Isometric Strength Testing as a Means of Controlling Medical Incidents on Strenuous Jobs

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This investigation was performed to determine if isometric strength tests can be used to select workers for strenuous jobs and to reduce occupational injuries which are caused by a mismatch between worker strength and job strength requirements. Twenty jobs in a tire and rubber plant were studied biomechanically to identify critical strength-demanding tasks. Four strength tests were designed to simulate these tasks, and performance criteria were established for passing the tests. New applicants were administered the tests during their preplacement examinations to determine if they possessed sufficient strength to qualify for the jobs. The medical incidence rate of employees who were selected using the strength tests was approximately one-third that of employees selected using traditional medical criteria. It was concluded that isometric strength tests can be used to reduce occupational injuries and should be considered for implementation in industries with strenuous jobs.

Mechanization and automation have significantly reduced the demands for human strength in the modern industrial environment. Nonetheless, muscular power remains an essential input to many occupations, particularly those involving handling of materials or maintenance work.[1] In these activities, the moving of heavy loads and the manipulation of tools and equipment produce high stresses which can result in serious injuries and illnesses. The National Safety Council reports that the leading cause of work injuries in the United States is the lifting, pushing, pulling and carrying of objects.[2] Recent epidemiological studies have demonstrated a strong correlation between manual handling activities and muscular-skeletal disorders, particularly problems of the lower back.[3-7] Furthermore, recent legal decisions indicate that these disorders may be compensable under the concept of cumulative injury.[8]

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It is apparent from the above discussion that manual handling activities present serious occupational health problems. Ideal solutions to these problems are to redesign jobs and to provide mechanical assists to workers in order to reduce wear and tear on their musculo-skeletal systems. However, the installation of mechanical aids requires extensive engineering redesign and may be limited to new facilities which are being planned or are in the early stages of construction. In situations where plant modification is infeasible, a realistic *and interim* alternative is to establish a program for selecting qualified workers for strenuous jobs.

This investigation was undertaken to develop and evaluate a system for employee selection based on isometric strength tests. The specific objectives of this study were as follows: (1) to use biomechanical models of human strength to identify critical elements of stressful jobs, and isometric strength tests to measure workers' strengths in simulations of those critical elements; (2) to assign workers to stressful jobs based on their performance on the strength tests; and (3) to evaluate the effectiveness of strength testing in reducing medical incidents.

A schematic representation of the employee selection system described herein is presented in Fig 1. An important feature of this system was that it required quantitative measures of both job requirements and employee strength. Details on the operation of this system are presented later in this paper.

Why Isometric Tests?

Employee selection programs have been used by industry for many years, and various medical procedures have been suggested for evaluating a person's ability to safely handle heavy loads. Traditional procedures range from clinical impressions based on features easily observed in a physical examination (e.g., age, gender, somatotype, muscular atrophy and skeletal anomalies) to

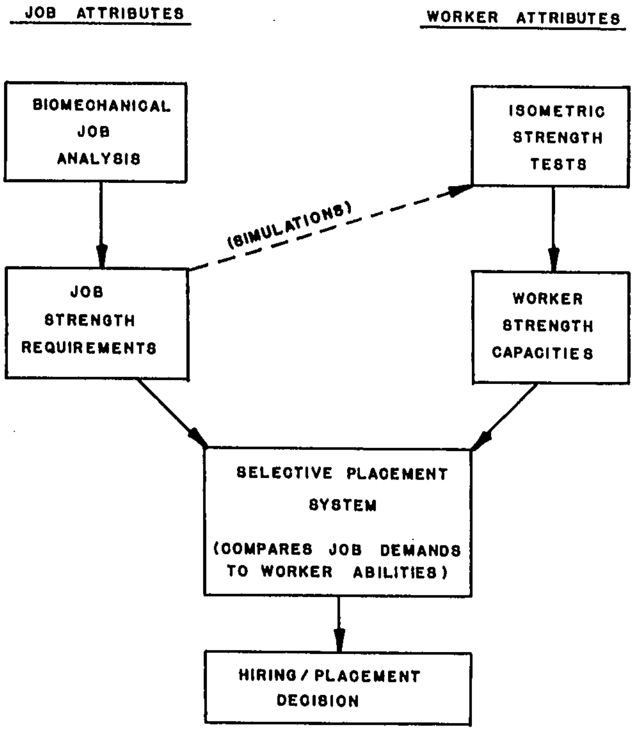

Fig 1. — Strength testing selective placement system.

