Estimating Pre-Injury Hand Functioning: A Statistical Approach for Reconstructing the Past

Gary L. Sigmon[1]
Hall P. Beck

Appalachian State University

Abstract

Assessments of functioning loss and treatment effectiveness often require an evaluation of a client's pre-injury abilities. The purpose of the present study was to demonstrate the use of multiple regression to estimate pre-injury hand strength and dexterity. The dependent variables were scores on the Jamar hand dynamometer, West 4 maximum torqueing test and Purdue Pegboard. The predictor variables were weight, height, hand volume and performance on the opposite hand. Twenty multiple regressions yielded a series of equations that vocational evaluators can use to accurately estimate pre-injury hand functioning.

Determining an individual's functioning level prior to injury is central to many issues confronting vocational evaluators. All evaluations of strength or dexterity loss necessarily involve a comparison of current performance to pre-injury performance. There are a variety of testing devices that can be used to measure the worker's present competence. However, often no assessment data were gathered before the worker was disabled. In such situations, vocational evaluators have few methods for establishing the client's pre-injury functioning. The primary goal of this study was to develop a series of equations to accurately estimate hand strength and dexterity prior to injury.

Appraisals of pre-injury competence also provide a standard for gauging the effectiveness of treatment. For example, assume that a worker injures her right hand in an industrial accident and is placed in a work hardening program. She obtained a dynamometer reading of 5 kg during her initial evaluation. Her gripping force was 22 kg after 3 weeks of training. Clearly, she has made considerable progress. But what force should she be able to exert if she has completely recovered from her injury? The evaluator must be able to determine the worker's strength of grip before the accident to know if rehabilitation has been completely successful.

Vocational evaluators have frequently utilized work history in conjunction with their professional judgment to estimate pre-injury functioning level. As a result, it is often impossible to specify the procedures or decision processes used making the appraisal. Furthermore, because the elusive quality of professional judgment varies extensively across evaluators, subjective assessments suffer from a lack of reliability.

Several empirical procedures provide an alternative to subjective appraisals. Evaluators could assume that an individual approximated the average of some normative group before their disability. Because many capacities are characterized by a great deal of variability, "assuming the average" often results in substantial errors.

A more accurate index of pre-injury functioning could be obtained by consulting studies that have documented the ratio of dominant to non-dominant hand performance (e.g., Berlin & Vermette, 1985; Lunde, Brewer, & Garcia, 1972; Patterson, 1965). For example, assume that females without hand disabilities average 5% higher scores with their dominant hands on a dynamometer. A reasonable estimate of dominant hand strength could be made by measuring non-dominant hand performance and multiplying that score by 1.05. Although the parsimony of this procedure is attractive, it has several shortcomings which result in needless errors.

[1]Additional information concerning this article can be obtained by writing to the authors at the Psychology Department, Appalachian State University, Boone, NC 28608. We would like to thank Lee Powel for her assistance in preparing this manuscript.

First, this method uses only a single variable, hand dominance, when frequently more accurate estimates can be made from an analyses based on a combination of variables. A second problem with this strategy is that it fails to consider that the ratio of dominant to non-dominant hand performance could change as a function of individual characteristics. For instance, dominant hand strength could be 10% greater than non-dominant hand strength for individuals with small hands. However, only a 2% difference in hand strength might occur in persons with large hands.

This paper will demonstrate a more precise method of estimating pre-injury performance. Multiple regression, using the principle of least squares, was the tool of inquiry. Weight, height, and hand volume were the main predictor variables. Performance on the Jamar hand dynamometer, the West 4 maximum torqueing test, and the Purdue Pegboard test of manipulative dexterity provided the dependent measures. Separate equations were developed to estimate the pre-injury dexterity and hand strength of individuals with impairments to left and right hands. A sample of women who had never had a serious hand injury was used to generate regression weights. This approach assumed that the relationship of predictor to performance variables is similar for non-injured persons and for injured persons prior to their debilitation. An example of the use of these equations by a vocational evaluators is presented in the final section of this manuscript.

Method

Subjects

The subjects were 41 females enrolled in psychology courses at Appalachian State University. All subjects were between 18 and 25 years of age, right-handed, and none had sustained a serious hand injury. The students received extra course credit for participating in the investigation.

