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Job Demands and Back Injury in Navy Personnel

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EXECUTIVE SUMMARY

Background

U.S. Navy policy directs that Navy personnel exercise three times per week. Department of Defense policy directs that occupation-specific fitness programs be developed for jobs with exceptional physical demands. However, no guidelines exist to determine which occupations should have specific guidelines.

Objectives

This study evaluated physical demand ratings (PDRs) by subject matter experts as a tool for determining which occupations should have occupation-specific fitness standards. One objective was to relate PDRs to occupational differences in back injury hospitalization rates. A second objective was to use the demands-injury rate relationship to set a criterion value for U.S. Navy occupations with physical demands that merit fitness standards exceeding current Navy-wide standards.

Approach

Job demand ratings for 73 entry-level U.S. Navy occupations were obtained from an earlier study by Reynolds, Barnes, Harris, and Harris (1992). The physical ability domain ratings for strength, stamina, flexibility, and balance were averaged to establish a total PDR. Ratings for communication skill, reasoning, reaction time, and dexterity demands were included to represent cognitive and psychomotor abilities. The Naval Health Research Center Epidemiological Interactive System computer system provided estimates of back injury hospitalization rates (BIRs). BIRs were determined for diagnoses of sprains and strains of the sacroiliac region or of other back regions. Overall hospitalization rates (i.e., rates for all diagnoses) also were computed. The rates were computed separately for each occupation. Correlation and regression analyses quantified the relationships between the job demands and hospitalization rates.

Findings

A. Total PDRs predicted occupational BIRs for paygrades E-1 and E-2 (r = .45), E-3 and E-4 (r = .36), and E-5 and E-6 (r = .36 to r = .46), but not for paygrades E-7 and above (r = .07).

B. Total PDRs predicted BIRs best when the E-1 through E-6 paygrades were combined into a single group (r = .59).

C. PDRs did not predict overall hospitalization rates (r = .11).

D. Cognitive and psychomotor demands were weak predictors of BIRs (median r = .05; maximum r = .23). The only significant correlate was the dexterity rating (r = .23). However, the dexterity rating was related even more strongly to overall hospitalization rates (r = .38). Communication demands also were related to overall hospitalization rates (r = .28).

E. The Hospital Corpsman and Dental Technician occupations were statistical outliers. The BIRs for these occupations were much higher than would be predicted on the basis of the physical demands

of their jobs. The PDR-BIR correlation increased to $r = .72$ with these outliers removed from the analysis.

F. A quadratic function provided greater accuracy in predicting BIRs than the linear functions that generated the results cited immediately above ($r = .74$).

G. The predicted BIR for a job with minimal physical demands was 2.21. The upper limit of the 95% confidence interval for this estimate was 4.28. The PDR-BIR predictive equation indicated that any occupation with a PDR > 2.93 would have a predicted BIR > 4.28. A PDR ≥ 2.93, therefore, provided the criterion rating value for classifying a U.S. Navy entry-level occupation as exceptionally demanding.

H. Applying the PDR ≥ 2.93 criterion, 31 of 73 (43.8%) entry-level U.S. Navy occupations would be classified as exceptionally demanding.

Conclusions

PDRs are effective, valid tools for segregating U.S. Navy occupations into high and low demand. Classification based on PDRs is valid because research has demonstrated that PDRs are strongly related to direct measures of the actual physical work done (e.g., how many pounds have to be lifted and carried how far) and to health risks. This study demonstrated the latter fact and showed how the health risk information can be used to specify a criterion PDR value to classify U.S. Navy occupations for the purposes of setting physical fitness standards. Occupations with PDRs below the criterion value have physical demands that can be met by existing general U.S. Navy fitness standards. Occupations with PDRs above the criterion could benefit from higher fitness standards. The suggested PDR criterion value for making this distinction is a preliminary estimate. The specific criterion might be modified by additional studies with other criteria (e.g., outpatient injury data for the job), but the present study demonstrated the effectiveness of the general approach. The findings also demonstrated that studying PDRs and injury rates in combination is an effective tool for identifying atypical occupations for more detailed study (e.g., Hospital Corpsman). Finally, the PDR-BIR relationship reported here provides a benchmark for evaluating occupational safety programs. Given this information, any program to reduce the risk of injury arising from U.S. Navy occupational requirements can be evaluated by three criteria: lower PDRs in the target occupations, lower BIRs in the target occupations, and lower BIRs relative to what would be expected given the PDRs for the target occupations. Noting that it takes substantial time to accumulate BIR data, the PDR criterion for effectiveness is probably the most useful because it can be applied soon after new programs are implemented.

Introduction

Sailors must be fit for duty. Fitness for duty includes having the physical abilities required to perform their jobs. Ability requirements vary from job to job because the tasks performed differ between jobs. Department of Defense (DoD) physical fitness guidelines recognize that this task variation exists and call for occupation-specific[1] fitness standards (Department of Defense, 1995).

Occupational physical fitness standards should be based on the physical demands of the job. Job demand ratings by subject matter experts (SMEs) are an inexpensive tool for determining the magnitude of those demands. Although SME ratings only infrequently have been validated against other methods of measuring the same job attributes (Harvey, 1990), experimental and observational evidence shows that they are valid indicators of physical task requirements. In an experimental study, Hogan, Ogden, Gebhardt, and Fleishman (1979) used artificial tasks to show that job demand ratings were strongly correlated (r = .77) with measured physical work (i.e., force times distance) in laboratory tasks. Carter and Biersner (1987) demonstrated that SME physical demand ratings (PDRs) were strongly related to field measures of the physical work requirements of a job. Their study employed Robertson and Trent's (1983) dichotomous classification of U.S. Navy jobs as the criterion. This criterion classified occupations as highly demanding or less demanding based on field observations of people performing the jobs and ergometric measurements taken on the job. Carter and Biersner (1987) found that Position Analysis Questionnaire (PAQ; Mecham, McCormick, & Jeanneret, 1977) ratings for the U.S. Navy jobs produced biserial correlations with this criterion that ranged from r = .69 for dynamic strength to r = .73 for static strength and r = .79 for explosive strength. The strongest association obtained was for a single item asking about physical exertion (r = .87).