sophisticated radiographic evaluations of the lower back.[6] Isometric strength testing was chosen for this investigation because it meets the following criteria established by Chaffin.[9]

Safety. — Any procedure used to select employees must be safe and should pose no hazard to the subject. Isometric strength tests have been proven safe in several earlier studies.[10-13] Over 3,000 workers have been tested using procedures recommended by the AIHA,[14] with no reported injuries.

Relationship to Job Requirements. — Current Federal legislation concerning equal employment opportunity requires that any employee selection test be related to the job being sought.[15,16] The exact nature of the physical tasks required of a worker determines the specific personal attributes which are important. Earlier studies have shown that strength in one working posture cannot be used to accurately predict strength in another.[6,14,17] The strength tests used in this investigation were carefully designed to simulate strenuous job elements, as will be pointed out later.

Reliability. — Isometric strength tests yield quantitative scores of a person's physical strength. These scores have been shown to be reproducible, with coefficients-of-variation ranging between five and ten percent.[13]

Prediction of Future Illness or Injury. — The ultimate test of any medical selection system is its ability to predict which individuals are at the highest risk of becoming injured. Previous studies using isometric tests disclosed that workers with strength abilities insufficient to meet job demands were at an increased risk of becoming injured. In some instances, the injury frequency rate experienced by over-stressed workers was nearly three times the frequency rate of workers who were matched to their jobs.[6,9,13]

Practicality. — A complete isometric strength testing apparatus can be purchased for between $1,000 and $4,000, and a nurse or medical technician can be trained to use the apparatus during a one-day session. In previous studies,[6,13] administration of the tests required between 15 and 30 minutes per person.

Methodology

This investigation was a field study conducted in a tire and rubber plant in which 20 entry level production jobs were included. All of these jobs were known to have high strength requirements and high rates of medical incidents.

To evaluate the effectiveness of isometric strength testing, it was necessary to perform an experiment in which the medical experience of employees selected and hired on the basis of strength test performance could be compared to the medical experience of employees hired under traditional medical criteria in effect at the plant. To allow this comparison, the design illustrated in Fig 2 was implemented by plant management. Major phases of the study are described further.

Biomechanical Job Analyses and Design of Strength Tests. — The first step in data collection was to evaluate biomechanically the strength requirements of the 20 jobs under investigation. To accomplish this, a three-dimensional biomechanical strength prediction model developed at the Ergonomics Laboratory of the Universi-

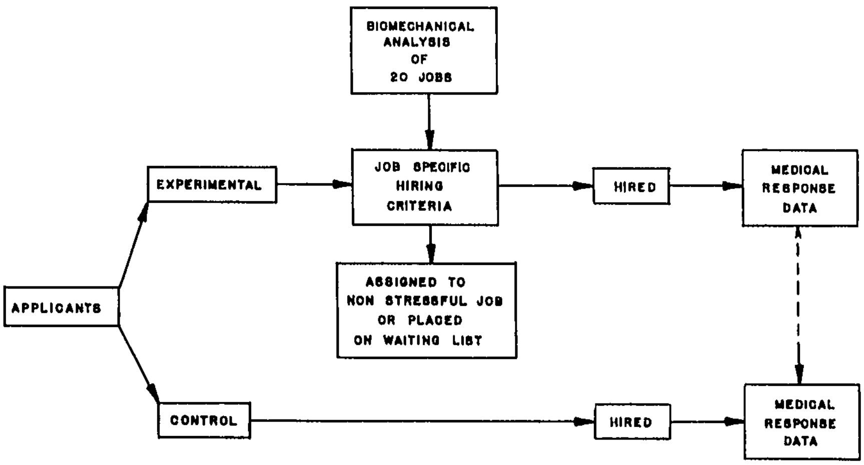

Fig 2. — Experimental design.

