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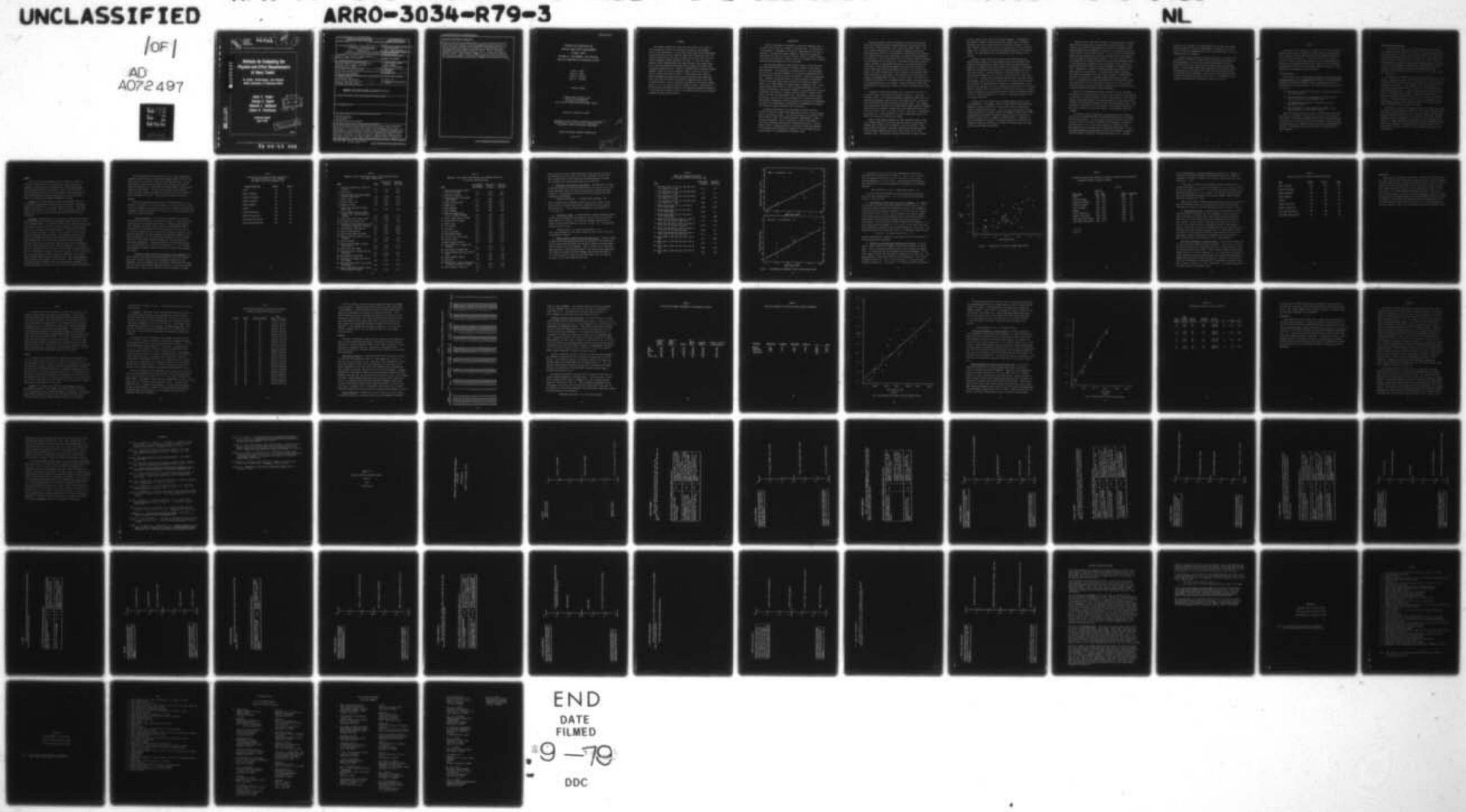

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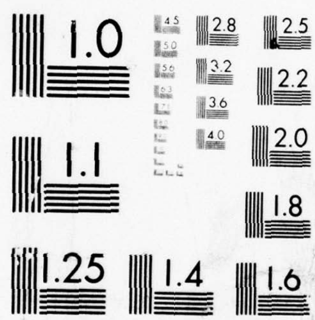

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Methods for Evaluating the Physical and Effort Requirements of Navy Tasks:

Metabolic, Performance, and Physical Ability Correlates of Perceived Effort

Joyce C. Hogan
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Technical Report
April 1979

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Two studies examined the reliability and validity of an index of perceived physical effort for assessing the metabolic and ergonomic costs of task performance. In each study, tasks whose actual performance costs were either available from work physiology literature or were calculated mathematically were rated by subjects who had no work cost information on physical effort required in the task. In the first study, subjects (N=50) completed pencil and paper ratings of tasks whose metabolic costs were known using physical ability dimensions and the index of perceived physical effort. Results indi-

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cated high correlations between metabolic costs and ratings of physical effort as well as ratings of various strength and stamina factors. In the second study, subjects (N=20) performed 24 diverse manual materials handling tasks whose ergonomic costs were calculated and rated each completed task on the index of physical effort. Results indicated a substantial relationship between actual ft.-lbs. of work and ratings of physical effort. Implications of the results are discussed in terms of the inherent psychometric properties of the index and its applied utility for determining criterion performance standards and job-related training.

ARRO-3034-R79-3

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TECHNICAL REPORT

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ABSTRACT

Two studies examined the reliability and validity of an index of perceived physical effort for assessing the metabolic and ergonomic costs of task performance. In each study, tasks whose actual performance costs were either available from work physiology literature or were calculated mathematically were rated by subjects who had no work cost information on physical effort required in the task. In the first study, subjects (N=50) completed pencil and paper ratings of tasks whose metabolic costs were known using physical ability dimensions and the index of perceived physical effort. Results indicated high correlations between metabolic costs and ratings of physical effort as well as ratings of various strength and stamina factors. In the second study, subjects (N=20) performed 24 diverse manual materials handling tasks whose ergonomic costs were calculated and rated each completed task on the index of physical effort. Results indicated a substantial relationship between actual ft.-lbs. of work and ratings of physical effort. Implications of the results are discussed in terms of the inherent psychometric properties of the index and its applied utility for determining criterion performance standards and job-related training.

INTRODUCTION

Effective assignment of personnel to physically demanding jobs in the Navy must be based on a number of considerations. A prerequisite to assignment is knowledge of the physical requirements of the jobs in question. Existing job analysis methods for measuring the physical requirements of jobs are, at best, limited. There is a need to develop and evaluate an objective, reliable, and valid assessment tool to measure physical work associated with task performance.

An increasing amount of recent research focuses on the idea that perceived physical effort may be a critical variable in the study of work behaviors. The estimation of required effort of task performance may serve as an important component of job analysis methodology and in the description of work structure, particularly in physically demanding work. However, the problem exists in integrating what is known about the effort concept from various disciplines to develop and support a generic, but robust method for studying physical demands of work. Work physiologists regard effort in terms of energy expenditure and it is usually expressed as a respiratory, metabolic, or cardiovascular variable. Ergonomists and industrial engineers consider effort in terms of work output variables including motions used, time elapsed, fatigue factors, and weight, distances and volume characteristics of materials handled. Psychologists interested in effort and perceived exertion have approached the study using experimental investigations of psychophysical responses and scaling of related variables such as difficulty.

Successful development of any assessment tool must take into account the empirical regularities known about the basic concept regardless of discipline of study. The idea that measures of perceived effort could serve as a basis for assessing physical requirements of jobs is virtually unexplored. This is surprising in light of the number of disciplines concerned with both work performance and effort. We have drawn on what is known about effort from several fields and attempted to link empirically perceptions of physical effort with physical work costs by means of a psychophysical assessment index.

The most systematic research conducted in the area of perceived effort and exertion has been by Gunnar Borg and his associates at the University of Stockholm (Borg, 1970; 1972; Borg & Noble, 1974). This basic research investigates the relationship between perceived and actual physical effort in task performance. Specifically, the research has examined how accurately individuals can perceive information about actual physical costs of performing work in relation to objective measures of physiological costs of that work. The major finding from a series of studies relevant to the present discussion, is that when subjects are instructed to rate verbally the degree of exertion they perceive at various times while performing physical work (e.g., on a bicycle ergometer), the verbal ratings are a direct function of the metabolic costs (Borg and Dalstrom, 1959; 1960). Borg describes this relationship of ratings and expended physical effort as fairly linear. He reports correlations on the order of .80 between verbal ratings of perceived exertion and measured heart rate, for example. Several additional studies have replicated this finding with a variety of tasks and measures (Borg, 1970; 1972).

A number of rating scale methods exist for obtaining estimates of perceived exertion and these are reviewed elsewhere (cf. Hogan and Fleishman, 1979). The category methodology developed by Borg (1972) has received considerable research use and has become central to studies of heart rate prediction while performing laboratory tasks. This category scaling procedure, Ratings of Perceived Exertion (RPE) contains 15-graded steps from 6 to 20, where alternate steps are anchored with verbal descriptions such as "very, very light" or "very, very hard." The numerical range used (i.e., 6-20) was chosen in order to match the variation in heart rate from 60 to 200 beats per minute.

There is some debate regarding the most appropriate type of scale to use, modifications of the scale typically result in very minor differences (Borg, 1977; Arstila, Wenderlin, Vuori and Valinski, 1974). Despite these differences, very high reliabilities have been reported using the RPE or modifications (Borg, 1977; Arstila et al.,1974; Stamford, 1976). Reliability has been established in terms of consistency or stability over time and interrater agreement. Consequently, the weight of evidence from Borg and others suggests that individuals performing tasks can reliably report the subjective estimates of exertion. Moreover, the data from the actual psychometric scale applications suggest that a definable function exists between subjective and physical forces. This relationship has a large bearing on the validity of the ratings.

Evidence for the validity of ratings of perceived exertion has resulted from a number of studies examining the relation between rated exertion and physiological criteria such as heart rate and oxygen consumption. For example, Borg (1962) reports a correlation of .85 between heart rate and RPE when the workload on a bicycle ergometer was varied from light to heavy. Similar findings are reported by Arstila, et al., 1974; Borg and Linderholm, 1967; Skinner, Borg, and Buskirk, 1969; and Bar-Or, 1977. Although high correlations between heart rate (HR) and RPE are reported, some of the above studies were criticized on the basis that work intensity was experimentally increased in a stepwise manner, which could bias the ratings in a similar manner and yield correlational artifacts. However, Stamford (1976) used several different work tasks (e.g., treadmill running and walking, stool stepping, bicycle riding) and different workload levels in a random presentation. He reports correlations between .74 and .90 between RPE and HR.