The data from 7 other women was not included in the analysis, because they were either left-handed, ambidextrous, or reported a serious hand injury.

Procedure

The subjects were greeted by a male evaluator and escorted to a 3.11 x 2.95 m room containing the testing equipment. Each subject verbally reported their height, weight, hand dominance, and whether or not their hand or wrist had been injured. Detailed notes were taken regarding the nature of the injury and if any treatment had been administered. The first author used these notes to determine if an injury was sufficiently severe to preclude inclusion in the data analysis.

The subjects were then assessed using Hand Volumeter Set #3511 (Volumeters Unlimited). This test required the person to gradually immerse her hand until her fingers straddled a rod situated in the beaker. Hand volume was determined by the amount of water displaced. The right hand was measured before the left hand.

Thirty measures were then taken using the Jamar BK-7498 hand dynamometer. The subjects were instructed to stand erect and to hold their elbow against their body while extending their hand at a ninety degree angle. Each subject held a ruler between their arm and torso to insure that extraneous body movements were minimized. Three trials were performed with each hand in each of the five positions of the Jamar. The testing sequence was: the right hand in position one, left hand in position 1, right hand in position 2, the left hand in position 2, etc. After each trial the evaluator removed the dynamometer from the subject's hand, recorded the exertion, and reset the needle to 0. Approximately 8 seconds separated each trial and 15 seconds were required to switch positions on the Jamar.

The West 4 (West 4 Work Capacity Evaluation Device User Manual, 1983) was administered next. The West 4 consists of six compression tubes mounted on a square steel crosspiece. Each compression tube contains a spring that can be tightened by turning a universal bolt head. An adjustment screw on the compression tube is used to vary the torque necessary to rotate the bolt head. The West 4 was attached to a table with the compression tubes 1.04 m above the floor. This placed the bolt head between the subject's waist and shoulder.

A nutdriver was used to turn the bolt head. As the subject rotated the bolt head, the evaluator gradually increased resistance by tightening the adjustment screw. A ruler placed between the arm and torso reduced superfluous movements. A torque gauge provided a measure of the subject's maximum level of output.

Three pronation trials were conducted with each hand, followed by three supination trials with each hand. A coin was tossed to determine whether the subject would first be tested with the dominant or non-dominant hand.

The Purdue Pegboard was administered using the procedures described in the examiner's manual (Tiffin, 1968). The first three tests required subjects to insert pins in small holes using the right hand, left hand, and both hands. A fourth test involved assembling pins, collars, and washers. Three trials were performed on each of four tests.

Results

Twenty multiple regressions were computed. Separate analyses estimated the pre-injury performance of persons with impairments to their right and left hands. For each hand, regressions were calculated using mean scores on the Jamar (Positions 1 through 5), the West 4 (pronation and supination) and the Purdue Pegboard (pin insertion with one hand, both hands and the assembly task) as the dependent measures.

If right hand performance was the dependent measure, the predictor variables were height, weight, left hand volume, and performance on the same task using the left hand. For example, height, weight, left hand volume, and left hand pronation were used to estimate right hand pronation scores on the West 4 maximum torqueing test. If left hand performance was estimated, weight, height, right hand volume, and right hand performance on the same task served as predictors.

A forward solution was used to determine the order that the predictor variables were regressed. Only variables that significantly increased the explained variance were included in the prediction equation. The investigators believed that at this stage of investigation the cost of a Type II error was greater than a Type I error. Therefore, the level of significance was set at a probability of .10 rather than .05.

Because of the large number of analyses, the results have been summarized in appendixes at the back of the manuscript. Regressions performed on the Jamar, West 4 and Purdue Pegboard are contained in Appendixes A, B and C, respectively. The appendixes include simple correlations between the variables, regression equations and tests of the statistical significance of regression coefficients.