The Rating Criterion Problem

If ratings are valid indicators of demand, the next question is "How high must the rating be to justify the establishment of occupation-specific fitness standards?" One answer to this question would be that all jobs should have occupation-specific fitness programs. The rationale for this approach would be that no two occupations have identical physical demands, so fitness standards must be tailored to the requirements of each job. Fitness standards then would range from minimal requirements for jobs with little or no physical demands to high levels of fitness for extremely demanding jobs.

The assumption that occupational specificity is necessary does not apply to the U.S. Navy. If all occupations had occupation-specific fitness programs, there would be a subset of occupations with minimal physical demands that might have no fitness requirement at all. This situation would be contrary to current U.S. Navy policy, which requires that each sailor meet Navywide minimum physical fitness standards. These standards promote good health. Given the current standards, the initial question must be rephrased to ask "What rating score implies physical demands that people can meet only if they meet existing physical fitness standards?"

The rephrased question implies the existence of a criterion physical demand level. The criterion physical demand level is reached when people who meet existing physical fitness standards either cannot perform one or more important job tasks, or when they face an unacceptable risk of physical injury when they do perform the task(s). The criterion PDR score is the physical demand rating corresponding to this physical demand level. Given a criterion value, PDRs can be used to classify occupations. Occupations receiving ratings above the criterion value would require occupation-specific fitness standards. Occupations with ratings lower than or equal to the criterion physical demand rating would not require occupation-specific standards.

A criterion value for PDRs is not available at this time. This study fills this gap by defining a criterion value based on the relationship between PDRs and back injury hospitalization rates (BIRs)for 73 U.S. Navy occupations. BIRs provide a reasonable frame of reference for setting a criterion because back injuries are a common consequence of overexertion on the job. BIRs increase when physical demands approach or exceed the strength of the average job incumbent in civilian occupations (Chaffin, Herring, & Keyserling, 1978; Genaidy, Kailash, Sarmidy, & Saria, 1990).

The physical demand-back injury association applies to Navy occupations. Marcinik (1981) found high rates of injury for occupations such as steelworker, constructionman, aviation ordnanceman, fireman, and builder and concluded that " . . . occupations demonstrating the highest hospitalization rates for back injuries . . . perform mostly physical work involving heavy lifting tasks" (p. 5). Chesson and Hilton (1988, pp. 13-14) noted that "Many of the lower risk [of back injury] occupational groups are desk jobs (e.g., cryptology and intelligence), whereas many of the high risk occupational groups require physical labor (e.g., health care, weapons control, and seaman-striker)." These back injuries are a significant cost to the U.S. Navy because these injuries are a common cause of work-related disabilities for sailors (McNally & Ferguson, 1982) and for civilian personnel working for the Department of the Navy (Doyle, Shepherd, & LaFleur, 1993). Back injuries, therefore, provided a criterion that is likely to be related to physical demands of U.S. Navy occupations and is a significant cost to the Navy.

This study used SME PDRs reported by Reynolds et al. (1992) to refine the qualitative descriptions in the prior studies. The SME PDRs quantified occupational demands with greater precision than "high" versus "lower risk" and "mostly physical work." This increased precision provided the basis for quantitative analysis of the relationship between physical demands and BIRs. The quantitative analysis produced a criterion physical demand rating value to identify demanding occupations.

Method

Job Demand Ratings

Job demand ratings for 73 entry-level Navy occupations were obtained from Reynolds et al. (1992).[2] Their study employed a Job Activities Inventory with ratings for 27 abilities. Each ability was rated for its importance to job performance. Ratings were on a 5-point scale with *Not Very Important*, *Somewhat Important*, *Important*, *Very Important*, and *Extremely Important* as response anchors. The responses were scored 1, 2, 3, 4, and 5, respectively. A *Not Applicable* response option also was available.[3]

The present study used 8 of the 27 ability ratings. Four ratings were for physical abilities:

> Strength: Ability to use muscle force to lift, push, pull, or carry heavy objects for a short period of time.
>
> Flexibility: Ability to bend, stretch, twist, or reach out with the body, arms, or legs.
>
> Body Balance: Ability to keep or regain one's balance or to stay upright when in an unstable position.
>
> Stamina: Ability to exert oneself physically without becoming out of breath.

A measure of Total Physical Demand was created by averaging the Strength, Flexibility, Body Balance, and Stamina scores for each occupation. This composite was created as a summary measure because ratings for specific physical abilities were so highly correlated ($r \geq .86$) that they appeared to measure a single construct.

Four other ability ratings were chosen to represent the cognitive and psychomotor ability domains identified in the Reynolds et al. (1992) factor analysis of the importance ratings. The factor loadings from that analysis were large, thereby indicating substantial interitem redundancy in each domain. This redundancy provides a justification for using the ratings for individual abilities as proxies for the underlying factors. The scale with the highest factor loading in the Reynolds et al. (1992) factor analysis was chosen to represent the domains of "Communication," "Cognitive Ability," "Perceptual Skill," and "Dexterity and Fine Motor Control," respectively:

> Oral Communication: Ability to use English words and sentences so others will understand and the ability to understand the speech of others. (Factor loading: .869)
>
> Reasoning: Ability to understand and organize a problem and then to select a method for solving the problem. (Factor loading: .767)
>
> Reaction Time: Ability to give a fast response to a signal (sound, light, picture) when it appears. (Factor loading: .849)
>
> Dexterity: Ability to quickly make skillful, coordinated movements of the fingers, hands, wrists, arms, or legs. (Factor loading: .901)

Hospitalization Rates

Hospitalization rates were obtained from the Epidemiological Interactive System (EPISYS; Jaeger, White, & Show, 1996; Show & White, 1993). The system provides Navy and Marine Corps inpatient hospitalization rates. The rates can be obtained for International Classification of Diseases, ninth revision (ICD-9; Medicode, Inc., 1991) diagnosis codes as a function of various demographic variables, including gender, age, occupation, and paygrade.