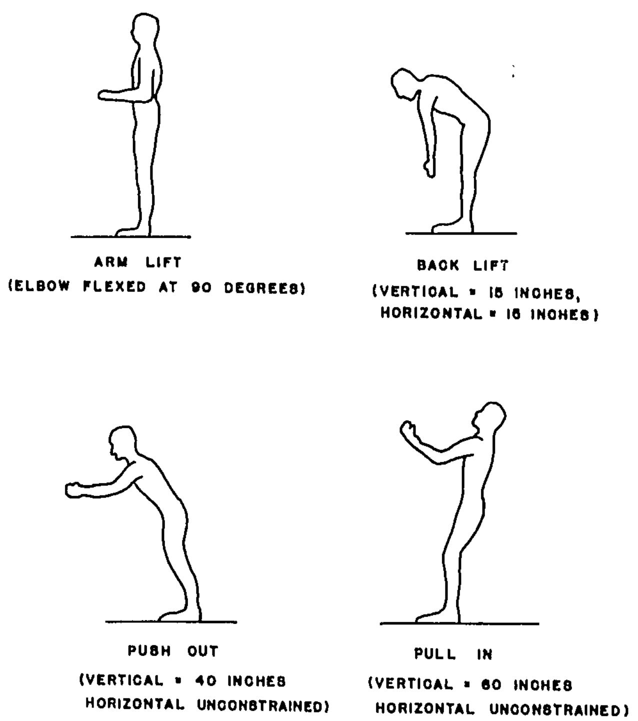

Fig 3. — Strength test postures.

ty of Michigan was used. Complete details on this computerized model are available in other studies.[18-21]

Job analyses were performed by the industrial engineering staff of the participating plant. During these analyses, each job was systematically broken down into a set of strength-demanding elements. For each of these elements, the following variables were recorded: (1) a basic description of the task (e.g., lift, push or pull); (2) a description of the body posture maintained while performing the task (e.g., stand, sit or squat); (3) the force (in pounds) which must be exerted in order to perform the task; and (4) the location of the hands in space (with respect to the feet). These data were collected for both task origin and destination, and at points judged to be most stressful during the trajectory of motion.

The data obtained in the job analyses were processed by the computerized model which predicted the percentages of males and of females capable of performing each element. These predictions were used to identify critical tasks (from the standpoint of strength) on each of the 20 study jobs. When the job analyses were completed, the strength requirements of several hundred tasks had been documented. These data were used to develop a set of four strength tests which simulated lifting and handling requirements common to all 20 jobs. These tests are illustrated in Fig 3. It was feasible to use only four tests because employees in the selected job classifications were handling similar products with similar handling equipment (e.g., hand trucks and conveyors) and work postures.

Next, job-specific performance criteria were established for passing the tests. To accomplish this, the biomechanical analysis of each job was reviewed to identify the most strength-demanding tasks occurring in the four test positions. Minimally acceptable scores for passing the tests were set equal to the forces required to perform the job (for example, if a job required a worker to lift a 30-pound tire from a conveyor, it was necessary to exert 30 pounds on the arm lift to qualify for the job). Criteria for each study job are presented in Table 1. It should be noted, however, that not every job contained tasks corresponding to all four strength-test postures. In such a case, the performance standard was set at zero for the particular posture. Further details on the design of these strength tests are available from other sources.[13]

Strength Testing. — Prior to the preemployment medical examination, all new applicants were assigned to either the control or the experimental group (Fig 2). Those designated as controls were hired solely on the basis of the results of the medical examination. During the exam, these applicants were strength-tested for documentation purposes, but the results of these tests were not used in the hiring decision. Applicants in the experimental group received the same medical examination and strength tests, but, in order to be hired, they had to exceed the strength standards established for the open job (Table 1), in addition to passing the medical exam.