Additionally, some studies have used physiological indices other than absolute HR. For example, Pavlina (1975) reported that relative HR (amount of increase relative to a resting level) was correlated more highly with RPE than absolute HR. Noble and Borg (1972) report a linear relation between RPE and oxygen uptake; and Gamberale (1972) found linear relationships using oxygen consumption and blood lactate production in addition to heart rate in a number of different tasks. In general, it can be concluded that ratings of perceived exertion are related to physiological indices of exertion in a variety of different physical tasks and over a wide range of workloads.

The second line of validity evidence for perceived exertion ratings comes from the studies that correlate RPE and physical output. In the research cited above, the psychophysical scaling studies determined the function between the psychophysical response (i.e., subjective exertion) to the stimuli of actual physical force. In the studies of the relation between RPE and physiological variables, workload was varied systematically to produce the physiological changes. Thus, the ratings of perceived exertion are related functionally to such task performance indices as load and duration (Cafarelli, Cain, and Stevens, 1977), speed and grade of walking or running, or bicycle ergonometric estimates of workload. Additionally, a number of applied studies have related RPE to work capacity or productivity. For example, Borg (1962) correlated work capacity estimates of RPE with piece-rate wages of lumber workers. He found a correlation of .54 between wages and rated work capacity (RPE = 17), whereas the correlation between wages and actual work capacity (workload at HR of 170 beats/min) was only .28. Thus, perceived exertion ratings are not only related to physiological indices, but also to the actual task difficulty or task performance.

Much of this research has not been integrated into any systematic determination of job requirements nor has it been translated into standards for personnel. A major limitation of these investigations is that they are largely a laboratory endeavor, although measurement of such effort has implications for objective assessment of jobs involving physical work. Such a measure is tied logically to any analysis of the physical abilities of jobs and if applied in a real world setting, its usefulness should be increased.

The present research problem was to develop perception of physical effort into an accurate and useful assessment methodology for evaluating physical work demands. It was necessary to demonstrate that individuals can rate reliably the amount of physical effort necessary in task performance and that these ratings have validity for predicting actual physiological and performance costs of performing those tasks. A valid assessment methodology would provide the basis for answering a number of critical questions concerning individual differences (e.g., strength, stamina, sex, training) in the requirements of such tasks, for establishing standards of physical requirements for different jobs on the basis of tasks, for sequencing work, and for grouping tasks in terms of common physical requirements.

The two studies presented evaluate the utility of an index of perceived physical effort to predict reliably work costs associated with task performance. Further, these studies investigate the role of physical factors which account for the rating variance of perceived effort. In each study subjects were required to rate physical effort they perceived for individual tasks about which they had no metabolic or performance cost information. These ratings were analyzed in terms of their relationship to actual work costs of task performance and to components accounting for the physical nature of the tasks.

STUDY 1

The purpose of this study was to investigate (a) the relationship between ratings of perceived physical effort and tasks of known metabolic differences and (b) the physical ability dimensions associated with tasks rated as effortful. The tasks selected for study were limited initially to those whose metabolic costs had been determined previously by work physiologists and were reported in the literature. Of these tasks, a final set of tasks were chosen on the basis of high probability of performance by Navy personnel.

Literature Review

A literature search of Psychological Abstracts, National Technical Information Service, and Ergonomics were reviewed for the terms energy expenditure, effort physiological indices, perceived exertion, etc. Relevant articles were obtained and classified according to the following criteria:

(a) the rating or psychophysical scaling of perceived effort and perceived exertion

(b) the actual physiological measurement of energy costs of various laboratory and occupational tasks

(c) the methodological concerns of developing indices of physiological costs

(d) the differences in energy expenditures between various subpopulations (e.g., sex, age, training)

Based on information from the search, a task bank was developed containing task statements that were most likely to be performed in Navy ratings. These task statements specified the relevant parameters of the task such as duration, distance, and weight of objects as well as the physiological or metabolic costs associated with performance of the task. The completed task bank consisted of approximately 150 task statements.

NOTAP Review and Interface

After a NOTAP briefing, selected NOTAP Occuational Analyses and Task Inventories were obtained for review. The documents acquired and considered essential were for the following ratings: Hull Maintenance Technician, Ship Serviceman, Builder, Steelworker, Gunners Mate, Fire Control Technician, Machinist Mate, Boatswain Mate, Electrician Mate, Torpedoman Mate, Tradesman, Mineman, Mess Management, Missle Technician, Aviation Structural Mechanic, Storekeeper, Aviation Machinists Mate, Aviation Support Equipment Technician, Equipment Operator, and Engineman. The NOTAP task data were used to select the relevant tasks for future study.

The NOTAP task information presented two limitations for the current project. Occupational briefs, task information that is verified by personnel performing in that rating, were available for only five ratings reviewed in the project. In the absence of this verification, the assumption was made that the tasks listed in the Task Inventories were performed by Navy ratings. A second limitation concerned the level of detail of the NOTAP task statements. Many of them were couched in a generic format that prohibited inferences about the physical demands of the work. Statements prefaced by verbs such as "install/repair" and delimited by no quantitative information require the reader to make broad inferences about the nature of the work.

Therefore, in light of the incomplete nature of the Navy task data available, the task statements chosen for further study represented tasks that might be performed across a wide range of ratings. The interface between the NOTAP review and the task statements contained in the bank developed initially resulted in 48 statements. These statements were edited to a common format which eliminated jargon and emphasized action, tools, and/or product. The ultimate goal of items included in this interface was to select relevant items that spanned the range of perceived effort.

Method

Using the task bank developed, ratings of physical effort and physical abilities required in performing the tasks listed were obtained. The objective was to determine the relationship between perceived physical effort and metabolic costs of task performance and to determine the physical ability components of perceived effort. These data provided an initial validation of an index of physical effort for assessing performance requirements of tasks.

Subjects. The rater sample consisted of 50 students from the University of Maryland and the Johns Hopkins University. Participants ranged in age from 16 to 52; the mean age was 25.2 years. There were 22 males and 28 females in the study. Raters had little or no knowledge of job analysis techniques and were paid $2.50 for their participation.

Procedure. Each subject was given a packet of materials containing a Physical Abilities Analysis Manual (Fleishman, 1978), instructions, and a set of response sheets. The written instructions described the rating task, procedures for using the Physical Abilities Analysis, and rating problems of halo, leniency, and central tendency. The Physical Abilities Analysis Manual consisted of scales for rating Effort, Static Strength, Explosive Strength, Dynamic Strength, Trunk Strength, Stamina, Extent Flexibility, Dynamic Flexibility, Gross Body Equilibrium, and Gross Body Coordination. For Effort and each physical ability the Manual provided a definition, distinctions among abilities, and a seven-point unipolar scale for determining the rating (see Appendix A). A response sheet was constructed for rating tasks on Effort and each separate physical ability. There were two forms of the response sheets. Form M contained the task items associated with Mets values (i.e., metabolic rate), and 15 manual material handling items (see Appendix B). Mets is work metabolic rate divided by basal metabolic rate per minute. Form K contained the same manual material handling items, but contained task statements that had been measured with reference to Kilocalories per minute (see Appendix C).

Using one physical ability rating scale at a time, subjects were required to rate the tasks listed on the response sheet in terms of the amount of ability (or Effort) necessary to perform the task. Ratings were made on a seven point scale where seven indicated the greatest amount of the ability (or Effort) any task could require, and one represented the least amount. The same tasks appeared on each response sheet, and when a subject completed ratings on one ability (or Effort), he/she proceeded to the next. Subjects were allowed to omit items.

Results

The data in the present study consist of 19,800 ratings (i.e., 10 abilities x 30 subjects x 40 task statements for Form K, and 10 abilities x 39 task statements x 20 subjects for Form M). A number of analyses were completed to address questions of rating reliability, rating validity, and individual rating differences.

Rater reliability. The reliability coefficients for each of the physical ability scales are presented in Table 1. These reliability coefficients are intraclass correlations, and represent the extent of rater agreement (cf. Winer, 1975, p. 285). As can be seen in Table 1 the reliability coefficients for Form M ranged from .68 in the rating of Explosive Strength to .95 in the rating of Dynamic Flexibility. The median reliability for Form M was about .88, and the reliability of the Effort ratings was .75. The reliability coefficient in Form K ranged from .66 in the ratings of Static Strength to .92 in the ratings of Gross Body Coordination. The median reliability coefficient was about .82, and the reliability of the Effort ratings was .71. Thus, ratings were adequately reliable, some of the abilities received more agreement than others.

