FACTORS RELATING TO OUTCOMES ON THE MAXIMUM VOLUNTARY EFFORT TEST

by

MICHAEL IWAMA

B.Sc., The University of Victoria, 1984
B.Sc., The University of British Columbia, 1987

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

(School of Rehabilitation Sciences)

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

September 1998

© Michael Kenko Iwama, 1998

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

~~Department of~~ School of Rehabilitation Sciences

The University of British Columbia
Vancouver, Canada

Date September 8, 1998

DE-6 (2/88)

Abstract

The Maximum Voluntary Effort test (MVE) is an integral part of a battery of tests commonly referred to as the Functional Capacity Evaluation (FCE). The MVE purportedly measures sincerity of effort by analyzing the degree of variation in repeated maximal handgrip strength trials. However not much is known about the performances of chronically disabled people on the MVE and the construct validity of the test is unclear.

The first purpose of this study was to describe the performance of a chronically injured population and compare it with known performances, particularly Matheson, Carlton and Niemeyer's (1989) sample. The second purpose was to determine how certain factors of a chronically injured population related to MVE outcome measures.

Descriptive and correlative statistical analyses were applied to data collected from the chart records of 100 consecutive injury claimants (female n= 69, male n=31) who had undergone an FCE at a private rehabilitation clinic in the lower mainland region of British Columbia. The performances of the total, female, and male samples on the MVE test were analyzed according to peak grip strength and variability. Maximum Voluntary Effort test outcomes (dependent variable) were examined according to their relationship to 5 demographic and 5 diagnostic independent variables.

Expected patterns of grip-strength performance were generally observed. A curvilinear relationship between strength and age was evident with mean grip strength scores peaking at the 31-36 years of age cohort for both genders. Male and dominant hand measures were slightly greater than female and non-dominant hand, respectively. Generally, grip-strength was substantially diminuted suggesting decreased physical strength and fatigue tolerance trends among the sample. Compared with Matheson et al's sample, median grip scores were similar but variance was generally greater by as much as 5.5%.

Three of the 10 independent variables showed statistically significant relationships with MVE outcomes; 'occupation' (demographic variable, Chi Square=13.562, df=5, p=.019), 'referral source' (diagnostic variable, Chi Square= 23.306, df=1, p=.000) and number of injury 'episodes' (diagnostic variable, Chi Square=27.600, df=2, p=.000). The relationship of depression, measured by the BDI, with MVE outcomes remained unclear as 16 subjects with positive MVEs had not completed the BDI.

TABLE OF CONTENTS

Abstract ii

List of Tables vii

List of Figures x

Acknowledgements xii

Dedication xiii

CHAPTER 1 Introduction 1

Background 3
The Maximum Voluntary Effort Test 5
MVE Test Protocol 6
Example Case: Negative MVE Outcome 10
Example Case: Positive MVE Outcome 12
Clinical and Research Issues 17
Statement of the Problem 18

CHAPTER 2 Literature Review 20

Evolution of Tests for Maximum Voluntary Effort 20
Bell Curve 22
Instrument Reliability 25
Protocol 26
Procedural Reliability 26
Coefficient of Variation 28
MVE Coefficient of Variation Reliability 30
Populations and Normative Data 30
Influence of Demographic Factors 33
Gender 33
Occupation and Education 34
Hand Dominance 34
Influence of Diagnostic Factors 35
Depression 35
Episodes 35

CHAPTER 3 Methods 38

Subjects 38
Confidentiality 39
Raters 40
Instruments and Test Administration 40
MVE Test Procedure 41
Revised Beck Depression Inventory 41
Procedure 45

Data Analyses 46
Purpose 1 46
Purpose 2 46
Demographic Variables 48
Age 48
Gender 48
Education 49
Hand Dominance 49
Occupation 50
Diagnostic Variables 51
Diagnosis 51
Depression 52
Referral Source 52
Episodes 53
Chronicity 53
Dependent Variable 54
MVE Test Outcome Measures 54

CHAPTER 4 Results 56
Section 1 Performance of Chronically Disabled Sample 56
Description of the Sample 56
Gender 57
Occupation 57
Diagnosis 57
Referral Source 58
MVE Test Outcome Subject Profiles 60
Performance Outcomes on the MVE Test 61
Performance by Jamar Grip Setting 61
Total Sample 61
Female Sample 66
Male Sample 71
Section 2 Analyses of Relationships Between Variables 78
Demographic Influences 78
Age 78
Education 79
Gender 80
Hand Dominance 81
Occupation 81
Diagnostic Influences 82
Diagnosis 83
Referral Source 83
Episodes 86
Chronicity 88
Depression 88