Discussion

The regression equations found in the appendixes tell the evaluator the variables that must be measured in order to assess pre-injury functioning. To illustrate, let us assume that an evaluator needs to estimate right hand performance on Position 2 of the Jamar (R-Pos 2). Regression 2 in Appendix A indicates that the regression equation consists of the intercept constant and the coefficients assigned to the weight (WT) and left hand performance at Position 2 (L-Pos 2) variables. In this case, the client weighed 130 lb and recorded 27 kg with the left hand at Position 2. To estimate right hand strength at Position 2, simply enter the weight and left hand performance in the equation. For example,

$$1.48 + .765 \text{ (L-Pos 2)} + .066 \text{ (WT)} = \text{R-Pos 2}$$

$$1.48 + .765 (27) + .066 (130) = 30.715 \text{ kg}$$

The coefficient of determination (R^2) is a measure of how well the regression analysis estimates performance. The equation estimating right hand performance at Position 2 accounts for 69% of the variability in subjects' scores. In other words, the evaluator can have confidence that the equation will provide an accurate estimate of pre-injury performance.

At least one predictor variable was significant in each of the regression analyses. The median coefficient of determination was .63, indicating that most of the equations explained a substantial proportion of the variability. In general, coefficients of determination were higher on the Jamar than on the West 4 or Purdue Pegboard. The performance of persons on the Purdue Pegboard with left hand injuries was especially difficult to estimate.

As expected, performance on the opposite hand was the best single predictor of hand functioning. A number of significant simple correlations (Appendixes A, B and C) were found between weight, height, opposite hand volume and various performance measures. However, these variables usually did not enter the regression equation because they were also highly correlated with opposite hand performance.

Several strategies are available to the researcher seeking to improve the accuracy of the equations found in this manuscript. The current study used only opposite hand performance and several easily obtained physical measures as predictors. It is likely that more precise appraisals would result if personality measures such as sub-clinical depression (e.g., Beck, Ward, Mendelsohn, Mock, & Erbaugh, 1961) and evaluation anxiety (Sarason, 1984) were included in the regression. Studies that measure performance changes that occur in the non-injured hand following a disability could also suggest useful modifications to the estimation equations.

Assessment errors could also be reduced by considering nonlinear regression models. This investigation assumed a linear relationship, because that is the most basic equation for summarizing the association between variables. However, there is no a priori reason to assume that a quadratic or more complex function would not have provided a more accurate regression equation.

Several precautions should be practiced in extrapolating the regression equations to other populations. Certainly, the equations should not be used with clients who have injured both hands. Also, the sample in this study consisted of right-handed females whose mean age was 20 years. Future investigations should determine the extent that these equations are representative of other groups. For example, it would be valuable to discover if similar regression coefficients would be obtained with a sample of males or older females.

Studies should also be conducted to verify the principle assumption of this investigation. That is, the regression coefficients describing the relationship of predictor to performance variables are similar in non-injured persons and clients prior to their injury.

In sum, the present study demonstrated that multiple regression can be used to establish equations that generate accurate estimations of pre-injury hand functioning. In the future, investigators should apply this methodology to other types of injuries, client populations, and assessment instruments. Research should also assess the contribution of other potentially useful predictor variables. This series of studies will provide vocational evaluators with more accurate procedures for determining the extent of disability and degree of treatment effectiveness.

References

Beck, A. T., Ward, C. H., Mendelsohn, M. Mock, J., & Erbaugh, J. (1961). An inventory for measuring depression. Archives of General Psychiatry, 4, 561-571.

Berlin, S., & Vermette, J. (1985). An exploratory study of work simulator norms for grip and wrist flexion. Vocational Evaluation and Work Adjustment Bulletin, 18, 61-65.

Lunde, B. K., Brewer, W. D., & Garcia, P. A. (1972). Grip strength of college women. Archives of Physical Medicine and Rehabilitation, 53, 491-493.

Patterson, H. M. (1965). Grip measurements as a part of the pre-placement evaluation. Industrial Medicine and Surgury, 34, 555-557.

Sarason, I. G. (1984). Stress, anxiety, and cognitive interference: Reaction to tests. Journal of Personality and Social Psychology, 46, 929-938.

Tiffin, J. (1968). The Purdue Pegboard: Examiner's manual. Chicago: Science Research Associates.

West 4 Work Capacity Evaluation Device User Manual. (1983). Huntington Beach, CA: Work Evaluation Systems Technology.