Validity of effort and ability ratings of task statements. The major research issue involved the determination of the extent to which naive raters could estimate the actual metabolic demands of a task statement. The actual demands were estimated by Kilocalories per minute, Mets, and the actual weight or operation involved in the manual materials handling tasks. Tables 2 and 3 present the task statements, the mean

Table 1

Reliability Coefficients of Rater Agreement of the Physical Abilities Scale Ratings for Each of the Task Statement Forms

Physical Ability	Form M	Form K
Effort	.75	.71
Static Strength	.70	.66
Explosive Strength	.68	.81
Dynamic Strength	.87	.84
Trunk Strength	.83	.74
Stamina	.92	.74
Extent Flexibility	.90	.83
Dynamic Flexibility	.95	.85
Gross Body Equilibrium	.93	.83
Gross Body Coordination	.94	.92

Table 2

Metabolic Costs, Mean Effort Rating, and Standard Deviations for Items in Mets Scale

Item	Mets	Mean Effort Rating	Standard Deviation
1. Sit at a desk and use a hand calculator	1.5	1.15	0.37
2. Drive a car	1.5	1.75	0.64
3. Use hand tools for light assembly work or radio repair	1.8	1.90	0.72
4. Drive a truck	1.8	2.90	1.33
5. Draft a floor plan	2.0	2.00	1.62
6. Operate a crane	2.5	3.60	1.50
7. Scrub, wax, and polish floors, walls, etc.	2.7	4.45	1.39
8. Drive a heavy truck or tractor trailer rig, including some unloading	3.0	4.55	1.47
9. Sand floors with a power sander	3.0	3.80	1.51
10. Cut wood with a power saw	3.0	3.30	1.49
11. Assemble or repair heavy parts such as machiner, plumbing, or motors	3.0	4.50	1.36
12. Stock grocery store shelves	3.0	2.60	0.82
13. Perform light welding	3.0	3.60	0.88
14. Jerk or pull ropes or cables	3.5	4.30	1.56
15. Crank up dollies, jacks, or hitch trailers	3.5	4.30	1.62
16. Lay tile floors	4.0	2.65	1.22
17. Paint, hang wallpaper, perform masonry work	4.0	4.75	1.52
18. Carry trays and dishes	4.2	2.90	1.41
19. Work on interior construction and finishing	5.0	4.25	1.02
20. Cut wood with a hand saw	5.5	4.40	1.31
21. Construct or remodel the exterior of a house	6.0	5.35	1.27
22. Work with heavy tools (e.g., picks or shovels)	8.0	5.15	1.04
23. Push or move heavy objects such as file cabinets or desks	8.0	5.15	1.18

Table 3

Metabolic Costs, Mean Effort Ratings, and Standard Deviations for the 25 Kilocalorie Items

Item	Kilocalories Per Minute	Mean Effort Rating	Standard Deviation
1. Type with an electric typewriter at 40 wpm	1.3	2.10	1.37
2. Sew with a machine	1.6	1.90	0.99
3. Wind electrical wire around small spools	2.2	2.00	1.11
4. Crank with both arms	2.3	4.90	1.24
5. Sweep floors	2.6	2.57	1.04
6. Peel potatoes	2.9	1.80	1.03
7. Clean windows	3.0	3.00	1.08
8. Work with sheet metal (i.e., cutting, fitting)	3.0	4.03	1.38
9. Hoist a shelf with a pulley	3.3	3.13	1.17
10. Scrub floors on knees	3.4	4.10	1.30
11. Clean a gun	3.7	1.90	0.84
12. Iron clothes	4.0	1.97	0.81
13. Cut grass	4.3	3.57	1.13
14. Hoe in a garden	4.4	3.63	1.40
15. Wring wash by hand	4.4	3.30	1.12
16. Lift up a car with a jack	4.5	3.53	1.55
17. Polish a floor	4.8	3.30	1.21
18. Beat carpets and mats	4.9	3.60	1.27
19. Load chemicals or cement into a mixer	6.0	4.93	1.51
20. Carry boxes of ammunition	6.3	4.70	1.64
21. Push a wheelbarrow with a 220 lb. load	7.0	5.87	1.04
22. Tend a heating furnace	7.0	3.37	1.42
23. Load coal	7.5	4.97	1.30
24. Shovel 20 lb. load a distance of 1 yard at 10 throws a minute	8.0	5.97	1.07
25. Dig a trench in clay soil	8.5	5.53	1.14

effort ratings, and the standard deviations of the ratings, as well as the metabolic and caloric costs of the task statements in Form M and Form K, respectively, Table 4 presents the manual materials handling task statements and the associated descriptive statistics.

1. Prediction of Kilocalories per minute. The mean ability ratings and the mean Effort ratings were correlated with the caloric cost of the 25 task statement items; the resulting correlation coefficients appear in Table 5. The prediction of the caloric cost of the tasks was best estimated by the equation:

Predicted Kcal/minute = 1.12 (Mean Effort Ratings)- .04

Figure 1 presents the scatterplot of the actual caloric costs of the tasks plotted on the mean rated Effort, along with the least-squares lines of best fit. The correlation represented in the scatterplot is $r = .75$ ($p < .01$).

2. Prediction of Mets. The mean ability ratings and the mean Effort ratings were correlated with the metabolic costs for the 23 task statements contained in Form M. The correlation between the mean Effort ratings and the actual metabolic costs was .72 ($p < .01$). The predictive equation of best fit was:

Predicted Mets = .97 (Mean Effort Ratings) - .26

Again, the scatterplot of the actual metabolic costs on the rated Effort is presented in Figure 1.

3. Manual material handling difficulty prediction. The mean ratings for each of the nine physical abilities and the mean Effort ratings were used to predict both the weight and the manual materials handling operation involved in the task statement. That is to say, the 15 items were coded according to the reference weight in the item and also dummy coded with respect to whether the task statement required the performer to (1) lift and carry, (2) reach over and behind and lift, (3) reach up and lower, or (4) reach under and pull out.

Table 4

Means and Standard Deviations
for the Manual Materials Handling Items

Item	Mean Effort Rating	Standard Deviation
1. Lift and carry a 30 lb. box from the floor to a table 15 ft. away	3.32	1.17
2. Lift and carry a 50 lb. box from the floor to a table 15 ft. away	4.72	1.14
3. Lift and carry a 70 lb. box from the floor to a table 15 ft. away	5.48	1.25
4. Lift and carry a 90 lb. box from the floor to a table 15 ft. away	6.20	1.05
5. Reach up and lower a 10 lb. box from a 5 ft. high cabinet	2.48	0.86
6. Reach up and lower a 30 lb. box from a 5 ft. high cabinet	4.00	1.11
7. Reach up and lower a 50 lb. box from a 5 ft. high cabinet	5.18	1.08
8. Reach over and behind a table in order to lift a 30 lb. box onto the table	4.12	1.06
9. Reach over and behind a table in order to lift a 50 lb. box onto the table	5.48	1.34
10. Reach over and behind a table in order to lift a 70 lb. box onto the table	6.04	1.21
11. Reach over and behind a table in order to lift a 90 lb. box onto the table	6.44	1.07
12. Reach under a table and pull out a 30 lb. box	2.72	0.86
13. Reach under a table and pull out a 50 lb. box	3.74	1.12
14. Reach under a table and pull out a 70 lb. box	4.82	1.38
15. Reach under a table and pull out a 90 lb. box	5.42	1.28

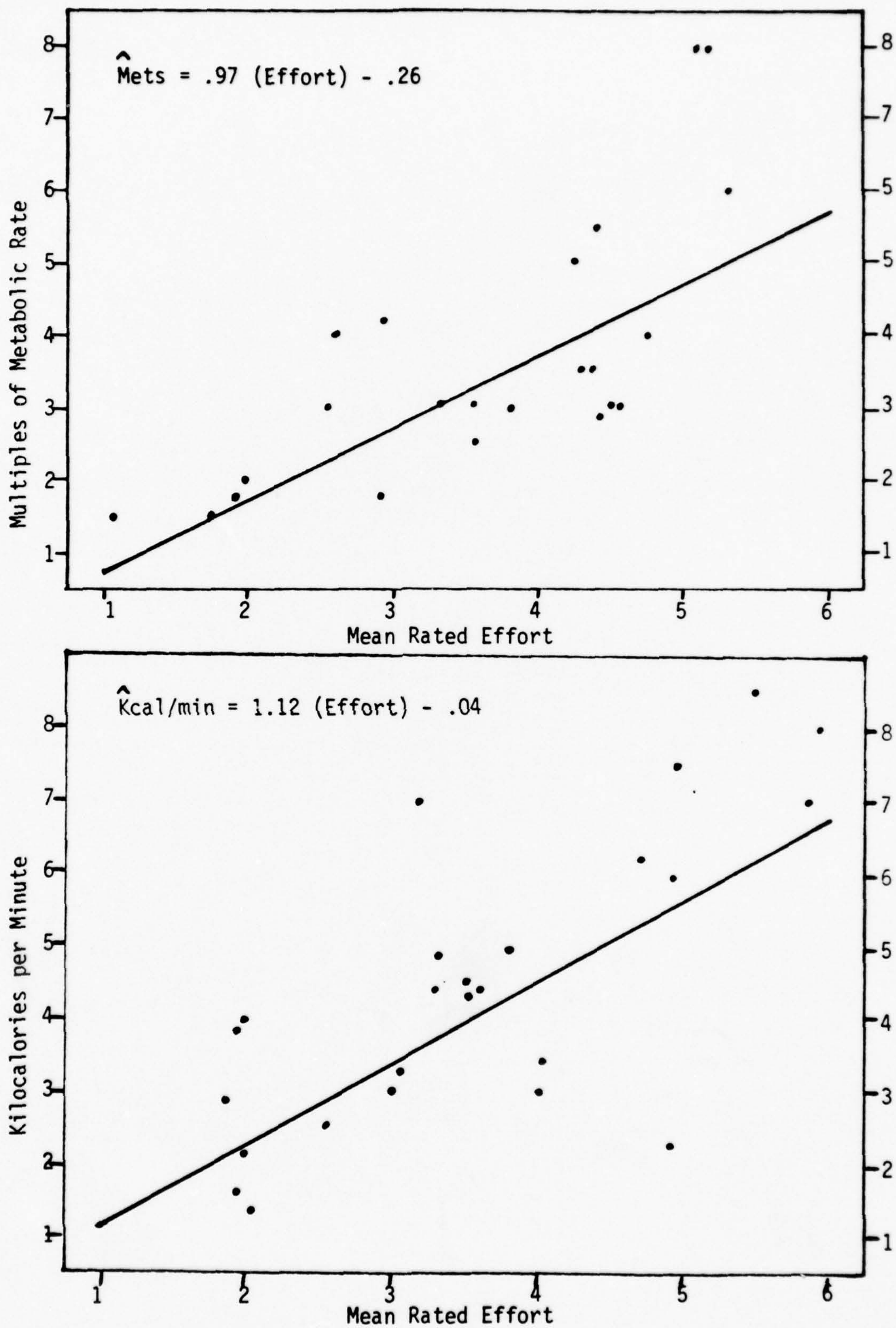

Figure 1. Scatterplot of Metabolic Costs on Mean Rated Effort

The weight of the box in the task statement was significantly correlated with the mean Effort ratings ($r = .88$, $p < .01$), as well as the four strength abilities (e.g., all r's $> .90$, $p < .01$) and the stamina component ($r = .95$, $p < .01$). The prediction of the weight of the reference box in the task statement was estimated by the following equation:

$$\text{Predicted Weight in Lbs} = 18\ (\text{Mean Rated Effort}) - 30$$

The only significant predictors of which operation was required were Gross Body Coordination ($r = .54$, $p < .05$) and Gross Body Equilibrium ($r = .50$, $p < .05$).

