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Demonstration of an Actuarial Method for Estimating Preinjury Hand Strength

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Assessments of the magnitude of performance loss caused by injury or disease necessarily involve a comparison of a person's performance before and after the onset of impairment. Well-established procedures are available for measuring current performance on a variety of evaluation instruments. However, few actuarial methods have been developed for estimating the person's performance prior to injury. This study demonstrated how regression equations can be used to estimate preinjury hand strength. Although the equations generated in this investigation are specific to hand strength, the methodology can be extended to estimate the preinjury performances of persons with a variety of physical and intellectual impairments.

INTRODUCTION

In the resolution of worker's compensation cases and personal injury litigation, physicians, rehabilitation psychologists, counselors, and evaluators are often asked to give expert opinion regarding the impact of an injury on a person's employability (1, 2). A critical component in forming such judgments is some estimation of the magnitude of the performance decrement resulting from the injury. An estimation of performance loss due to injury can be obtained by applying the following algorithm: (1) measure the person's current performance on tasks affected by the injury, (2) estimate performance on these same tasks prior to injury, and (3) compute the pre-post difference.

Extensive research, conducted with a variety of psychoeducational and physical assessment instruments, allows professionals to obtain reliable and valid estimates of current performance (3). Conversely, estimations of preinjury performance have received very little attention in the rehabilitation literature.

Preinjury estimates can be based on either clinical or actuarial judgments. Evaluators using the clinical method combine information from professional experiences, opinions, and intuitions in making judgments. The human judge is eliminated in the actuarial method; the results of the evaluation depend solely on empirically-demonstrated relations between the data and the behavior being estimated.

The well-documented superiority of actuarial over clinical judgments (4,5) suggests that an actuarial analysis would produce relatively accurate estimates of pre-injury performance. However, most actuarial formula predict future behaviors, such as the industrial production of job applicants, therapeutic outcomes of mental health patients, or the grades of prospective college students. In contrast, preinjury assessments are estimates of behaviors that no longer exist and may never exist again.

The retrospective nature of preinjury assessments presents a special problem for evaluators, because the behavior of interest cannot be directly measured. For instance, administering an intelligence test to a person who has sustained a serious head injury will not yield a valid measure of that individual's preinjury intellect. One potential solution to this problem is to measure a sample of persons who are similar to the individual prior to the onset of injury, disease, etc. Data from the uninjured sample could then be summarized and an actuarial decision rule formulated. The actuarial statistic or equation could then furnish an estimate of the pre-injury performance of a person who has incurred a disability.

A straightforward application of this approach is to calculate the mean performance of a sample of uninjured persons. If the person was representative of the uninjured sample before the onset of injury, the evaluator could assume that the individual's preinjury performance approximated the mean of the uninjured sample. "Assuming the average" provides a simple objective procedure for estimating pre-injury performance. However, this approach will result in large assessment errors if the individual's preinjury performance was very different from the mean of the standardization sample.

An alternative actuarial procedure is to calculate a multiple regression and Use the resulting equation to estimate preinjury performance. For instance, measures of weight and height from an uninjured sample could be regressed upon performance on a back dynamometer. Evaluators could then assess the weight and height of a person with a back injury and use the regression equation to estimate preinjury back strength.

The primary purpose of this investigation is to demonstrate a regression approach with the potential for providing preinjury performance estimates for a variety of physical and intellectual assessment instruments. Hand strength was selected as an exemplar of this methodology, because hand injuries are one of the most frequent sources of disability claims in worker's compensation cases (6).

Static measures of hand strength provided the dependent measures for a series of preinjury regression equations. Hand volume, weight, height, and opposite hand strength were the independent variables. These variables were selected for study, because they can be easily obtained and no computation is involved.

METHOD

Subjects

The subjects were 247 females and 157 males enrolled in psychology courses at Appalachian State University. All subjects were between 18 and 25 years of age (*M* = 20.2) and none had sustained an injury that affected their current hand strength.

Procedure

A brief interview was conducted to determine if injury or disease affected the subject's current hand strength. Three persons were not tested because they reported severe hand injuries. Weight and height were recorded using a Health-o-Meter manufactured by the Continental Scale Company. Right and left hand volumes were measured by the amount of water displaced when the subject's hand was immersed in a volumeter (Volumeter Set #3511, Volumeters Unlimited).