CHAPTER 5 Discussion 92
Performance of a Disabled Sample on the MVE Test 92
Grip Strength Performance 94
Bell Curve 101

Variability of Repeated Scores 102
Relationship of Factors to MVE Test Outcomes 111
Demographic Influences 112
Diagnostic Influences 112
Referral Source 113
Episodes 115
Chronicity 116
Depression 117
Clinical Relevance and Implications for Future Research 121
Conclusion 125

References 128

Appendices 134

Appendix I MVE Study Data Recording Sheet 135

Appendix II Raters and Relationship with MVE Test Outcomes 137

Appendix III Coding Guidelines for MVE Study Data 139

Appendix IV Certificate, Ethical Review Committee 141

Appendix V Revised Beck Depression Inventory (BDI) Test Sheet 143

List of Tables

Table 1 Negative MVE Outcome Measures of Case Subject A 11

Table 2 Positive MVE Outcome Measures of Case Subject B 13

Table 3 Maximum Allowable MVE Cut-points for Disabled Male Workers (n= 89) 15

Table 4 Maximum Allowable MVE Cut-points for Disabled Female Workers (n= 32) 16

Table 5 Coefficient of Variation Cut-off Points Reported in the Literature 29

Table 6 Test-Retest Reliability Coefficients of the Jamar Hand Dynamometer 41

Table 7 Final Data Transformation Categories for Age 48

Table 8 Final Data Transformation Categories for Education 49

Table 9 Initial Data Transformation Categories for Occupation 50

Table 10 Final Data Transformation Categories for Occupation 51

Table 11 Final Data Transformation Categories for Chronicity 54

Table 12 Occupational Group Representation in the Sample by Percentage 57

Table 13 Diagnostic Group Representation in the Sample by Percentage 58

Table 14 Descriptive Statistical Data of the Study Sample of Selected Independent Variables of the Study, by Total Sample and by Gender Group 59

Table 15 Demographic Characteristics of Subjects According to MVE Outcomes 60

Table 16 Diagnostic Characteristics of Subjects According to MVE Outcomes 61

Table 17 Descriptive Statistical Measures of Dominant Hand Grip Performance of the Total Sample Across the 5 Grip Settings on the MVE Test 62

Table 18 Descriptive Statistical Measures of Non-dominant Hand Grip Performance of the Total Sample Across the 5 Grip Settings on the MVE test 64

Table 19 Descriptive Statistical Measures of Female Dominant Hand Grip Performance Across the 5 Grip Settings on the MVE Test 66

Table 20 Descriptive Statistical Measures of Female Non-dominant Hand Grip Performance Across the 5 Grip Settings on the MVE Test 668

Table 21 Female Dominant Hand Coefficient of Variation, Mean and Standard Deviation and Resulting Cut-off Scores Across Grip Settings, for this Sample and Matheson's (1989) Sample 70

Table 22 Female Non-dominant Hand Mean Coefficient of Variation and Standard Deviation and Resulting Cut-off Scores Across Grip Settings, for this Sample and Matheson's (1989) Sample 71

Table 23 Descriptive Statistical Measures of Male Dominant Hand Grip Performance Across the 5 Grip Settings on the MVE Test 72

Table 24 Descriptive Statistical Measures of Male Non-dominant Hand Grip Performance Across the 5 Grip Settings on the MVE Test 74

Table 25 Male Dominant Hand Coefficient of Variation, Mean and Standard Deviation and Derived Cut-off Scores Across Grip Settings, for This Sample and Matheson's (1989) Sample 76

Table 26 Male Non-dominant Hand Coefficient of Variation, Mean and Standard Deviation and Resulting Cut-off Scores Across Grip Settings, for This Sample and Matheson's (1989) Sample 77