4. Prediction of caloric cost of all task statements. For comparison purposes, the mean ratings were combined for the two groups. Kilocalorie per minute estimates were obtained for the 23 task statements in Form M by multiplying the Mets estimate by 1.32 (which was the estimate of the Kcal/min rate at rest). Test estimates of the relation between the Kcal/min required for performance and the various ability requirements obtained were essentially averages of the Form M and Form K correlations. The most highly correlated predictors were Stamina ($r = .75$, $p < .01$) and Explosive Strength ($r = .75$, $p < .01$). Mean rated Effort was also significantly related to the Kcal/min estimates ($r = .70$, $p < .01$). The regression equation predicting the caloric cost from mean rated Effort was:

$$\text{Kcal/min} = 1.20\ (\text{Mean Rated Effort}) - .19$$

Figure 2 presents the scatterplot of the caloric costs of the 48 tasks on the mean rated Effort estimates.

5. Prediction of energy costs with physical abilities. As can be seen in Table 5, there are a number of significant predictors of energy costs. All of the physical abilities can be used to predict the energy costs. In the case of the 25 Kilocalories per minute statements, all of the strength abilities are significantly related to the caloric cost. The best predictor of the caloric cost was Trunk Strength ($r = .76$, $p < .01$); followed by Effort ($r = .75$, $p < .01$), Stamina ($r = .75$, $p < .01$), and Explosive Strength ($r = .74$, $p < .01$). In a multiple prediction framework,

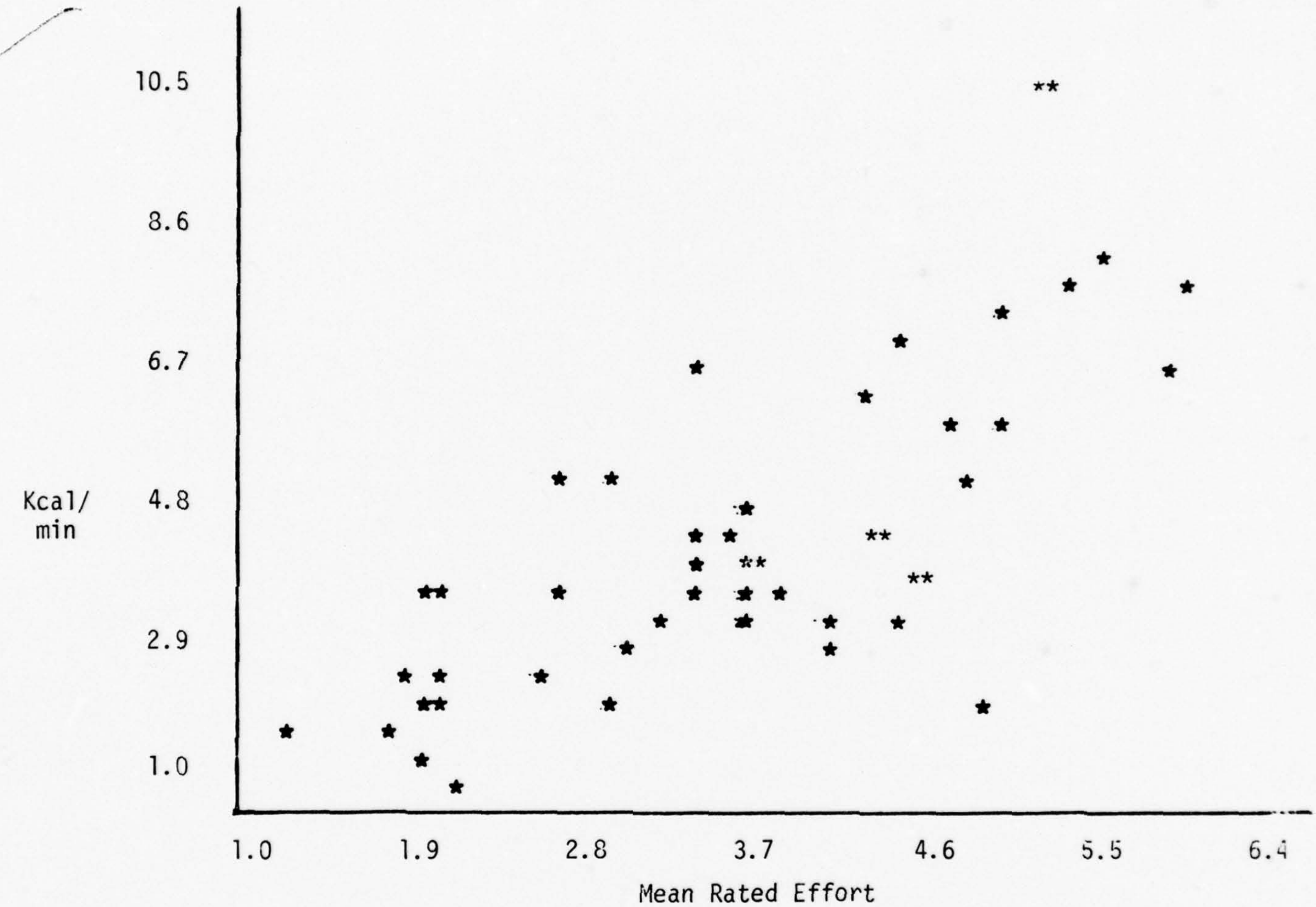

Figure 2. Scatterplot of Kcal/min on Mean Rated Effort

Table 5

Correlation Coefficients between the Predictor Ratings and the Metabolic and Manual Materials Handling Criteria

	Criteria			
	Metabolic			
Predictors	Kcal	Mets	Pounds	Operation
Effort	.75**	.72**	.88**	.36
Static Strength	.73**	.67**	.93**	.30
Explosive Strength	.74**	.77**	.94**	.34
Dynamic Strength	.72**	.71**	.93**	.38
Trunk Strength	.76**	.65**	.91**	.39
Stamina	.75**	.77**	.95**	.34
Extent Flexibility	.66**	.47**	.85**	.18
Dynamic Flexibility	.59**	.57**	.90**	.35
Gross Body Equilibrium	.69**	.62**	.73**	.54*
Gross Body Coordination	.60**	.41**	.79**	.50*

* $p < .05$

** $p < .01$

Trunk Strength enters a multiple regression equation first. However, due to the multicollinearity between the strength abilities, Gross Body Coordination, and Dynamic Flexibility, and entered with the next two steps (multiple R = .87).

In the case of the Mets task statements, the best predictors were Explosive Strength (r = .77, $p < .01$) and Stamina (r = .77, $p < .01$). Effort was the third best predictor (r = .72, $p < .01$) and Dynamic Strength was the fourth best predictor (r = .71, $p < .01$). In a multiple regression framework, the three best predictors are Explosive Strength, Static Strength, and Stamina (multiple R = .87).

These results tend to indicate that the difficulty of a work activity in terms of the energy costs can be predicted from the perceived ability requirements, as well as from the conceptually similar ratings of effort.

6. Prediction of effort. The physical ability correlates of effort were examined with respect to the task statements in Form M and Form K. Table 6 presents the correlations of mean effort and the nine physical abilities for the both forms of the task statement scales and for the total ratings. As can be seen in the table, the concept of effort, as rated, is most highly related to strength and stamina. Both groups of subjects rated effort and the four strength abilities and stamina similarly. Correlations in both cases were greater than .90. These results indicate that tasks that are perceived to require a great deal of effort are also perceived to require a great deal of strength abilities and stamina. Other abilities were also correlated, but to a lesser extent.

Individual differences in rating validity. Validity coefficients were calculated for each subject using the individual's task ratings of Effort, and the associated cost of performing that task. A large range of validity in ratings occurred across raters. These individual validity coefficients ranged from .82 to .32 with a mean of .55. It is clear that perceptions of effort required in work are differentially accurate with some individuals demonstrating fairly high levels of precision. Analysis of the nature of individual differences in evaluating effort suggested no systematic rating bias in terms of rater's sex, age, or experience. This may have been due to the generic nature of the tasks rated.

Table 6

Physical Ability Correlates of Mean Rated Effort

Item	Form M	Form K	Total
Static Strength	.96	.96	.96
Explosive Strength	.94	.93	.94
Dynamic Strength	.95	.96	.95
Trunk Strength	.91	.94	.92
Stamina	.92	.94	.93
Extent Flexibility	.83	.89	.86
Dynamic Flexibility	.63	.70	.64
Gross Body Equilibrium	.86	.88	.87
Gross Body Coordination	.74	.92	.83

Conclusions

These results corroborate and extend the findings of Hogan and Fleishman (1979) which indicate that ratings of physical effort are highly related to actual metabolic costs. Ratings of physical effort and physical abilities required for task performance tend to be reliable across raters although some individuals are more accurate in their perceptions of physical effort than others. This study demonstrated the physical factors contributing most to effort ratings. The physical ability components of effort are those of stamina and the strength factors and these performance dimensions account for ratings in tasks that are perceived to require a great deal of effort. It appears that the index of physical effort is a valid and reliable predictor of metabolic costs across a wide range of physically demanding tasks.

STUDY 2

The purpose of the second study was to assess the validity of the physical effort scale using actual task performance. The previous studies required raters to evaluate physical effort without performing any tasks of interest. This was possible only to the degree that the tasks were generic and quantifiable. The limitation of this previous approach is that it is difficult to control for the rater's knowledge or familiarity with the task and its requirements. The second study involved designing tasks to be performed by subjects, standardizing these tasks for performance, and administering the tasks to subjects who would rate them for physical effort. This validity investigation differed from the previous study in two distinct ways. First, the raters were physically required to perform each task before rating it on the physical effort scale. Second, the work costs associated with each task were calculated by the investigators using ergonomic measures. Previous research was based on physiological indices of work output.

Method

A task bank of 24 manual materials handling tasks were developed based on combinations of 8 levels of a weight factor and 3 levels of a distance factor. Physical work for each task was calculated in foot pounds and converted to joules. Subjects, who had no experimental information about work costs, performed each task in a randomized sequence and rated the individual tasks using the physical effort scale. The objective was to determine the relationship between perceived physical effort ratings and the ergonomic costs of work in materials handling tasks. These data assess the validity of the physical effort index in terms of actual task performance and ergonomic measures of that work.