The BIR for each occupation was determined using the ICD-9 codes "Sprains and strains of the sacroiliac region" (ICD-9 code 846) and

"Sprains and strains of other and unspecified regions of the back" (ICD-9 code 847) as the definition of back injury.

BIRs were based on first-admission diagnoses. Any subsequent admission for the same problem was not included in the computations. Rates were expressed as the number of first-admission cases per 10,000 person-years of observation. Rates were determined separately for four enlisted paygrade groups: (a) E-1 and E-2, (b) E-3 and E-4, (c) E-5 and E-6, and (d) E-7 and above. Paygrade was considered a potential moderator of the physical demands-back injury rate relationship because occupational exposure to job physical demands may decrease with increasing seniority. For example, personnel in the E-7 and above group are in positions that typically involve leadership and administrative responsibilities. These individuals would be expected to perform the physically demanding tasks in their occupation less often than would sailors who were E-4 or below.

Paygrades were grouped based on the similarity of back injury rates. Similar rates were assumed to indicate roughly comparable exposure to physical job demands. These rates were 6.78 for E-1, 7.06 for E-2, 5.84 for E-3, 5.05 for E-4, 3.87 for E-5, 3.89 for E-6, 2.90 for E-7, 2.74 for E-8, and 2.15 for E-9. The grouping used in the analyses, therefore, combined paygrades with similar back injury rates within group (i.e., differences of 0.84 or less in the rate per 10,000 person-years), but relatively large differences between groups (i.e., a drop of at least 0.99 from the lowest rate in one paygrade group to the highest in the next group up).

One additional hospitalization criterion was determined for each occupation. Overall hospitalization rate was chosen as an indicator of the effects of malingering, hypochondriasis, stress, and other factors that could increase rates for many types of illness. To the extent that overall hospitalization rate is an index of the cumulative effects of these general influences on health, a weak relationship with this criterion combined with a strong relationship with BIR would be ideal. This pattern would be consistent with the view that occupational differences in BIRs were caused by occupational differences in physical demands.[4]

Data Analysis

Data analyses were performed with the SPSS-X statistical package (SPSS, Inc., 1992). Correlation and regression were the primary analysis procedures. One-tailed significance tests were used because job demands were expected to increase BIRs. Details of specific analyses are given in the Results section.

Results

Table 1 presents the primary study findings. The most important trends were:

(A) PDRs predicted BIRs for paygrades up to E-6 ($.31 \leq r \leq .48$), but not for paygrades E-7 and above ($r \leq .10$).

(B) PDRs did not predict overall hospitalization rate ($r < .11$).

(C) Cognitive and psychomotor job demands were weakly related to BIRs.

Considered individually, not even the largest correlation ($r \le .23$, $p < .025$, one-tailed) would satisfy a Bonferroni-adjustment of the significance criterion. This adjustment would set a more extreme significance standard because four predictor variables were used in the analyses. The simplest use of this criterion is to divide the acceptable studywide error rate ($p < .05$) by the number of tests performed (4 per criterion) to yield a criterion significance level ($p < .0125$). The closest any observed correlation came to this criterion was $p < .025$. It was equally clear that there was no general trend for cognitive and psychomotor demands to predict BIRs. The first four BIRs in the table represent all of the raw data in the study. The median correlation for these BIRs was $r = .05$.

Table 1. Correlations Between Physical Demand Ratings and Back Injury Hospitalization Rates

	Back Injury Hospitalization Rate for Paygrades:						Overall Hospital-ization
	1-2	3-4	5-6	7-9	1-6	1-9	Rate
Physical Demands							
Strength	.42**	.31**	.48**	.10	.55**	.55**	.05
Stamina	.48**	.42**	.43**	.09	.62**	.61**	.11
Flexibility	.41**	.35**	.45**	.05	.56**	.54**	.08
Balance	.46**	.34**	.39**	.05	.54**	.53**	.01
Total	.45**	.36**	.46**	.07	.59**	.57**	.07
Other Demands							
Communication	.00	.22*	-.14	.21*	.07	.11	.28*
Reasoning	-.07	.10	-.12	-.13	-.01	-.04	.00
Reaction Time	.11	.08	-.02	-.01	.07	.07	-.04
Dexterity	.15	.23*	.08	.02	.23*	.22	.38**

*$p < .05$, one-tailed **$p < .01$, one-tailed

Note. "-" indicates a range of paygrades combined for the analysis (e.g., "1-2" indicates E-1 and E-2; "7-9" indicates E-7, E-8, and E-9).

Optimum Criterion

The paygrade trend stimulated further analyses to identify the optimum level of aggregation for the BIR criterion. The correlations in Table 1 were substantial and statistically significant for the E-6 and below paygrades, but these correlations were near zero for the paygrades E-7 and above. One interpretation of this pattern of correlations would be that personnel in the E-1 through E-6 paygrades were exposed to some common causal factor(s) linking job demands to increased risk of back injury. Exposure to the actual physical demands of the job is a logical candidate for this hypothesized causal factor. The absence of a correlation for paygrades E-7 and above suggests that whatever common causal factor(s) was(were) shared by paygrades E-6 and below was(were) missing for personnel in paygrades E-7 and above. This absence would be consistent with a shift to administrative and leadership responsibilities that reduced the frequency of performing the physically demanding tasks in one's occupation. The net effect is that PDRs for entry-level jobs are valid indicators of physical demands only up to the E-7 paygrade.