Finally, grip strength was tested with the adjustable-handle Jamar BK-7498 (Therapeutic Equipment Company) hand dynamometer. Jamar is a widely used type of dynamometer, and has been found to have a relatively high calibration accuracy (7). The distance between handles was set at 4.70 cm (position 2).

For each trial, the subject was standing, the shoulder was adducted and neutrally rotated, the elbow flexed at 90%, and the forearm and wrist were in a neutral position. The testing procedures were those recommended by the American Society of Hand Therapists (8).

Three trials were performed using the Jamar dynamometer with the right hand, followed by three trials with the left hand. After each trial, the evaluator took the dynamometer from the subject, recorded the exertion, and reset the needle to 0. Approximately 12 seconds separated trials. The purpose of the investigation was described to the subjects at the conclusion of the session.

Data Analysis

Reliability coefficients were calculated to assess consistency across the three grip strength trials. Separate alpha coefficients (9) were computed for females and males using their right and left hands. All alphas exceeded .94; consequently, mean trial scores were used in all subsequent analyses. Four multiple regressions (10) were calculated which could be used to estimate the preinjury performance of persons with unilateral hand injuries.

RESULTS

Separate analyses were made of the right and left hand grip strengths of both sexes. The regressions estimating right hand grip strength used left hand grip strength, left hand volume, height, and weight as independent variables. If left hand grip strength was estimated, right hand grip strength, right hand volume, height, and weight served as independent variables. A stepwise procedure was employed to select the set of variables that best predicted the dependent measure, and to eliminate superfluous variables from the regression equation. Variables were entered if their inclusion produced a statistically significant increment the explained variance ($p < .05$) after partialing the variables already in the equation. At each step, the variable with the largest probability of F was removed if $p > .10$.

The means, standard deviations, and correlations between variables are found in Tables I and IL For both females and males, left hand performance was the best single estimator of right hand performance. Similarly, right hand performance provided the best estimate of left hand performance. A number of significant bivariate correlations were found between hand volume, height, weight, and the dependent measures (Table II). However, these variables were not always entered in the equations, because they provided information that was redundant with variables previously included in the analyses. Table III reveals that each of the regression equations was significant (all $ps < .001$).

Table I. Means and Standard Deviations of Weight, Height, Hand Volume, and Grip Strength[0]

	Weight	Height	Right volume	Left volume	Right grip	Left grip
Females						
M	59.92	165.40	388.93	384.37	28.75	25.45
SD	9.65	6.22	47.17	46.56	5.18	5.14
Males						
M	76.80	179.97	517.96	510.40	46.82	41.76
SD	13.48	6.73	62.42	61.43	9.48	7.99

[0]The following units of measurement were used: weight, kg; height, cm; hand volume, cc; grip strength, kg.

Table II. Bivariate Correlations of Weight, Height, Hand Volume, and Grip Strength[0]

	Weight	Height	Right volume	Left volume	Right grip	Left grip
1	1.00	*45b*	.78b	.7	*.36b*	*.36b*
2	*.44b*	1.00	*.36b*	*.35b*	.1	*.2ob*
3	*.79b*	.4	1.00	*.95b*	*.45b*	*Alb*
4	.7	*.44b*	*.95b*	1.00	*.44b*	*.45b*
5	*_34b*	*.32b*	*.5lb*	*.44b*	1.00	.8lb
6	.2	*.33b*	.48b	*.47b*	.7	1.00

[0]Data from female subjects is above the diagonal and data from male subjects is below the diagonal.
bp < .001.

Table III. Regression Equations for Estimating Preinjury Grip Strength[a]

	Regression equation	R^2[b]
Females		
Right grip	4.82 +0.77(Left Grip) +0.0l(Left Volume)	.66[c]
Left grip	0.76 +0.78(Right Grip) +0.04(Weight)	.66[c]
Males		
Right grip	2.70 +0.90(Left Grip) +0.08(Weight)	.64[c]
Left grip	5.39 +0.62(Right Grip) +0.0l(Right Volume)	.63[c]

[a]The following units of measurement were used: weight, kg; hand volume, cc; grip strength, kg.
[b]Multiple correlation adjusted for shrinkage.
[c]$p < .001$.

DISCUSSION

For both females and males, the regressions of hand volume, weight, height, and opposite hand performance on grip strength were highly significant. Statistical significance indicates that the regression equations provided more accurate estimates of grip strength than the sample means (10). Furthermore, the proportion of variance accounted for (Table III) is sufficiently high to be meaningful in a clinical setting. Thus, our recommendation is that rehabilitators use these equations, rather than the mean of the standardization sample, to estimate preinjury hand strength.