Subjects. The subjects were 20 male college students from the University of Maryland. They ranged in age from 18 years to 31 years, with a mean height of 69.1 inches, and weight of 154 pounds. All subjects were screened regarding medical history and subjects with a previous history of back injury or recent trauma to any joints of the lower extremity were excluded from study. Subjects were paid $10.00 for their participation.

Procedure. Twenty-four manual materials-handling tasks requiring lifting and carrying boxes of various weights over three different distances were used to validate the physical effort scale. Each task involved lifting and carrying a weighted box for a designated distance. Eight boxes, weighing 10, 26, 30, 47, 50, 64, 70, and 90 pounds, were designed to be identical in size, shape, and outward appearance. Each box was lifted and carried over distances of 10, 15, and 20 feet by each rater. All tasks were standardized for movements required by the subjects.

The work involved in each task was calculated using the equation W = F x D (work = force x distance). The total work computed included the weight of the box (F), the distance the box was lifted (L = 2.37 ft.), and the distance it was carried (C). For example: Total Work (TW) = F (L + C). If the subject lifted and carried a 26 pound box 20 feet, his work output was 581.75 ft. lbs. (or 788.85 joules). The poundage of the boxes was selected to result in individual tasks yielding approximately equal work costs. For example, the task 26 lbs. lifted and carried 20 ft. which equals 581.75 ft. lbs. (788.85 joules) is identical in work costs to the task 47 lbs lifted and carried 10 ft. which equals 581.625 ft lbs. (788.68 joules). All tasks including box weight, distance carried, and work required for performance are listed in Table 6.

Before participating in the experiment, the subjects were instructed in the use of the physical effort rating scale. The rating method used was a 7-point scale with values from 1 to 7 formulated by Fleishman and Hogan (1978). Each number on the scale was anchored with behavioral descriptions from 1.0 = "operate a desk calculator" to 6.0 = "operate a jack hammer" with 3.4 = "perform light welding." The scale was displayed on an easel in the laboratory. Specific lifting procedures were explained and demonstrated to each subject for the purpose of uniform lifting techniques and injury prevention.

Table 7

Manual Materials Handling Tasks With Associated Weight, Distance Carried And Work Costs

Task #	Weight	Distance Carried	Work Joules (ft. lbs.)
1	10	10	167.81 (123.75)
2	10	15	173.75 (235.61)
3	10	20	303.41 (223.75)
4	26	10	436.29 (321.75)
5	26	15	585.45 (431.75)
6	26	20	788.85 (581.75)
7	30	10	503.42 (371.25)
8	30	15	706.82 (521.25)
9	30	20	910.22 (671.25)
10	47	10	788.68 (581.62)
11	47	15	1107.34 (816.63)
12	47	20	1385.22 (1051.63)
13	50	10	893.03 (618.75)
14	50	15	1178.03 (868.75)
15	50	20	1517.03 (1113.75)
16	64	10	1073.95 (792.00)
17	64	15	1507.87 (1112.00)
18	64	20	1941.79 (1432.00)
19	70	10	1174.64 (866.25)
20	70	15	1649.24 (1216.25)
21	70	20	2123.84 (1566.25)
22	90	10	1510.25 (1113.75)
23	90	15	2120.45 (1563.75)
24	90	20	2730.65 (2013.75)

Prior to testing, the 24 tasks were randomized without replacement for each subject. Instructions were given verbally by the experimenter to each subject. Subjects executed each task in the designated order; they had no knowledge of box weight or distance to be moved. A one minute intertrial interval permitted the subject to rate the task using the physical effort scale. All ratings were obtained immediately after task performance and the subjects were told to indicate verbally the whole number that represented the amount of physical effort the task required. If the subject did not execute a task (e.g., lift and carry 90 lbs. a distance of 15 ft.), the task was rated "7", the maximum possible rating.

Results

The data in the present study consist of ratings from 20 subjects on each of 24 tasks totalling 480 ratings. Associated with each task performed was a rating of physical effort and the actual foot pounds of work necessary to accomplish the task. The results are presented with descriptive statistics, rating reliability, scale validity, and individual task differences.

Descriptive statistics. Descriptive statistics calculated on ratings for each task are presented in Table 8. Rating means were ordered systematically with increases in work. Mean task ratings spanned the 7 point scale with neither a floor nor ceiling reached in any mean task rating. Rating frequencies across the 7 point scale tended to be distributed normally except for the mean ratings in the 4 to 5 scaling interval. Subjects tended not to rate tasks as requiring an average amount of physical effort. Moreover, when they did, the rating dispersion for those tasks across subjects increased. Rating standard deviations were relatively small ranging from .47 to 1.16 indicating uniformly high interrater agreement across tasks. The task receiving the largest rating standard deviation, "Lift and carry a 64 lb box a distance of 10 ft", obtained a rating mean of 4.75 further indicating rating difficulty with tasks of average perceived physical effort.

Rater reliability. Limited by the lack of replication and no method for ordering scores, an intraclass correlation was computed to determine

Table 8

Descriptive Statistics for Ratings of Physical Effort on Manual Materials Handling Tasks

TASK: WEIGHT/DISTANCE	TASK #	MEAN	STANDARD DEVIATION	ST.ERR. OF MEAN	COEFF. OF VARIATION	SMALLEST VALUE	SMALLEST Z-SCORE	LARGEST VALUE	LARGEST Z-SCORE	RANGE
10 lb/10 ft	1	1.300	.470	.1051	.36166	1.000	-.63808	2.000	1.48885	1
10 lb/15 ft	2	1.350	.489	.1094	.36249	1.000	-.71522	2.000	1.32826	1
10 lb/20 ft	3	1.500	.688	.1539	.45883	1.000	-.72648	3.000	2.17945	2
26 lb/10 ft	4	2.000	.795	.1777	.39736	1.000	-1.25831	3.000	1.25831	2
26 lb/15 ft	5	2.350	.988	.2209	.42046	1.000	-1.36628	5.000	2.68195	4
26 lb/20 ft	6	2.150	.813	.1817	.37801	1.000	-1.41499	3.000	1.04586	2
30 lb/10 ft	7	2.300	.801	.1792	.34840	1.000	-1.62233	4.000	2.12151	3
30 lb/15 ft	8	2.650	.745	.1666	.28119	1.000	-2.21429	4.000	1.81169	3
30 lb/20 ft	9	2.750	.967	.2161	.35147	1.000	-1.81057	4.000	1.29327	3
47 lb/10 ft	10	3.200	1.005	.2248	.31414	1.000	-2.18851	5.000	1.79060	4
47 lb/15 ft	11	3.700	.865	.1933	.23365	2.000	-1.96644	5.000	1.50375	3
47 lb/20 ft	12	3.850	1.040	.2325	.27013	2.000	-1.77886	5.000	1.10578	3
50 lb/10 ft	13	3.650	.933	.2087	.25570	2.000	-1.76792	5.000	1.44648	3
50 lb/15 ft	14	3.800	.894	.2000	.23538	2.000	-2.01246	5.000	1.34164	3
50 lb/20 ft	15	3.900	.852	.1906	.21852	2.000	-2.22941	6.000	2.46409	4
64 lb/10 ft	16	4.750	1.164	.2603	.24509	2.000	-2.36222	6.000	1.07374	4
64 lb/15 ft	17	4.650	.988	.2209	.21249	3.000	-1.66989	6.000	1.36628	3
64 lb/20 ft	18	5.000	1.124	.2513	.22478	3.000	-1.77951	7.000	1.77951	4
70 lb/10 ft	19	5.250	1.020	.2280	.19420	3.000	-2.20686	7.000	1.71645	4
70 lb/15 ft	20	5.250	1.070	.2392	.20380	3.000	-2.10295	7.000	1.63563	4
70 lb/20 ft	21	5.650	1.040	.2325	.18407	3.000	-2.54810	7.000	1.29809	4
90 lb/10 ft	22	6.100	.968	.2164	.15867	4.000	-2.16963	7.000	.92984	3
90 lb/15 ft	23	6.300	.801	.1792	.12719	5.000	-1.62233	7.000	.87356	2
90 lb/20 ft	24	6.200	.951	.2128	.15346	4.000	-2.31225	7.000	.84082	3

extent of rater agreement. This analysis which uses variance estimates of ratings between tasks and within tasks resulted in a reliability coefficient of .83. The coefficient indicates that the extent of rater agreement was sufficient and statistically reliable.

Validity of physical effort ratings. The major question of validity required determining the relationship between subjects' ratings of physical effort and the actual work costs. Table 9 presents the correlation matrix for independent and dependent variables. The primary correlation of interest was the relationship between physical effort ratings and total work involved in actual task performance. This resultant correlation was .77, a substantial validation of the physical effort scale in predicting work costs. Ratings of physical effort were also highly related to box weight manipulated in the tasks with a correlation coefficient of .86. No statistical relationship existed between physical effort ratings and the distance through which the boxes were moved. Analysis of anthropometric characteristics of subject's height and weight indicated a lack of relationship between these independent variables and effort ratings.

A multiple regression of physical effort ratings and work components was computed to determine the best combination of predictors for effort ratings. This regression analysis, presented in Table 10, indicates that the best predictor of rated effort was box weight with an $R = .86$. The addition of the distance variable provided only .4% predictive increment and the further addition of the total work variable failed to make a statistical contribution to R.