If the causal processes underlying the PDR-BIR relationship were shared by all paygrades, standard psychometric models would make it reasonable to aggregate across all paygrades. The preceding arguments suggest a possible discontinuity in exposure to the physical demands of the job at the E-7 paygrade. Based on this argument, aggregating across personnel in paygrades E-1 through E-6 will provide the most precise statistical estimates of the effects of physical demands (Nunnally & Bernstein, 1994). Increased precision is equivalent to more reliable measurement (American Psychological Association, 1985). Higher reliability means stronger correlations with other measures because of reduced attenuation of true population correlations due to measurement error (Nunnally & Bernstein, 1994).

Applying the preceding logic to the present case, correlations obtained with BIRs estimated by treating personnel in the E-1 through E-6 paygrades as a single group should be larger than those that consider paygrades two at a time. Table 1 clearly supports that contention. The correlations between the BIR estimated with paygrades E-1 through E-6 combined (hereafter, E-1/6 BIR) ranged from $r = .54$ to $r = .62$. Each of those correlations was substantially larger than the maximum value obtained when paygrades were considered two at a time (i.e., $r = .48$).

The psychometric logic predicts that further aggregation will reduce correlations. If the BIR for paygrades E-7 and above is not affected by the same factor(s) that apply for E-6 and below, adding the BIR rate for this group to the E-6 and below rate is the equivalent of adding noise (i.e., random variation) to the criterion. The random component of the variation will not be related to job demands, so aggregation across all nine paygrades should reduce the size of the physical demand-BIR correlation. In fact, aggregation across all nine paygrades produced correlations .00 to .02 lower than obtained when aggregating across paygrades E-1 through E-6.

Outlier Effects. Correlation and regression analyses can be distorted by outlier or influential data points (Myers & Well, 1991). When the E-1/6 BIR was regressed on physical demands, the studentized-deleted residual for the Hospital Corpsman occupation was $z = 7.41$. This value was more than twice the $|z| \geq 3.00$ criterion commonly used to identify outliers. A second occupation, Dental Technician, approached the criterion value in the initial regression ($z = 2.75$) and substantially exceeded the criterion ($z = 3.95$) with the HM occupation removed in a second analysis. A third regression deleting both HM and DT occupations yielded no further outliers (absolute $z \leq 2.65$).

Removing the two outliers improved the predictive power for job demands. Removing the HM occupation increased the correlation between physical demands and E-1/6 BIR from $r = .59$ to $r = .68$. Removing the DT occupation further increased the correlation from $r = .68$ to $r = .72$. Applying Rosenthal and Rubin's (1982) binomial effect size display concept, these differences mean that the accuracy of predicting which occupations would have above-average BIRs increased from 79.5% to 84.0% to 86.0%. The number of correct predictions for individual occupations increased from 58 to 60 to 61 even though the number of occupations for which predictions were made dropped from 73 to 72 to 71. If the outliers were added to the "high rate" prediction group, the number of correct predictions would be 58, 61, and 63, respectively. These figures indicate the incremental predictive value of treating HM and DT occupations as outliers.[5]

Curvilinearity

Quadratic and cubic functions were fitted to the data to test for a curvilinear relationship to back injury rates. With the outlier data points excluded, a linear equation accounted for 51.8% of the BIR variance. A quadratic equation accounted for 54.9% of that variance. A cubic equation accounted for 55.0% of the BIR variance. The additional variance explained by addition of a quadratic term (3.1%) was statistically significant ($F_{1,68} = 4.67$, $p < .035$). The additional variance explained by the cubic term (0.1%) was too small to be statistically significant ($F_{1,67} = 0.15$, $p < .700$).

The quadratic equation could be simplified further. Only the quadratic term in this equation had a statistically significant regression weight (linear, $t = -1.00$, $p < .160$; quadratic, $t = 2.14$, $p < .018$). Dropping the linear term from the equation reduced the predictive power of the equation only slightly from $R = .741$ to $R = .736$. The R^2s for the equations differed by only .007, so adding the linear term to a predictive equation that already included the quadratic term would yield $F_{1,67} = 1.06$, $p < .307$. The shrunken R^2 for the reduced equation (shrunken $R^2 = .53553$) was virtually identical to that for the full equation (shrunken $R^2 = .53556$). Test statistics with values near 1.00 imply that the linear term accounted for almost exactly the amount of variance expected by chance for a single degree of freedom. The linear term, therefore, was dropped from the equation to provide the following parsimonious model:

$$BIR' = 1.937 + (0.273*D^2) \quad (SEE = 1.054) \quad \text{(Equation 1)}$$

where the prime (′) indicates the predicted back injury rate and "D" indicates the total job physical demands rating.[6]

A Rating Criterion Value to Identify High Demand Occupations

The last analysis step computed a specific PDR value that can be used to classify U.S. Navy occupations into low and high demand jobs. The performance of people in high demand jobs presumably would benefit from fitness standards higher than the current Navywide standards. This criterion value for PDRs was determined by combining Equation 1 with a statistical definition of elevated BIR. The procedure was:

A. Determine BIR′ for a hypothetical job with minimal physical demands (i.e., one rated 1.00). This minimum BIR′ was 2.210.

B. Use the standard error of estimate (SEE = 1.054) for Equation 1 to compute a 95% confidence interval around the minimum BIR′. This interval was ±2.066 (i.e., 1.96 * 1.054).[7]

C. Determine the upper limit of the 95% confidence interval. This limit was 4.276 (i.e., 2.210 + 2.066).

D. Set BIR′ equal to 4.276 in Equation 1 and solve for D as follows:

$$1.937 + (0.273 * D^2) = 4.276$$

Subtracting the constant in the equation from both sides yields

$$0.273 * D^2 = 4.276 - 1.937 = 2.339$$

Solving this equation produces

$$D = 2.927.$$

These computations define 2.927 as the critical value for job demands. Rounding off, any job rated 2.93 or higher on total physical demand has a BIR′ that is statistically significantly higher than the BIR′ for a minimal demand job. This rating value, therefore, can be a criterion that provides a working definition of a job with an elevated BIR′.