To illustrate how regression equations can yield estimates of preinjury hand strength, let us consider the case of a 20-year-old sewing machine operator who injured her right hand. Conditions specific to her situation indicated that performance at position 2 of the Jamar dynamometer would provide a useful index of pre-injury hand strength. Table III shows that left hand grip strength and left hand volume made statistically significant contributions to the explained variance, and were included in the equation.

The sewing machine operator recorded a dynamometer score of 27 kg with her left hand and had a left hand volume of 400 cc. The regression equation estimating the right hand strength of females (Table III) requires only a few computations.

$$4.82 + 0.77(\text{Left Grip}) + \text{O.Ol}(\text{Left Volume}) = \text{Estimated Right Grip}$$
$$4.82 + 0.77(27) + \text{o}.01(400) = 29.61 \text{ kg}$$

The estimate of the young woman's preinjury strength was then compared to her current strength to estimate the magnitude of loss due to the injury. She was tested before her first therapy session, obtaining a score of 10 kg with her right hand. Her estimated preinjury grip strength was subtracted from her grip strength, yielding an estimated loss of 19.61 kg. From this point, the percent loss was easily calculated.

$$\text{current strength} - \text{estimated preinjury strength} = \text{change}$$
$$10.000 - 29.61 = -19.61 \text{kg}$$

$$(\text{change}/\text{estimated preinjury strength}) * 100 = \text{percent change}$$
$$(-19.61/29.61) * 100 = -66.23\%$$

In addition to providing a vital component in estimating strength loss due to injury, preinjury strength estimates may furnish a standard for assessing the extent of the individual's recovery. For example, the sewing machine operator eventually obtained a right hand score of 20 kg with the Jamar dynamometer. Such an improvement indicated that the estimated loss of hand strength had decreased from 66.23% to 32.46%.

$$20.000 - 29.61 = -9.61 \text{ kg}$$
$$(-9.61/29.61) * 100 = -32.46\%$$

A full recovery from the injury would be demonstrated when a person's current hand strength equalled the estimated preinjury strength.

Several restrictions must be followed in the use of these equations. The equations can only be applied when there is reason to believe that an individual was similar to the uninjured sample before the onset of injury. For instance, age has been shown to have a substantial impact on grip strength (11). The present study used a sample of young adults to derive the regression equations. Therefore, these equations cannot be used with other age groups. Also, preinjury estimates will be invalid if any of the independent variables are affected by injury or disease. Some persons, including many arthritis and carpel tunnel patients, experience impairments to both hands. In many such cases, opposite hand performance and hand volume are impacted and unsuitable for estimating preinjury hand strength. Estimation errors will also result if the individual experiences a large weight change following an injury.

Investigations need to be conducted to further substantiate the clinical utility of regression equations in estimating preinjury performance. Empirical studies that compare the accuracy of actuarial and clinical estimates of preinjury performance are the next logical step in the research process. Reports on the use of preinjury regression equations in the resolution of workers compensation cases and personal injury litigation would also be of interest.

In conclusion, hand strength provided an exemplar to demonstrate an actuarial procedure for estimating preinjury performance. Preinjury regression equations were obtained by: (1) choosing a sample of uninjured persons who were representative of the client before the onset of impairment, (2) assessing members of the uninjured sample on a group of variables that were correlated with the behavior of interest, and (3) computing the regression equation that best described the relationships between the independent and dependent variables.

Although the equations presented in this paper are specific to young adults tested with the Jamar dynamometer, preinjury regression equations can be established for virtually any physical or intellectual assessment instrument. For instance, level of formal education, socioeconomic status, and occupational history could be regressed upon the IQ scores of a sample of uninjured persons, and the resulting equation used to estimate the intellectual capacities of head-injured clients before their disability. Similarly, weight, height, hand, arm, and leg strength could serve as independent variables that furnish estimates of preinjury back strength.

What is needed is a series of studies that generate equations for estimating the preinjury performance of clients with back, upper extremity, leg, head, and other impairments. Hopefully, it will soon be routine for evaluators to refer to the rehabilitation literature or test manuals for preinjury equations, and to use this information to make actuarial assessments of the magnitude of performance loss due to injury.

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