Table 27 Distribution of MVE Test Outcomes According to Age 79

Table 28 Distribution of MVE Test Outcomes According to Education 80

Table 29 Distribution of MVE Test Outcomes According to Gender 80

Table 30 Distribution of MVE Test Outcomes According to Hand Dominance 81

Table 31 Distribution of MVE Test Outcomes According to Occupation 82

Table 32 Distribution of MVE Test Outcomes According to Diagnosis 83

Table 33 Distribution of MVE Test Outcomes According to Referral (n=100) 84

Table 34 Distribution of MVE Test Outcomes According to Episode 86

Table 35 Distribution of MVE Test Outcomes According to Chronicity 88

Table 36 Distribution of MVE Test Outcomes According to Depression 89

Table 37 Summary of Analyses of Relationships Between Independent and Dependent Variables 90

Table 38 A Comparison of Mean Peak Dominant Hand and Non-dominant Hand Grip Scores for this Sample's Strongest Male and Female Cohorts (Category 2; 31-36 years) and Corresponding Cohorts in Mathiowetz, et al (1985) 95

Table 39 Comparison of Median Hand Grip Scores (kgs) Among Males Across 5 Grip Settings on the MVE Test 101

Table 40 A Comparison of Reported Ranges of Maximum Allowable CV Cut-off Points Utilizing the Jamar Dynamometer 103

Table 41 Profiles of Subjects with Reported and Missing BDI Data 119

List of Figures

Figure 1. Female subject (right) being administered the MVE test using the Jamar hand dynamometer. 7

Figure 2. Hand position and grasp of the Jamar hand dynamometer set at position 3. 9

Figure 3. Grip, upper extremity, and body positioning of the testee during the MVE test. 43

Figure 4. Box plots summarizing dominant hand mean grip strength scores by Jamar hand grip setting among the total sample (n=100). 63

Figure 5. Box plots summarizing non-dominant hand mean grip strength scores by Jamar hand grip setting among the total sample (n=100). 65

Figure 6. Box plot graphs summarizing dominant hand mean grip strength scores by Jamar hand grip setting among the female sample (n=69). 67

Figure 7. Box plot graphs summarizing non-dominant hand mean grip strength scores by Jamar hand grip setting among the female sample (n=69). 69

Figure 8. Box plot graphs summarizing dominant hand mean grip strength scores by Jamar hand grip setting among the male sample (n=31). 73

Figure 9. Box plot graphs summarizing non-dominant hand mean grip strength scores by Jamar hand grip setting among the male sample (n=31). 75

Figure 10. Frequency of positive MVE test outcomes in the sample according to referral. 85

Figure 11. Frequency of positive MVE test outcomes in the sample according to number of injury episodes. 87

Figure 12. Serial combined, dominant and non-dominant maximal hand grip score (lbs.) means listed according to the three trials of the MVE test. 98

Figure 13. Number of total sample scoring (+) MVE tests according to 2 separate sets of CV cut-off values; Matheson et al (1989), This Study. 106

Figure 14. Number of males from study sample scoring (+) MVE tests according to 3 separate sets of CV cut-off values; Matheson et al (1989), Combined (using mean CVs from Matheson et al (1989) and mean SDs from this study), and This Study (using both mean CVs and mean SDs from this study. 107

Figure 15. Number of females from study sample scoring (+) MVE tests according to 3 separate sets of CV cut-off values; Matheson et al (1989), and this study. 108

Acknowledgements

I would like to gratefully acknowledge the assistance, direction and mentorship of my supervisory committee;

Dr. Lyn Jongbloed, Ph.D.,	Supervisor, Chair Supervisory Committee
Dr. Anne Carswell, Ph.D.,	Member, Supervisory Committee
Dr. David Crockett, Ph.D.,	Member, Supervisory Committee
Dr. James Frankish, Ph.D.,	External Examiner

I would also like to acknowledge the support I received from the Arthritis Society of British Columbia, which granted me 2 scholarships through the course of my graduate studies.

Dedication

This thesis is dedicated to my Father, Fred Kazuo Iwama, who has, throughout his life, exemplified maximum voluntary effort.