Applying the proposed high demand rating criterion to the set of entry-level U.S. Navy jobs, the proposed rating criterion classified 32 of 73 (43.8%) of U.S. Navy occupations as elevated risk specialties. Hospital Corpsman would be included in the elevated risk specialties in this classification, while Dental Technician would be assigned to the normal risk specialties. Excluding Hospital Corpsmen and Dental Technicians, 31 of 71 (43.7%) occupations would be classified as high risk. If an observed BIR of 4.28 or higher defines a high risk occupation, the PDR criterion would correctly classify 33 of 41 (80.5%) low risk occupations and 26 of 32 (81.3%) of high risk occupations.[8]

Discussion

U.S. Navy occupations with SME PDRs of 2.93 or higher should be classified as high physical demand jobs. This criterion rating value is based on the prediction that jobs with ratings this high or higher will demonstrate BIRs that significantly exceed the rate expected in a job with minimal physical demands. This criterion value assigns 44% of entry-level U.S. Navy occupations to the high physical demand category.

The classification criterion is based on a valid measure of occupational demands. The validity of psychological scales, including rating scales such as the PDRs, is established by empirical evidence to support proposed scale interpretations (American Psychological Association, 1985). Prior to this study, Carter and Biersner (1987) provided evidence that PDRs correlate with other methods of measuring those demands. Reynolds et al. (1992) showed that PDRs formed a distinct psychometric factor when analyzed with ratings of cognitive and psychomotor ability requirements. This study extended the available evidence by demonstrating that PDRs were strongly related to BIRs, while other types of demands were, at best, weakly related to BIRs. The reverse was true for general hospitalization rates, which were predicted more strongly by cognitive and psychomotor ability ratings than by PDRs.

The pattern of empirical evidence supports the construct validity of SME PDRs. Conceptually, these ratings measure the physical work or exertion required by the job. Physical demands, in turn, appear to cause back injuries on the job (Chaffin et al., 1978; Genaidy et al., 1990).

Carter and Biersner's (1987) data demonstrated convergent validity between PDRs and other methods of measuring the same construct. PDRs demonstrated the conceptually appropriate relationship to back injuries in the present study.

Discriminant validity evidence also is important (American Psychological Association, 1985). It is noteworthy, therefore, that PDRs were not related to general hospitalization rate. This negative finding makes it unreasonable to dismiss the BIR association as a manifestation of processes such as malingering or hypochondriasis. These and other similar mechanisms that would be expected to affect a broad spectrum of complaints and illnesses would lead to the prediction that BIRs would be related to overall hospitalization rate.

The results for cognitive and psychomotor ability requirement ratings further the view that PDRs are distinct from those attributes. Reynolds et al.'s (1992) factor analysis established PDRs as a distinct psychometric factor with modest correlations to ratings in the psychomotor and cognitive domains. The fact that cognitive and psychomotor abilities demonstrated a very different pattern of association to hospitalization measures further differentiates PDRs from these other ability ratings. This discriminative validity helps rule out the possibility that PDRs are merely one indicator of the general stressfulness of the job. If so, other demands would be moderately to highly correlated with physical demands, and the different demand measures would have similar patterns of association to criterion measures.

The pattern of available evidence supports the convergent and discriminant validity of PDRs. Using these ratings to identify jobs that merit occupation-specific fitness standards, therefore, provides a legitmate basis for setting standards that reflect the actual physical demands of the job.

A criterion value is required to translate PDRs, which form a theoretically continuous scale, into a high demand versus low demand dichotomy for job classification. The validity of this classification does not depend solely on the validity of the PDRs. The validity of this classification also depends on the appropriateness of the methods used to choose the criterion value. For example, a rating of "4.00" might be chosen arbitrarily as evidence of high physical demands. There would be no guarantee that the resulting classification would satisfy the intent of the DoD guidelines to ensure that people are fit enough for their jobs. Many jobs with PDRs < 4.00 still might expose incumbents to unacceptable risks of injury that could be reduced by appropriate physical training. The point to this example is that the rationale and assumptions for selecting a criterion value must be examined to ensure validity.

The criterion value of 2.93 developed in the present study was based on the simple rationale that an occupation-specific elevation of BIR is one manifestation of heavy physical demands on the job. Two assumptions were made to translate this rationale into a specific criterion value. The first assumption was that the PDR-BIR relationship demonstrated in this study is accurate. This assumption can be questioned on several grounds, including limited coverage of the criterion domain. Other hospitalization diagnoses or outpatient treatment criteria could produce different criterion values. The second assumption involved the statistical criterion for identifying an increased BIR. This statistical criterion was a less than 1 in 20 chance that the observed BIR would have occurred by chance if the true rate for the occupation was equal to the BIR predicted for a minimum demand job. This criterion could easily be changed. For example, the probability criterion could be shifted to a 1 in 10 chance. Alternatively, the reference job could be defined as mildly demanding (e.g., 1.50 on the rating scale) instead of minimally demanding. Such changes would alter the computation of a criterion value and change the classification for some occupations. For this reason, the proposed critical value should be regarded as a working criterion that could be modified by future research findings or by using different assumptions based on policy constraints affecting physical readiness programs. The most important aspect of establishing this criterion may be the demonstration that this approach is feasible.