Appendix A

Summary of multiple regressions estimating pre-injury performance on the Jamar dynamometer

Regression Equation	R^2	F^a	Simple Correlations				
Regression 1: Estimate Right Hand Position 1				HT	LV	L-Pos 1	R-Pos 1
Step 1			WT	.49***	.58***	.28*	.37**
6.38 + .807 (L-Pos 1)	.458	32.91***	HT		.14	.08	.10
			LV			.17	.31*
			L-Pos 1				.68***
Regression 2: Estimate Right Hand Position 2				HT	LV	L-Pos 2	R-Pos 2
Step 1			WT	.49***	.58***	.44**	.50***
7.74 + .843 (L-Pos 2)	.670	79.13***	HT		.14	.28*	.29*
Step 2			LV			.40**	.41**
1.48 + .765 (L-Pos 2) + .066 (WT)	.695	43.20***	L-Pos 2				.82***
Regression 3: Estimate Right Hand Position 3				HT	LV	L-Pos 3	R-Pos 3
Step 1			WT	.49***	.58***	.34*	.42**
5.95 + .875 (L-Pos 3)	.814	170.12***	HT		.14	.34*	.36*
Step 2			LV			.30*	.33*
0.48 + .832 (L-Pos 3) + .052 (WT)	.829	92.29***	L-Pos 3				.90***
Regression 4: Estimate Right Hand Position 4				HT	LV	L-Pos 4	R-Pos 4
Step 1			WT	49***	.58***	.32*	.35*
3.05 + .976 (L-Pos 4)	.797	152.67***	HT		.14	.38**	.34*
			LV			.25	.34*
			L-Pos 4				.89***
Regression 5: Estimate Right Hand Position 5				HT	LV	L-Pos 5	R-Pos 5
Step 1			WT	.49***	.58***	.29*	.33*
5.63 + .800 (L-Pos 5)	.717	99.01***	HT		.14	.32*	.43**
Step 2			LV			.27*	.29*
-14.46 + .746 (L-Pos 5) + .327 (HT)	.747	56.12***	L-Pos 5				.85***
Regression 6: Estimate Left Hand Position 1				HT	RV	R-Pos 1	L-Pos 1
Step 1			WT	.49***	.58***	.37**	.28*
6.54 + .567 (R-Pos 1)	.458	32.91***	HT		.04	.10	.08
			RV			.27*	.13
			R-Pos 1				.68***
Regression 7: Estimate Left Hand Position 2				HT	RV	R-Pos 2	L-Pos 2
Step 1			WT	.49***	.58***	.50***	.44**
2.43 + .794 (R-Pos 2)	.670	79.13***	HT		.04	.29*	.28*
			RV			.37**	.35*
			R-Pos 2				.82***
Regression 8: Estimate Left Hand Position 3				HT	RV	R-Pos 3	L-Pos 3
Step 1			WT	.49***	.58***	.42**	.34*
-0.82 + .930 (R-Pos 3)	.814	170.12***	HT		.04	.36*	.34*
			RV			.26	.20
			R-Pos 3				.90***
Regression 9: Estimate Left Hand Position 4				HT	RV	R-Pos 4	L-Pos 4
Step 1			WT	.49***	.58***	.35*	.32*
2.13 + .816 (R-Pos 4)	.797	152.67***	HT		.04	.34*	.38**
			RV			.22	.15
			R-Pos 4				.89***
Regression 10: Estimate Left Hand Position 5				HT	RV	R-Pos 5	L-Pos 5
Step 1			WT	.49***	.58***	.33*	.29*
0.42 + .897 (R-Pos 5)	.717	99.01***	HT		.04	.43**	.32*
			RV			.17	.15
			R-Pos 5				.85***

Note. Jamar scores are measured in kilograms, weight in pounds, height in inches and hand volume in cubic centimeters. R=Right hand. L=Left hand. LV=Left hand volume. RV=Right hand volume. Pos=Position.

[a] F=(regression mean square)/(residual mean square). On Step 1 there were 1 and 39 degrees of freedom. On Step 2, 2 and 38 degrees of freedom.