The regression pattern of physical effort ratings and total work was further examined graphically and predictively. The scatterplot of mean effort ratings and total work is presented in Figure 3 along with the regression line of best linear fit. The correlation represented by the rating means of the tasks and the total work across the 24 cases was .88. The prediction of total work required in task performance from effort ratings was best estimated by the equation:

$$\text{Predicted Total Work} = 42 + 183\ (\text{Effort Rating})$$

Table 9

Correlations Between Independent and Dependent Variables

	Subject's Height (SHT)	Subject's Weight (SWT)	Effort	Box Weight (WT)	Distance (DIST)	Weight x Distance (Total-Work)
SHT	1.00	.39	.06	.00	.00	.00
SWT	.39	1.00	-.02	.00	.00	.00
EFFORT	.06	-.02	1.00	.86	.07	.77
WT	.00	.00	.86	1.00	-.00	.86
DIST	.00	.00	.07	-.00	1.00	.46
TOTAL WORK	.00	.00	.77	.86	.46	1.00

Table 10

Multiple Regression of Effort Ratings and Work Components

Variable	Multiple R	R Square	RSQ Change	Simple R	B	Beta
Weight	.861	.74	.742	.86	.064	.877
Distance	.864	.75	.005	.07	.035	.079
Total Work	.864	.75	.000	.77	-.000	-.018
(Constant)					.143	

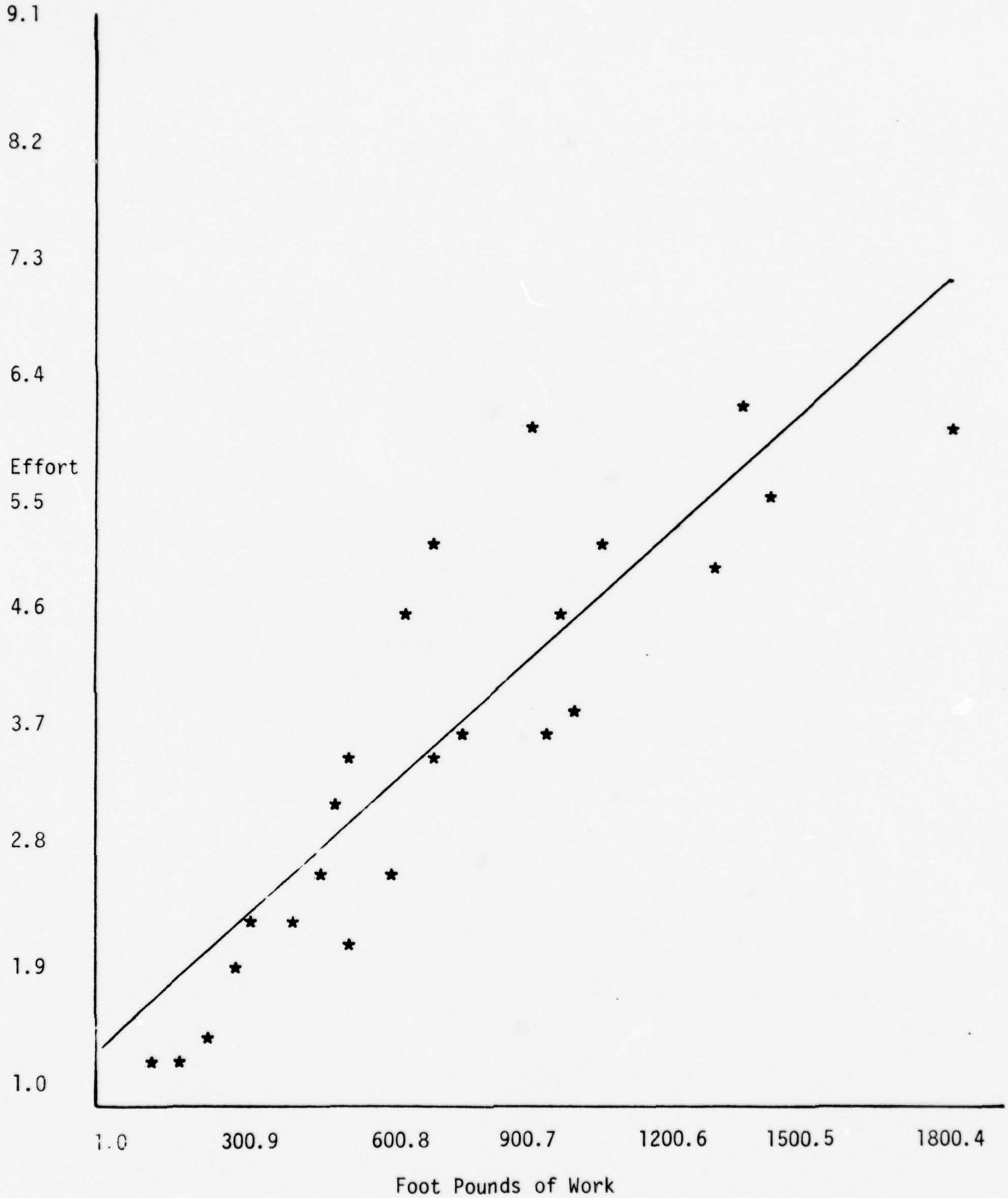

Figure 3

Plot of Rated Physical Effort and Foot Pounds of Work

The regression pattern of physical effort ratings and box weight was also examined graphically and an equation was derived for predicting box weight from ratings. The scatterplot of the mean effort ratings and weights involved in the 24 tasks is presented in Figure 4, along with the least-squares line of best fit. Since rating means and weights across the 24 tasks were perfectly rank ordered, the correlation represented in this scatterplot was .99. The prediction of box weight involved in task performance from effort ratings was best estimated by the equation:

$$\text{Predicted Weight} = 14.6 + 9.0\ (\text{Effort Rating})$$

Individual differences in rating validity. Validity coefficients were calculated for each subject using the pairs of scores resulting from the physical effort ratings and the associated work cost from each task. This resulted in 24 pairs of scores for each subject. The validity coefficients across raters ranged from .71 to .89 with a mean of .83. These results indicate substantially accurate evaluations of work requirements. Although subjects were asked to rate physical effort involved in performing the overall task, validity coefficients were also calculated for each subject using the individual's rating of physical effort and box weight. As expected from the magnitude of r in the previous analysis, individual rating validities were uniformly high with a range from .80 to .98 and a mean of .92.

Rating differences on tasks of similar work cost. Four pairs of tasks were designed to be of approximately equal work costs but dissimilar in weight and distance components. These pairs also spanned the range of workloads from 581.62 ft.-lbs. to 1566.25 ft.-lbs. Although each pair of tasks required nearly the same ft.-lbs. of work for performance, t-tests of mean effort ratings revealed significant differences in perception of physical work associated with similar tasks. Table 10 presents the task pairs, mean effort ratings, associated work, and t-values. Mean comparisons between tasks 6 and 10, 14 and 19, and 17 and 20 obtained rating differences significant at the .01 level. Mean physical effort for tasks 21 and 23 was rated different at the .02 level of significance.

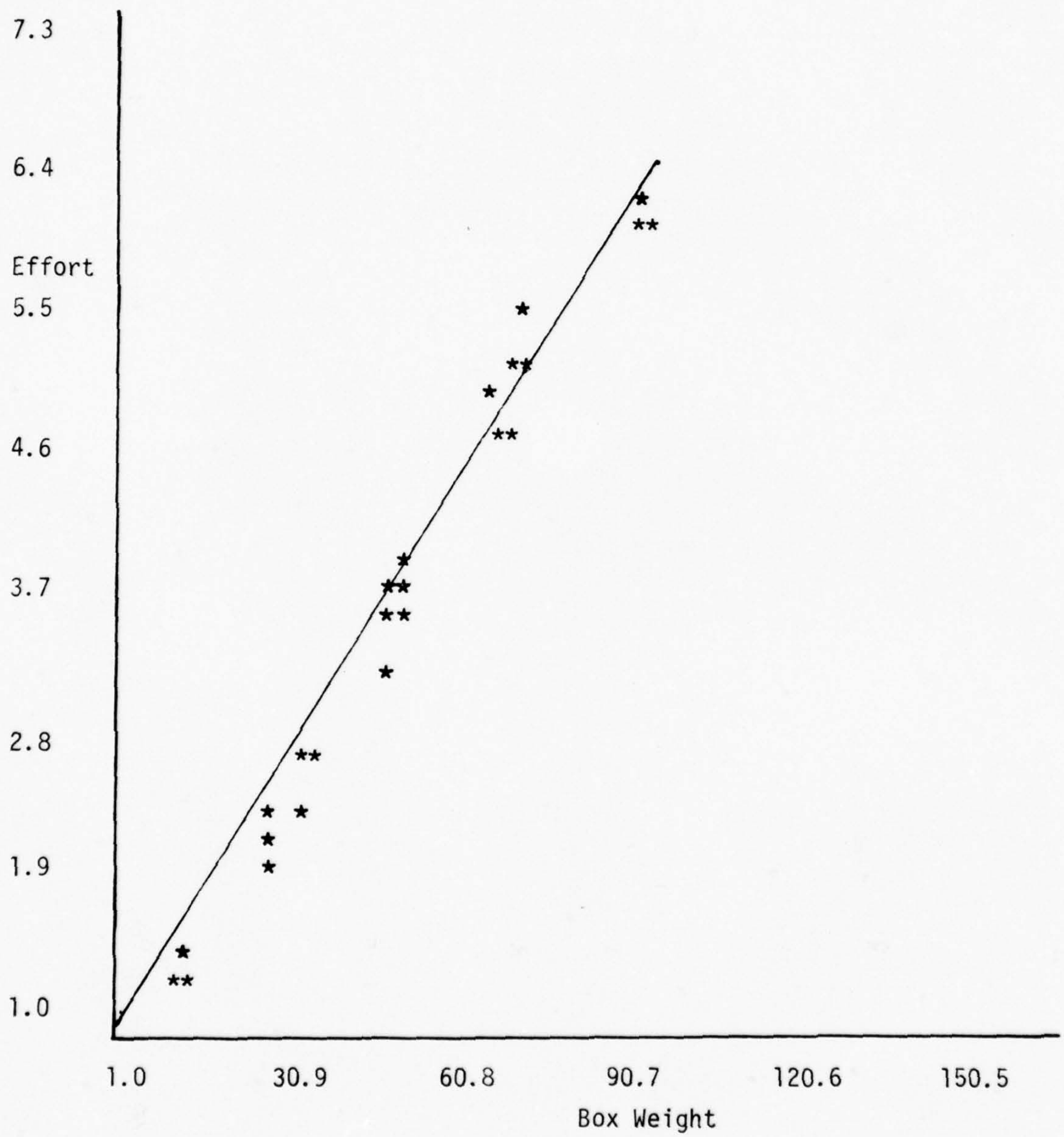

Figure 4

Plot of Rated Physical Effort and Box Weight

Table 10

Differences On Tasks Of Similar Workload

TASK NUMBER	MEAN EFFORT RATING	WEIGHT IN LBS.	DISTANCE IN FEET	WORK IN FT.-LBS.	DF	t VALUE	P <
6 10	2.15 3.20	26 47	20 10	581.75 581.62	19	-4.70	.0001
14 19	3.80 5.25	50 70	15 10	868.75 866.25	19	-5.90	.0001
17 22	4.65 6.10	64 90	15 10	1112.00 1113.75	19	-5.44	.0001
21 23	5.65 6.30	70 90	20 15	1566.25 1563.75	19	-2.56	.019

Each comparison involved differing minimal weights of 20 pounds and for each task pair, the task involving the greater weight received the higher rating. This further suggests that the basis for most task effort ratings was the weight component of total workload.

