injury as well as the cost of injury for at least the first four years of an employee's career in physically demanding occupations as demonstrated over the period of this study.

It is estimated that strength testing will reduce the incidence of injury in physically demanding occupations 20% (up to 50% among flight attendants) and days lost by 50% (up to 75% for flight attendants). Considering the fact that non-strength tested subjects were composed of individuals who would have passed and those who would have failed strength testing, then we can conclude that these estimates of the impact of strength testing on injury are conservative. If United were to institute strength testing as a condition of employment in physically demanding occupations then the estimated savings in terms of medical and salary costs (in 1980 dollars) would be well in excess of one half million dollars per year.

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