The PDR-BIR correlations in this study were exceptionally strong relative to similar previous work. This point is important because weaker associations would mean a larger standard error. Inserting a larger standard error into the computations for critical value would raise the critical value. Similar previous work suggests that job ratings and clinically defined health criteria yield correlations in the range of r = .20 to r = .40 with an upper limit of r = .50. These estimates are based on a single study by Shaw and Riskind (1983) who related 32 PAQ dimensions (Mecham et al., 1977) to six causes of mortality for 92 occupations. Statistically significant ($p < .05$) associations were found with greater than chance frequency (27%). The PAQ dimensions that appear most similar to PDRs ("Performing activities requiring general body movements," "Performing handling/manual activities," and "General physical coordination") produced fewer significant associations (11%) and a lower maximum correlation (r = .34). PDR-BIR correlations of r = .60 to r = .70 would not be expected given the much weaker associations in this prior work.

Three methodological factors may account for the strength of association in the present study. First, Shaw and Riskind (1983) based their study on a psychological stress model. Health criteria were chosen because they were related to stress rather than because they were related to some specific job demand. In contrast, the present BIR criterion was chosen as a fairly specific consequence of exposure physical demands with a previously demonstrated association with qualitative assessments of those demands in the population under study (Chesson & Hilton, 1988; Marcinik, 1981). Second, Shaw and Riskind's (1983) health criterion data were organized according to the Dictionary of Occupational Titles (DOT; U.S. Department of Labor, 1977). U.S. Census Bureau Occupational Codes had been used to group jobs when computing the PAQ profiles. According to Shaw and Riskind (1983), "In most cases, [the health criterion study] job titles very closely matched job titles used in the DOT [Dictionary of Occupational Titles] and those found in the PAQ data bank" (p. 255). This matching procedure appears to leave more room for mismatches than in the present study where the same U.S. Navy enlisted classifications (NECs) were used to define the jobs rated and the at-risk populations for the health criterion. Third, occupational demand measures may be preferable to measures of job conditions or job behaviors when attempting to establish the effects of job elements on people. For example, Carter and Biersner (1987) found that objectively assessed physical demands were more strongly related to an item representing physical effort (r = .87) than to PAQ composites reflecting physical demands ($r \leq .79$). That effort item was similar to the PDR items used in the present study. Job rating composites may be less efficient for this type of prediction because they tend to reflect qualitative categories of behavior (e.g., lifting) rather than the amount of effort actually required to perform the tasks.

The quadratic form of the function relating SME PDRs to BIRs has important practical implications. Suppose the tasks comprising an occupation rated 4.00 were changed enough to reduce the rating to 3.50. The predicted BIR would drop by 1.01 admissions per 10,000 person-years (i.e., $0.27 * [4.00^2 - 3.50^2]$). The same change in a occupation initially rated 1.50 will reduce the predicted BIR by only 0.34 admissions per 10,000 person-years (i.e., $0.27 * [1.50^2 - 1.00^2]$). The current equation, therefore, supports the view that, all other things equal, highly demanding jobs should be given the highest priority in programs to reduce back injury risk. If the PDR-BIR association had been linear, the same benefit would have been predicted for both jobs. In this case, any difference in priorities for the two occupations would have to be based on additional considerations (e.g., ease of introducing change).

The quadratic function was contingent on treatment of outliers. If the Hospital Corpsman and Dental Technician occupations had been retained in the final analysis, a linear relationship between physical demands and BIRs would have been acceptable. It is important, therefore, to consider the legitimacy of excluding those two occupations. Outliers can result from chance factors operating within a single population or from having a mixture of two or more distinct populations represented in a data set (Barnett & Lewis, 1978). In the present case, statistical criteria made chance factors an unlikely explanation. At the same time, the two occupations in question share similarities which suggest that these occupations may, indeed, form a distinct subpopulation within the overall set of U.S. Navy occupations. For example, both occupations work primarily in medical care settings. Both occupations also have a greater proportion of females than the U.S. Navy at large. These factors could affect either the likelihood of injury, the probability of being hospitalized if injured, or both. The cumulative effect of these factors might shift the overall probability of hospitalization sufficiently to make the two occupations outliers.

These suggestions regarding the Hospital Corpsman and Dental Technician occupations illustrate that hypotheses can be generated that differentiate these occupations from other U.S. Navy occupations. However, generating a hypothesis does not make it true. Further study would be needed to establish the truth value of these speculations. In the present context, the hypotheses do make it clear that regarding the Hospital Corpsman and Dental Technician occupations as a distinct subpopulation is at least a defensible position. Results of studies of civilian populations also indicate high back sprain and strain rates for practical nurses and nurses aids (e.g., Klein, Jensen, & Sanderson, 1984). This information reinforces the position that the present findings are not likely to be mere statistical aberrations, but real phenomena whose dynamics should be investigated to reduce risks and control costs.

The present study findings can be useful in framing U.S. Navy fitness policy. In the context of current DoD policy, the rating criterion derived here classifies 44% of U.S. Navy occupations as candidates for higher physical fitness standards. The findings also imply that a set of strength standards would be a particularly useful addition to current fitness standards. Strength is distinct from the aerobic and muscle endurance components represented by current fitness standards (Chief of Naval Operations, 1990). The risk of back injury increases as the strength demands of the job approach the strength of the average incumbent (Chaffin et al., 1978; Genaidy et al., 1990). If a job cannot be redesigned, properly constructed fitness programs can shift this ratio. Strength training studies indicate that strength gains of 10% to 15% can be achieved in relatively short periods of time (American College of Sports Medicine, 1990). Once the gains have been made, strength can be maintained with reduced frequency or duration of training (American College of Sports Medicine, 1990). The quadratic function relating PDRs to BIR implies that making the person a little stronger could substantially modify the risk of back injury. Further research is needed to determine the actual benefits of physical training for incumbents of Navy jobs.[9]

Several limitations of this study provide issues to be resolved by further research. A wider range of inpatient and outpatient health criteria should be examined to catalog the full range of effects of physical job demands on the health of U.S. Navy personnel. Greater detail on the effects of physical work demands is needed to provide a more comprehensive basis for estimating the health costs of performing a demanding job. Further study of back injuries and other health problems among Hospital Corpsmen and Dental Technicians would help verify the outlier status of these occupations and develop means of reducing the risks associated with their work. Replicating the present findings in other populations would strengthen the empirical basis for inferences. Extension to other military services could provide a basis for more uniform methods of establishing physical fitness requirements in the DoD.