Conclusions

These reliability and validity results support fully the findings of the prior phase of research. Validity of the physical effort scale is confirmed using effort ratings correlated with actual performance work costs. The correlations between ratings of physical effort and ft.-lbs. of work were substantial, with the best predictor of effort rating weight of the object moved. Individual rater validities were high both in terms of total work costs and the weight component of the task. Evaluations of tasks of similar workload revealed that ratings are heavily associated with task weight. Although tasks were uniformly structured and their components were similar, this permitted an initial performance validation of the physical effort methodology.

DISCUSSION

The results of these two studies corroborate and extend the earlier findings of Hogan and Fleishman (1979) for the development of a perceived physical effort index, with the original intent to develop an assessment device for determining physical requirements of tasks across a range of physical demands and jobs. There are a number of results from both studies that can be summarized as follows. First, task ratings of perceived physical effort were found highly related to metabolic costs, ergonomic costs, and ratings of physical abilities in task performance. The associated correlations were substantially high for both general and specific tasks, both idealized performance and actual performance, and both untrained male and female raters. Second, ratings of perceived physical effort are reliable for both generic and narrowly specified tasks with no differences in ratings attributable to age, sex, or occupational experience. Third, the dimensions of the physical domain which are most highly related to individual perceptions of effort are the various strength and stamina factors. This is indicated by the substantial correlations between effort ratings and physical ability dimensions of strength and stamina as well as effort ratings and weights manipulated in the manual materials handling tasks. Finally, there are individual differences in rater validity. It appears, however, that rater validity is enhanced by actual task performance as evidenced by a more restricted validity range and a higher mean correlation coefficient.

A tentative conclusion of these results is that what individuals perceive as effortful in a task may be that component which contributes most heavily to the physical nature of the task. The Physical Abilities Analysis of the tasks in Study 1 indicate substantial correlations between metabolic costs of performance and ratings of stamina and the four strength factors. Correlations between ratings of physical effort and stamina and strength factors indicate that these are the major components in individuals' ratings. This appears to be confirmed with respect to the static strength requirements by the results of Study 2 where the weight component of task performance was highly related to effort ratings. Further, these results corroborate the same findings determined earlier with job level information (Hogan, Ogden, and Fleishman, 1978). This suggests that if the physical factor structure of a task were known, predictions of perceived physical effort and actual work costs could be made based on the factor accounting for the most variance in task performance. The advantage of this methodology is that it is not limited to a particular physical dimension or physiological assessment, but allows for predictions across a range of tasks with different performance dimensions.

A major implication of these results is that the index of perceived physical effort is a reliable and valid assessment device for predicting work costs. This index can be used to reflect either metabolic or ergonomic costs of task performance which can be translated into performance requirements of personnel. The effort index is a means by which diverse tasks can be ordered and taxonomized according to physical demands without actual physiological and ergonomic assessments. The results of such a taxonomic structure can be used to indicate performance standards in a rating classification and to establish job-related criteria for entry and performance in that rating. Once criteria for performance are established, it is then possible to develop job-related training that meets the concerns for internal and external validity. The index of perceived physical effort has been developed with sufficient psychometric properties to provide the basic methodology for criterion specification and training procedures of physical requirements in Navy jobs.

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Appendix A

Physical Abilities Analysis Manual

(Form B)

and

Instructions

PHYSICAL ABILITIES ANALYSIS MANUAL
(Form B)

Developed by

Edwin A. Fleishman, Ph.D.

1. EFFORT

Requires extensive physical exertion.

7

6 --Operate a jackhammer.

5

4 --Perform light welding.

3

2

Requires little physical exertion

1 --Sit at a desk using a hand calculator.

2. STATIC STRENGTH

This is the ability to use muscle force to lift, push, pull, or carry objects. This ability can involve the hand, arm, back, shoulder, or leg.

HOW STATIC STRENGTH IS DIFFERENT FROM OTHER ABILITIES:

Use muscle to exert force against objects.	vs.	Dynamic Strength (4) and Trunk Strength (5): Use muscle power repeatedly to hold up or move the body's own weight.
Use continuous muscle force, without stopping, up to the amount needed to lift, push, pull or carry an object.	vs.	Explosive Strength (3): Gather energy to move one's own body to propel some object with short bursts of muscle force.
Does not involve the use of muscle force over a long time.	vs.	Stamina (6): Does involve physical exertion over a long time.

2. STATIC STRENGTH

7	Requires use of all the muscle force possible to lift, carry, push or pull a very heavy object.
6	--Lift bags of cement into a truck.
5	
4	
	--Pull a sack of mulch across a yard.
3	
2	
	--Lift a package of bonded paper.
1	Requires use of a little muscle force to lift, carry, push or pull a light object.

3. EXPLOSIVE STRENGTH

This is the ability to use short bursts of muscle force to propel one's self, as in jumping or sprinting, or to throw objects. It requires gathering energy for bursts of muscular effort.

HOW EXPLOSIVE STRENGTH IS DIFFERENT FROM OTHER ABILITIES:

Use short bursts of muscle force to move the body or an object.	vs.	Static Strength (2): Use continuous muscle force to lift, carry, or pull objects. *Dynamic Strength* (4) *and* Trunk Strength (5): Use muscle force to hold up, pull up, or push up the body repeatedly or continuously.
Does not involve use of muscle force over a long time.	vs.	Stamina (6): Does involve physical exertion over a long period of time.

3. EXPLOSIVE STRENGTH

Requires bursts of all the muscle force possible to propel one's own body weight or objects.

7

6 --Run up a hill with fire hose and equipment.

5

4 --Chop wood with an axe.

3

2 --Dive into a pool.

--Push back a typewritter carriage.

1

Requires bursts of a little muscle force to move one's own body weight or objects.

4. DYNAMIC STRENGTH

This ability involves the degree to which the muscles do not fatigue when exerted in repeated or continuous movements. This is the ability to support, hold up, or move the body's own weight repeatedly or continuously over time.

HOW DYNAMIC STRENGTH IS DIFFERENT FROM OTHER ABILITIES:

Hold up or move one's body weight.	vs.	Static Strength (2): Move objects.
Use one's muscles to continue to hold up or move one's body weight.	vs.	Explosive Strength (3): Use short bursts of muscle force to propel the body or an object.
Hold up or move one's entire body weight with the arms.	vs.	Trunk Strength (5): Hold up or move part, not all, of your body, using mainly stomach and lower back muscles.
Involves the degree to which the specific arm muscles do not give out.	vs.	Stamina (6): Involves the degree to which one does not get winded during physical exertion.

4. DYNAMIC STRENGTH

Requires use of all muscle force possible to hold up or move the body weight for long periods.

7

--Climb mountain using rope, hammer, and pitons.

6

5

--Pull oneself onto a ledge.

4

--Climb an extension ladder.

3

2

--Conduct a survey on a street corner.

1

Requires use of a little muscle force to hold up or move the body weight for a short time.

5. TRUNK STRENGTH

This ability involves the degree to which one's stomach and lower back muscles can support part of the body repeatedly or continuously over time. The ability involves the degree to which these trunk muscles do not "give out," or fatigue, when they are put under such repeated or continuous strain.

HOW TRUNK STRENGTH IS DIFFERENT FROM OTHER ABILITIES:

Hold up or move part, not all, of one's body, using stomach and lower back muscles.	vs.	Dynamic Strength (4): Hold up or move one's entire body weight with the arms and shoulder muscles.
Hold up or move part of one's body weight.	vs.	Static Strength (2): Move objects.
Use your stomach and back muscles to continue to hold up or move part of one's body.	vs.	Explosive Strength (3): Use short bursts of muscle force to propel one's body or an object.
Involves the degree to which the stomach and back muscles do not give out.	vs.	Stamina (6): Involves the degree to which one does not get winded during physical exertion.

5. TRUNK STRENGTH

Requires use of all the stomach and lower back muscle force possible to hold up or move part of your body for as long as possible.

7

--Do 100 sit-ups.

6

--Lift rocks from the ground.

5

--Lay carpet.

4

3

--Sit up in a reclining chair.

2

--Bend over to get chemical sample of pool water.

1

Requires use of a little stomach and lower back muscle force to hold up or move part of your body for a short time.

6. STAMINA

This is the ability to exert oneself physically over a period of time without getting winded or out of breath.

HOW STAMINA IS DIFFERENT FROM OTHER ABILITIES:

Does involve physical exertion over a long time.	vs.	Static Strength (2) and Explosive Strength (3): Do not involve using muscle force over a long time.
Involves not getting winded.	vs.	Dynamic Strength (4) and Trunk Strength (5): Involves one's muscles not getting tired.

6. STAMINA

Requires physical activity of the whole body over a long time, with great strain on the heart and blood vessels.

7

--Dig ditches all day.

6

--Jog three miles.

5

--Nail shingles on a roof.

4

3

--Mow a small yard.

2

--Wash a chalkboard.

1

Requires physical activity of the whole body over a short time with little strain on the heart and blood vessels.

7. EXTENT FLEXIBILITY

This is the ability to bend, stretch, twist or reach out with the body, arms and/or legs.

HOW EXTENT FLEXIBILITY IS DIFFERENT FROM OTHER ABILITIES:

Involves degree of bending; does not involve repeated or speeded bending.	vs.	Dynamic Flexibility ( ): Does involve speeded and repeated bending.

7. EXTENT FLEXIBILITY

Requires a high degree of bending, stretching, twisting or reaching out into unusual positions.

7

6

--Work as a lineman on a utility pole.

5

4

--Coil up hoses on a firetruck.

3

2

--Reach for a microphone in a patrol car.