If a person was not hired because of his or her failure to meet the strength requirements of the open job(s), the application was placed on a 90-day hold. During this time period, the applicant was hired into any new job opening for which he or she was qualified based on strength-test results. Once an individual had been hired, however, strength-test scores were not considered for future job transfers because of the seniority system in effect at the plant.

During the strength tests each applicant performed a sustained (five-second) voluntary isometric exertion simulating each of the four work postures illustrated in Fig 3. The final three seconds of the exertion were measured, and an average of this period was used to score performance. These procedures were consistent with the "Ergonomics Guide" recommendations issued by the American Industrial Hygiene Association.[13] In addition to strength measurements, employment and medical histories were recorded for each participant.

Table 1. — Strength Requirements (Pounds) by Job.

	Job Requirement			
Job Code	Arm	Back	Push	Pull
001-01	42	42	0	0
001-02	77	77	54	0
001-03	33	33	0	0
001-04	66	66	66	0
001-05	38	38	65	56
001-06	73	73	0	56
001-07	30	0	42	0
001-08	65	0	65	0
001-09	77	85	0	0
001-10	78	78	80	80
001-11	65	72	44	44
001-12	65	72	44	44
001-13	52	52	70	48
001-14	75	120	71	75
001-15	52	52	0	0
001-16	52	52	74	0
001-17	52	52	60	60
001-18	52	52	52	56
001-19	52	97	0	0
001-20	52	97	0	0

Table 2. — Population Descriptive Statistics.

Measure	Males (n = 54) Mean	Range	Std. Dev.	Females (n = 27) Mean	Range	Std. Dev.
Height (inches)	70.1	64-77	2.2	65.3	61-71	2.3
Weight (lbs.)	179.5	135-263	31.3	149.0	115-256	33.2
Age	28.7	18-59	8.1	32.7	21-42	5.9
Arm lift (lbs.)	87.1	42-140	20.2	50.1	28-76	13.9
Back lift (lbs.)	131.2	54-283	45.0	81.9	38-172	32.6
Push out (lbs.)	76.4	36-280	43.8	52.8	28-108	16.6
Pull in (lbs.)	117.5	65-200	35.2	75.6	46-133	21.5

Table 3. — Classification of Study Participants.

Classification	Males	Females	Total
Control	32	19	51
Control (not hired)	3	1	4
Experimental	16	4	20
Experimental (not hired)	3	3	6
Total	54	27	81

Medical Monitoring. — At the time of strength testing, the medical record of each subject was tagged to indicate participation in the study. In the future, all visits to the medical department for job-related illness or injury were reported to the investigators by the plant physician or the duty nurse. More specifically, the following items were recorded for each reportable visit: (1) complaint type (two categories) — (a) skin contact or impact or both (lacerations, abrasions, bruises, burns, etc.), (b) musculo-skeletal (strains and sprains, including disorders of the back); (2) body part affected; (3) days lost (as a result of the incident); and (4) days restricted.

Results

Eighty-one subjects (54 males and 27 females) applied for the 20 study jobs in the participating plant. Descriptive statistics (means, ranges and standard deviations) were computed for anthropologic measures (height, weight and age) and for strength scores for each gender and are presented in Table 2. A detailed demographic analysis is beyond the scope of this paper. Nonetheless, the anthropologic and strength attributes of participants in this investigation were found to be quite similar to those of steel, electronic and aluminum workers measured in earlier studies.[6,13]

A breakdown of participation by study classification and by gender is presented in Table 3. Of the 55 subjects originally assigned to the control group, four were not hired because of health problems discovered during their preemployment medical examination. The decision not to employ these applicants was independent of their performance on the strength tests. Of the 26 subjects assigned to the experimental group, six were not hired into the 20 study jobs either for medical reasons or because of poor performance on the strength tests.

During a monitoring period of approximately one year, 54 visits to the medical department were recorded for the 71 hired employees. Nineteen of the visits were due to musculo-skeletal problems. Table 4 presents a summary of incidents and exposure hours for each group. In addition, incidence rates (the number of incidents per 200,000 work hours) are given.