The fact that refinement is possible is no reason to overlook the importance of what is already known about SME PDRs for U.S. Navy occupations. This study and previous work indicate that SME PDRs are valid indicators of work in U.S. Navy occupations. As such, these ratings are a valuable tool for job analysis to determine which occupations would benefit from occupation-specific physical fitness standards that would exceed current Navywide requirements.

Footnotes

[1]Occupation is used in this paper instead of the U.S. Navy term "rating." This usage was adopted to avoid confusing the object to be rated (i.e., the occupation) with the scores derived from the rating process. Occupation is the civilian equivalent of a naval rating.

[2]Reynolds et al. (1992) provided data for 75 entry-level occupations. The EPISYS data did not include the occupation of Pattern Maker (PM). The Equipment Operator (EO) occupation was dropped from the study because hospitalization rates could not be estimated accurately. The estimated BIR for EOs was 0.00, but Marcinik (1981) found EOs to have a high BIR. The discrepancy between the two studies may derive from the fact that the EPISYS estimate was based on only 494 person-years of observation. A single hospitalization would change the EO back injury rate to 20.24 per 10,000 person-years and would shift the EO occupation from the lowest rate to the highest rate.

[3]The effect of treating "Not Applicable" responses as missing data was explored. For some occupations, more than half of the respondents chose this option for one or more of the physical ability ratings. In these cases, the actual job ratings were based on only a few data points which arguably were not representative of the full SME population. The alternative approach of scoring "Not Applicable" as "0" was evaluated as a means of incorporating the judgments of the full sample of SMEs. The average rating for each occupation was recomputed from frequency distributions in the appendix to Reynolds et al. (1992). The revised scores treated the set of response options as a 0 to 5 scale with "Not Applicable" responses scored as 0. These rescored ratings produced correlations that typically were less than those obtained with the Reynolds et al. (1992) scoring procedure. The typical difference was small, but the trend was consistent. Considering the correlations involving BIRs and physical demands, the average effect of using the Reynolds et al. (1992) scoring was an increase of .02 in the size of the correlation. The results for the Reynolds et al. (1992) scoring have been reported in this paper because the larger correlations indicated greater validity for this approach.

[4]The appropriate interpretation of any correlations between overall hospitalization rate and PDRs is important. This measure is intended to assess factors that produce a generalized tendency toward higher hospitalization rates. The absence of an association between PDRs and overall hospitalization rates would not rule out any relationships to specific medical problems. This paper shows, for example, a strong association with BIRs in the presence of a near-zero association with overall hospitalization rate. The absence of an association between PDRs and overall hospitalization rate also would not absolutely eliminate hypochondriasis, malingering, and other similar explanations as reasons why PDRs predict hospitalization rates. However, the idea of a generalized tendency would have to be replaced by more complex explanations arguing for specific causal chains rather than general processes. For example, people in physically demanding jobs might express malingering or hypochondriacal tendencies specifically as complaints of back problems. This specificity of expression might occur because back problems are a plausible consequence of on the job exertion and are difficult to diagnose. Such explanations must be viewed with caution because they are post hoc, and, therefore, tailored to the specific findings to be explained. There is a substantial

difference between such explanations and a priori predictions. Nevertheless, the potential relevance of the proposed post hoc explanations to the interpretation of PDR-hospitalization rate correlations should not be ignored. The overall hospitalization rate has been used in this study as a general indicator of which could signal the relevance of any of several alternative interpretations of PDR-BIR correlations. The alternative interpretations proposed here involve generalized tendencies to seek medical care. The findings obtained with the general hospitalization rate measure are useful in determining how the general set of alternative interpretations may be. The findings do not provide a basis for choosing between those alternatives. Results obtained with the general hospitalization measure should be viewed with these considerations in mind.

[5]Transforming the dependent variable is an alternative method of minimizing the influence of outliers. This alternative was less effective than deleting the outlier cases in the present analyses. Square root and natural logarithm transformations of the dependent variable increased the PDR-BIR correlations to $r = .65$ and $r = .63$, respectively, for the full sample. However, deleting the outlier occupations still improved predictive precision. With the Hospital Corpsman occupation deleted, the same correlation ($r = .68$) was obtained whether raw scores, the square root of those scores, or the natural logarithm of those scores was the dependent variable to be predicted. When both the Hospital Corpsman and Dental Technician occupations were deleted, the correlation actually was larger for the raw score ($r = .72$) than for the square root ($r = .70$) or logarithmic transformations ($r = .71$) of BIRs. Thus, deleting outliers increased the validity coefficients even after transformation, but transformation did not increase validity after removing the outliers. Outlier deletion, therefore, was the simplest method of minimizing the effect of the exceptional occupations.

[6]The treatment of outlier data points affected the predictive precision of the regression equations, but had relatively modest effects on the parameter values in those equations. In the linear equation, the slope was .231 for the full sample, .276 with the Hospital Corpsman occupation deleted, and .183 with both the Hospital Corpsman and Dental Technician occupations deleted. The corresponding intercepts were 1.577, 1.435, and 1.447. The corresponding regression weights in the quadratic equation were .277, .269, and .273. The intercept estimates for the quadratic equation were 2.096, 2.034, and 1.938. The parameter values for the quadratic equation were more robust to the effects of outliers than the values for the linear equation. The range of regression weights for the quadratic equation was .008 compared with .093 for the linear equations. The range for regression weights was 2.9% of the median regression weight for the quadratic equation and 40.2% of the median weight for the linear equation. Estimated values for the intercept differed slightly more for the quadratic equation (range = .158) than for the linear equation (range = .132). However, the latter figure represented 9.1% of the median value for the linear intercepts, while the former value represented 6.3% of the median value for the quadratic equation. The relative robustness of the quadratic equation is an additional reason to prefer this equation to the linear equation as a model for predicting BIRs.