1

Requires a low degree of bending, stretching, twisting or reaching out.

8. DYNAMIC FLEXIBILITY

This is the ability to bend, stretch, twist, or reach out with the body, arms and/or legs both quickly and repeatedly.

HOW DYNAMIC FLEXIBILITY IS DIFFERENT FROM OTHER ABILITIES:

Involves both <u>speed and repeated</u> bending or stretching.	vs.	Extent Flexibility (7): Requires <u>no</u> speed, just degree of bending or stretching in <u>single</u> movements.
Involves the degree to which the <u>muscles "bounce back"</u> during repeated bending or stretching.	vs.	Stamina (6): Involves the degree to which <u>one does not get winded</u> when doing physical work over time.

8. **DYNAMIC FLEXIBILITY**

Requires many fast and repeated body bending, twisting or stretching movements.

7

6 --Do the butterfly stroke in a championship swim competition at the Olympics.

5 --Saw dead wood.

4

--Milk cows.

3

--Fill a bag with shells at the seashore.

2

1

Requires few repeated bending, twisting or stretching movements where speed is not important.

9. GROSS BODY EQUILIBRIUM

This is the ability to keep or regain one's body balance or to stay upright when in an unstable position.

This ability does <u>not</u> include balancing objects.

9. GROSS BODY EQUILIBRIUM

Requires keeping or getting back body balance when many forces are working against keeping body balance. These forces work randomly so that one can't tell when next force will act on him, how long it will last or how strong it will be.

7

6 -- Work on high rise construction.

5

4 --Install ceiling panels.

3 --Climb a stool in placing stock on shelves.

2 --Mow a flat area of grass.

1

Requires keeping or getting back balance when one force which is fairly weak works against body balance.

10. GROSS BODY COORDINATION

This is the ability to coordinate the movement of the arms, legs and torso together in activities where the whole body is in motion.

10. GROSS BODY COORDINATION

Requires a high degree of overall body coordination to do difficult sets of movements.

7

--Perform a skilled ballet dance.

6

5

--Descend from branches after trimming a large tree.

4

3

--Get around an obstacle course with no time limit.

2

--Walk through a doorway.

1

Requires a small degree of overall body coordination to do simple common movements.

INTRODUCTION AND DIRECTIONS

This study involves the estimation of physical demands of various occupational tasks. Every job is made up of a number of different tasks. One way to describe these tasks is with the abilities needed by the worker to do the job. Abilities are traits the worker has which allow him/her to perform different kinds of tasks.

There are many kinds of different abilities. For the most part, we are only interested in the physical part of jobs and the physical abilities that help the worker perform various tasks. There are ten physical abilities of interest in this study. They include: effort, static strength, explosive strength, dynamic strength, trunk strength, stamina, extent flexibility, dynamic flexibility, gross body coordination, and gross body equilibrium.

The PHYSICAL ABILITIES MANUAL contains the scales for determining the amount of an ability requirement of a task. Your job is to evaluate whether or not an ability is required and if so, how much of the ability is required. To determine how much of an ability is required an estimation procedure called rating will be used. To familiarize yourself with the rating process, open up the Manual to the first page which presents the definition of effort. On the top of the page is the description of the ability (and in some cases a description of how one ability differs from other abilities); on the bottom of the adjoining page is the rating scale. As you see, the rating scale goes from 1 (a very low amount of the ability) to 7 (a very high amoung of the ability). Notice that some of the levels on this 7-point scale are labeled with descriptions called scale anchors. These anchors serve to identify the various types of tasks associated with the amount of the ability--or the numbers on the left. You will be asked to assign a number between 1 and 7 to tasks you rate which represents what you feel is the amount of ability required to perform the task.

Now look at the RESPONSE SHEETS. There are 10 of these sheets, one for each of the ten different abilities. Each response sheet contains 40 task descriptions. Quickly scan through the 40 tasks. Some of the tasks imply that the task may be performed for a certain length of time. Where no time limit is implied, assume that the worker is to perform the task for 1 hour. We realize that some of the task descriptions are vague and that some may be unfamiliar; however, do the best you can to rate the task. Again, your task is to estimate the amount of ability required to perform the task and write the number (from 1 to 7) in the space provided on the left of the statement. If you feel that the task requires NO ability of a given type, put a 0 in the space.

There are a number of problems people have when they are asked to rate tasks. The first is that people assume that most tasks require an "average" amount of the ability--however, these tasks were selected across a wide range of ability requirements, thus there is no reason to expect that most tasks should require "about a 4." Another problem is consistently rating too high or too low. This can be overcome by looking at the tasks in order to try and get a sense of the "range" of the requirements. Third, when you finish one ability and move on to the next one, people tend to "try to be consistent" and worry about how they rated the tasks on the prior abilities. Don't worry about that, look closely at the definition of each ability and rate each task according to the definition.

Finally, a number of people find this a difficult task. We ask only that you give the task some serious and deliberate thought. Others find the task very boring--so feel free to take a break, because there is no time limit. Be sure to ask questions if you do not understand any part of these directions.

In order to begin, open the Manual to the EFFORT definition and scale. Look at the Response Sheet (the first one) that says EFFORT under the Form (K or M). Please note your age, sex, and occupation in the top right-hand corner of the first response sheet.

The first item on the task sheet is:

______Lift and carry a 70 lb. box from the floor to a table 15 ft. away

Is this task harder (requiring more effort?) than "Perform light welding?" If so, then the assigned acale value might be a 4,5,6, or 7. Does this task require more effort than "operate a jackhammer" or does it require less effort? In other words, use the anchors to evaluate the tasks by asking if the task requires more or less of the ability defined.

When you decide on the appropriate value, write it in the space provided on the Response Sheet and go to the next task. Finish rating all 40 tasks and then turn to the next ability in your Manual. Complete the ratings for all ten Response Sheets using the ten ability scales in the Manual.

Appendix B

Response Sheet for Effort and

Physical Ability Ratings of Tasks

(Mets-Multiples of Metabolic Rate)

NOTE: Every packet of rating materials contained ten of these sheets--one per each rating scale.

FORM M

______ Lift and carry a 70 lb box from the floor to a table 15 ft away
______ Stock grocery store shelves
______ Operate a crane
______ Reach over and behind a table in order to lift a 50 lb box onto the table
______ Work with heavy levers, dredges, etc.
______ Drive a car
______ Lift and carry a 30 lb box from the floor to a table 15 ft away
______ Cut wood with a hand saw
______ Push or move heavy objects such as file cabinets or desks
______ Reach up and lower a 30 lb box from a 5 ft high cabinet
______ Jerk or pull ropes or cables
______ Work with heavy tools (e.g., picks or shovels)
______ Work on interior construction and finishing
______ Reach under a table and pull out a 50 lb box
______ Use hand tools for light assembly work or radio repair
______ Perform light welding
______ Reach up and lower a 10 lb box from a 5 ft high cabinet
______ Hammer, saw, or plane wood
______ Reach over and behind a table in order to lift a 30 lb box onto the table
______ Sit at a desk and use a hand calculator
______ Lay tile floors
______ Lift and carry a 90 lb box from the floor to a table 15 feet away
______ Drive a truck
______ Draft a floor plan
______ Reach under a table and pull out a 30 lb box
______ Lift and carry a 50 lb box from the floor to a table 15 feet away
______ Drive a heavy truck or tractor trailer rig, including some unloading
______ Carry trays and dishes
______ Reach over and behind a table in order to lift a 70 lb box onto the table
______ Crank up dollies, jacks, or hitch trailers
______ Construct or remodel the exterior of a house
______ Sand floors with a power sander
______ Reach over and behind a table in order to lift a 90 lb box onto the table
______ Cut wood with a power saw
______ Lift and carry a 10 lb box from the floor to a table 15 feet away
______ Reach under a table and pull out a 90 lb box
______ Paint, hand wallpaper, perform masonry work
______ Reach up and lower a 50 lb box from a 5 ft high cabinet
______ Scrub, wax, and polish floors, walls, etc.
______ Reach under a table and pull out a 70 lb box
______ Assemble or repair heavy parts such as machinery, plumbing, or motors

NOTE: Every packet of rating materials contained ten of these sheets--
one per each rating scale.

Appendix C

Response Sheet for Effort and

Physical Ability Ratings of Tasks

(Kcal-Kilocalories per minute)

NOTE: Every packet of rating materials contained ten of these sheets--one per each rating scale.

FORM K

_____ Lift and carry a 70 lb box from the floor to a table 15 ft away
_____ Wring wash by hand
_____ Dig a trench in clay soil
_____ Reach over and behind a table in order to lift a 50 lb box onto the table
_____ Load chemicals or cement into a mixer
_____ Wind electrical wire around small spools
_____ Lift and carry a 30 lb box from the floor to a table 15 ft away
_____ Beat carpets and mats
_____ Type with an electric typewriter at 40 wpm
_____ Reach up and lower a 30 lb box from a 5 ft high cabinet
_____ Tend a heating furnace
_____ Lift up a car with a jack
_____ Iron clothes
_____ Reach under a table and pull out a 50 lb box
_____ Load coal
_____ Peel potatoes
_____ Reach up and lower a 10 lb box from a 5 ft high cabinet
_____ Hoist a shelf with a pulley
_____ Reach over and behind a table in order to lift a 30 lb box onto the table
_____ Push a wheelbarrow with a 220 lb load
_____ Crank with both arms
_____ Lift and carry a 90 lb box from the floor to a table 15 ft away
_____ Carry boxes of ammunition
_____ Sew with a machine
_____ Reach under a table and pull out a 30 lb box
_____ Lift and carry a 50 lb box from the floor to a table 15 ft away
_____ Shovel 20 lb load a distance of 1 yard at 10 throws a minute
_____ Scrub floors on knees
_____ Reach over and behind a table in order to lift a 70 lb box onto the table
_____ Clean windows
_____ Sweep floors
_____ Clean a gun
_____ Reach over and behind a table in order to lift a 90 lb box onto the table
_____ Cut grass
_____ Reach under a table and pull out a 90 lb box
_____ Polish a floor
_____ Reach up and lower a 50 lb box from a 5 ft high cabinet
_____ Work with sheet metal (i.e., cutting, fitting)
_____ Reach under a table and pull out a 70 lb box
_____ Hoe in a garden

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