Appendix B

Summary of multiple regressions estimating pre-injury performance on the West 4

Regression Equation	R^2	F^a	Simple Correlations				
Regression 1: Estimate Right Hand Pronation				HT	LV	L-Pro	R-Pro
Step 1			WT	.49***	.58***	.26*	.30*
11.26 + .591 (L-Pro)	.361	21.98***	HT		.14	.16	.18
			LV			.38**	.26
			L-Pro				.60***
Regression 2: Estimate Right Hand Supination				HT	LV	L-Sup	R-Sup
Step 1			WT	.49***	.58***	.20	.24
8.88 + .763 (L-Sup)	.613	61.81***	HT		.14	.11	.14
			LV			.32*	.27*
			L-Sup				.78***
Regression 3: Estimate Left Hand Pronation				HT	RV	R-Pro	L-Pro
Step 1			WT	.49***	.58***	.30*	.26*
9.76 + .609 (R-Pro)	.361	21.98***	HT		.04	.18	.16
			RV			.14	.27*
			R-Pro				.60***
Regression 4: Estimate Left Hand Supination				HT	RV	R-Sup	L-Sup
Step 1			WT	.49***	.58***	.24	.20
2.68 + .803 (R-Sup)	.613	61.81***	HT		.04	.14	.11
			RV			.11	.12
			R-Sup				.78***

Note. West 4 scores are in inch pounds, weight in pounds, height in inches and hand volume in cubic centimeters. R=Right hand. L=Left hand. LV=Left hand volume. RV=Right hand volume. Pro=Pronation. Sup=Supination.

[a] F=(regression mean square)/(residual mean square). On Step 1 there were 1 and 39 degrees of freedom.

***$p < .001$. **$p < .01$. *$p < .05$.

Appendix C

Summary of multiple regressions estimating pre-injury performance on the Purdue Pegboard

Regression Equation	R^2	F^a	Simple Correlations				
Regression 1: Estimate Right Hand Pin Insert				HT	LV	L-PI	R-PI
			WT	.49***	.58***	.06	.04
Step 1			HT		.14	-.20	-.12
9.14 + .544 (L-PI)	.221	11.08**	LV			-.13	-.16
			L-PI				.47***
Regression 2: Estimate Both Hands Pin Insert				HT	LV	L-PI	Both
(Right Hand Injury)			WT	.49***	.58***	.06	.04
Step 1			HT		.14	-.20	-.23
-1.57 + .942 (L-PI)	.650	72.57***	LV			-.13	-.10
			L-PI				.81***
Regression 3: Estimate Assembly Task				HT	LV	L-PI	Assem
(Right Hand Injury)			WT	.49***	.58***	.06	-.03
Step 1			HT		.14	-.20	-.19
-5.70 + 2.876 (L-PI)	.700	91.26***	LV			-.13	-.24
			L-PI				.84***
Regression 4: Estimate Left Hand Pin Insert				HT	RV	R-PI	L-PI
			WT	.49***	.58***	.04	.06
Step 1			HT		.04	-.12	-.20
9.86 + .406 (R-PI)	.221	11.08**	RV			-.24	-.10
			R-PI				.47***
Regression 5: Estimate Both Hand Pin Insert				HT	RV	R-PI	Both
(Left Hand Injury)			WT	.49***	.58***	.04	.04
Step 1			HT		.04	-.12	-.23
5.95 + .478 (R-PI)	.225	11.30**	RV			-.24	-.02
			R-PI				.47***
Regression 6: Estimate Assembly Task				HT	RV	R-PI	Assem
(Left Hand Injury)			WT	.49***	.58***	.04	-.03
Step 1			HT		.04	-.12	-.19
12.64 + 1.709 (R-PI)	.332	19.36***	RV			-.24	-.21
			R-PI				.58***

Note. Purdue Pegboard scores indicate the number of pins inserted or pieces assembled. Weight is measured in pounds, height in inches and hand volume in cubic centimeters. R=Right hand. L=Left hand. LV=Left hand volume. RV=Right hand volume. PI=Pin insert. Assem=Assembly task.

[a] F=(regression mean square)/(residual mean square). On Step 1 there were 1 and 39 degrees of freedom.

***$p < .001$. **$p < .01$. *$p < .05$.