[7]The assumption of normality made in these computations applies to the distribution of regression errors in predicting BIRs. This error distribution is not the same as the sampling error for each BIR estimate. The sampling error for each estimated BIR will depend on the rate of back

injuries and the sample size within the occupation. If this sampling error were computed for each occupation in this study, the distribution of those errors probably would not be normal. This error estimate refers to the accuracy of estimation of the rate, not the accuracy with which that rate, once estimated, can be predicted. The two issues may be linked, but the present approach simply applied the common regression assumption that prediction errors are distributed normally. Application of the Kolmogorov-Smirnov (Siegel, 1959) test to the residuals for the regression equation indicated that they were, in fact, normally distributed ($z = 0.58$, $p < .894$).

[8]The high physical demand occupations were Electrician's Mate, Gas Turbine System Technician (Mechanical), Hospital Corpsman, Machinery Repairman, Aviation Support Equipment Technician, Aviation Structural Mechanic (Safety Equipment), Storekeeper, Mess Management Specialist, Ship's Serviceman, Aviation Electrician's Mate, Machinist's Mate, Construction Mechanic, Mineman, Boiler Technician, Aviation Structural Mechanic (Metal Structures), Aviation Structural Mechanic (Hydraulic Systems), Hull Technician, Engineman, Torpedoman's Mate, Construction Electrician, Aviation Boatswain's Mate (Fuel), Aviation Machinist's Mate, Gunner's Mate, Damage Controlman, Steelworker, Postal Clerk, Aviation Boatswain's Mate (Aircraft Carrier), Utilitiesman, Aviation Boatswain's Mate (Aircraft and Other Equipment), Builder, Molder, and Aviation Ordnanceman. These occupations have been listed here in ascending order of their rated physical demands.

[9]The performance of the average Navy sailor may improve less than expected from physical training programs. A previous study by Marcinik, Hodgdon, Englund, and O'Brien (1987) suggests that implementing programs aboard Navy ships may produce slightly lower gains than seen in other physical training settings. Aboard ship, the typical improvement on a strength measure may be 5% to 10%, although some specific strength measures may show 15% gains. This qualification, however, may be influenced by the specific structure of Marcinik et al.'s (1987) training program. That program combined circuit weight training at 60% of one repetition maximum strength with either interval or continuous running. Also, it should be noted that the estimated gains may not apply to the full crew. This extrapolation would be appropriate only if 100% of the crew participated in the fitness program. This outcome is unlikely. However, if program designs can be tailored to occupational physical fitness needs and if 100% participation can be ensured by some method, physical training programs can be reasonably expected to increase the strength of shipboard U.S. Navy personnel by 10%. The net effect on BIRs then would depend on the degree of mismatch between this enhanced strength level and the tasks comprising the job.

Performing the job may provide some of the training effects needed to reduce risk of back injury. Analysis of the pretest data from a study of sailors aboard a U.S. Navy destroyer (Marcinik, unpublished data) showed that people in more physically demanding occupations are somewhat stronger than people in less demanding occupations. The research that provided the data recorded the occupational specialty of each participant. This information made it possible to use the PDRs reported by Reynolds et al. (1992) to classify participants as incumbents in low (Total Demand < 2.93) demand occupations ($n = 46$) or elevated (Total Demand ≥ 2.93) demand occupations ($n = 100$). One-tailed significance tests for the hypothesis that the low demand group would be weaker than the elevated demand group identified greater strength in the elevated demand group. Statistically significant differences were noted for shoulder press ($p < .043$), arm curl ($p < .002$), latissimus pull ($p < .009$), and bench press ($p < .015$). Using the low demand occupations as the reference group, the elevated demand group was 5.9% higher on the shoulder press strength, 10.8% higher on the arm curl strength, 7.0% higher on latissimus pull strength, and 6.5% higher on the bench press strength. The two groups did not differ on leg press strength ($p < .294$), leg press endurance ($p < .462$), bench press endurance ($p < .457$), sit-ups ($p < .384$), or flexibility ($p < .062$). Overall, the elevated demand occupations could be characterized as having greater upper body strength than the low demand occupations, but the two groups were comparable on lower body strength and muscle endurance. If these results generalize to other U.S. Navy work populations, differences between low and elevated demand groups are on the order of 5% to 10% and may be confined to upper body strength. If the differences were not the result of selection processes that put people who were stronger to begin with in the more demanding jobs, the job provides some preparation for meeting the physical demands. The preparation is not enough, however, because people in high demand jobs still suffer an excess rate of back injury.

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Department of Defense physical fitness guidelines call for occupation-specific fitness standards for exceptionally demanding occupations. Physical demand ratings (PDRs) can be an efficient tool for identifying those occupations, but no previous study has defined a rating criterion score to determine which occupations should be classified as exceptionally demanding. This study examined the relationship between PDRs and back injury hospitalization rates (BIRs) for 73 entry-level U.S. Navy occupations. The study demonstrated a strong relationship between PDRs and BIRs (r = .59), which increased substantially when two outlier occupations were dropped from the analysis (r = .72). A quadratic function was used rather than a linear function (r = .74). Applying the quadratic function, any occupation with a rating of 2.93 or higher had a predicted BIR significantly higher than the predicted BIR for a minimally demanding job. Using this criterion to define an exceptionally demanding job, 44% of the 73 occupations studied would require occupation-specific fitness standards.

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