To test for differences in the rates experienced by the groups, the following chi-square test was used[22]:

$$\chi^2_{m-1} = \sum_{i=1}^{m} \frac{(E_i - O_i)^2}{E_i}$$

where:

χ^2_{m-1} = test statistic with (m-1) degrees of freedom

m = number of groups being compared (in this case m = 2)

E_i = expected number of incidents in group i, based on exposure hours

O_i = observed number of incidents in group i

i = 1, 2, 3, . . . m.

The values of E_i were computed with the following equation:

$$E_i = \frac{H_i \times O_T}{H_T}$$

where:

H_i = hours of exposure in group i

H_T = total hours of exposure across all groups

O_T = total observed incidents across all groups

A restriction on this test is that the expected number of incidents in each group (E_i) must exceed 2.5.[23]

Table 4. — Incidence Rates for Control and Experimental Employees.

Group	No.	Exposure Hours (x 1000)	All Medical Visits Obs.	Exp.	Rate	χ^2 Test Stat (sig)	Musculo-Skeletal Visits Obs.	Exp.	Rate	χ^2 Test Stat (sig)
Control	51	31	52	48.1	335.4	2.89	19	16.92	122.6	*
Experimental	20	4	2	5.9	100.0	(0.10)	0	2.08	0	
Total	71	35	54	—	308.6	—	19		108.6	

* Expected visits insufficient to compute test statistic

When all medical visits were considered, the incidence rate for the control group was observed to be over three times the incidence rate for the experimental group. Using the chi-square test presented above, this difference was found to be marginally significant ($p < 0.10$). It is interesting to note that when only musculo-skeletal visits were considered, it was found that none of these incidents was suffered by the experimental group. Because of the small expected value, however, a statistical analysis was not feasible. Regardless of the scheme used for classifying incidents, workers hired on the basis of the strength-testing system suffered fewer incidents than those hired using the traditional medical criteria.

(It should be noted that the results given in Table 4 are based only on exposure to the 20 study jobs. Existing labor agreement within the plant prohibited intervention for experimental purposes in job transfers. For this reason, many of the study participants were assigned for part of the monitoring period to jobs which were not included in the strength-testing investigation. Medical incidents and exposure hours on these jobs were not included in the analyses presented here.)

Discussion

This study reinforces the findings of earlier studies[6 10 14] which show that strength is a human attribute that: (1) can be quantitatively measured, and (2) can protect a person from becoming injured when performing a strenuous job. Furthermore, it demonstrates that a systematic employee selection/placement program, based on biomechanical job analysis and isometric strength tests, can be used to control occupational injuries which result from a mismatch between worker strength and job requirements. A comprehensive evaluation of this study cannot be made without longer term exposure to job stresses and follow-up medical data. Serious health problems, particularly those affecting the lower back, may only become apparent after extended assignment to a stressful job. Nonetheless, the preliminary results indicate that strength testing can be used to control some of the costs and human suffering associated with the injuries and illnesses which arise in the course of manual handling activities.

A comprehensive strength-testing program, similar to the one used here, is recommended for industries whose jobs require a significant degree of manual materials handling. An important part of such a program is the biomechanical job analysis phase. These analyses identify and isolate job elements which place high strength demands on the work force. Once these elements have been identified, it may be possible to design and implement engineering controls to reduce strength demands and to create a safer working environment.

As stated in the opening paragraphs, the ideal solution to the manual materials handling problem is to redesign stressful jobs so that they will accommodate the physical capabilities of the work force. After this has been done, selection procedures will not be needed as it would be reasonable to assume that practically all applicants could safely and effectively perform all jobs. In the near future, however, this goal may not be technologically or economically feasible in all industries. Selective placement programs provide a realistic alternative, as long as they meet the criteria discussed previously. Based on the findings of this and earlier studies,[6 11] isometric strength testing is an effective and valid tool which can be used by industry as part of an employee selection and placement program.

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