CHAPTER 1

Introduction

Maximum Voluntary Effort (MVE) testing, in its various forms, continues to be an important and controversial component of functional assessments of disabled people. The test is routinely administered by rehabilitation professionals as one part of a battery of tests commonly referred to as Functional Capacity Evaluations (FCE). Functional capacity evaluations have become a necessary procedure in adjudicating disability insurance and workers compensation board claims for the purposes of determining next step rehabilitation and treatment plans, procurement of rehabilitation equipment and costs for future care and compensation for loss of work. As can be imagined, given the litigious context surrounding the adjudication process, the health professionals/testers must rely on some procedures to validate (or invalidate) the testee's claim for further care and compensation. Since tests of functional capacity are dependent on the testee giving full effort for the outcomes to be reliable, certain procedures have been implemented into the FCE process to help test administrators verify whether the testee was indeed performing to the best of their ability. Failure by the claimant to 'prove' their sincerity by demonstrating less than maximal effort during the FCE can adversely effect the client's case or claim and invoke negative labels, such as 'faker', 'malingerer' and 'symptom magnifier' and other unfavorable social consequences. Arguably, the most important and relied upon procedure in the FCE to confirm sincerity of effort in the testee is the MVE test.

The MVE test is based upon the assumption that an individual's ability to demonstrate maximum effort repeatedly is indicative of his or her sincerity of effort. The MVE test is purported to measure sincerity of effort by analyzing the degree of variation in repeated

maximal strength trials. The greater the variability in repeated maximal trials, the less sincere the subject is regarded to be.

A popular MVE test protocol among occupational therapists (OT) is the one suggested by Matheson (1984) which employs the Jamar hand Dynamometer (Jamar)(J.A. Preston, Jackson, MI) for measuring repeated maximal grip strength measurements. Variability of repeated scores is summarized by the coefficient of variation (CV) statistic and these CV scores are evaluated by comparing each against a set of established maximum allowable cut-off points. Ten CV scores are yielded by the testee and if more than two of the CVs exceeds the respective cut-off scores, the client is regarded to be putting forth less than full effort.

Despite its routine use in disability insurance claims adjudication, relatively little has been researched regarding its validity. The lack of empirical support for the MVE is particularly problematic, given that such testing appears to play an integral role in validating functional assessment outcomes and diagnosing "malingering and motivational problems" (Matheson, 1988), Abnormal Illness Behaviors (AIB) (Niemeyer, 1991) and Symptom Magnification Syndromes (SMS)(Matheson, 1988), in injured people. A misdiagnosis can have profound effects upon compensation, future options for rehabilitation, and litigation outcomes for the testee.

Several questions related to the validity of the MVE test are raised. At present it is uncertain that sincerity of effort is being measured by this test. Could the MVE test be measuring attributes of the client other than sincerity of effort? In addition, those few studies, from which the critical measures for the MVE test have been derived, are based mainly on non-injured populations. Since descriptions of MVE test performance of injured or chronically disabled groups are scant, we are left to wonder whether injured people perform differently

than non-injured people. The MVE test is administered mainly to injured subjects and therefore could be discriminating and unfair for the population for which it is intended.

Using an invalid measure of sincerity of effort could amount to much more than a mere misdiagnosis or invalidated functional evaluation. Since functional evaluation outcomes are often relied upon to determine rehabilitation goals, vocational counseling, financial support and compensation (Tramposh, 1992), an erroneous MVE test outcome could result in devastating consequences for the patient in need of such resources. The appropriation of more aggressive rehabilitation to address likely interactions of physical, psychological and social factors (Matheson, 1991; Niemeyer, 1989) that may lie behind sub-maximal performance during a functional evaluation would appear to be a logical next step. However, a failed MVE appears to represent potent evidence to conveniently terminate further rehabilitation interventions and disability benefits. Rehabilitation professionals increasingly providing service to disability insurance carriers, workers compensation boards and insurance company lawyers, whose best interests lie in limiting liability, may feel pressured to use the MVE test to identify 'malingerers' and 'symptom magnifiers'. Clinical experience would attest to the frequency with which the MVE test is used in such context. Positive MVE results (denoting less than maximal effort) frequently leads to client labeling with terms that hold negative connotations that rarely elicit further appropriate rehabilitation.

Background

Clinicians, who rely on functional evaluation outcomes as a basis to plan and monitor the progress of their patients in a rehabilitation program, do so with the assumption that the testee has performed the evaluation with maximum effort. As accurate and robust as a functional evaluation might appear to be, interpreting the testee's performance with a full

measure of confidence would be difficult if the testee's performance over the evaluation cannot be measurably confirmed as maximal. Since functional performance measures are highly dependent on the testee's degree of effort (Matheson, 1988), the role sincerity of effort plays in the interpretation of functional evaluations is paramount. Personal injury litigation, workers compensation claims, and long-term disability benefit arbitration occur within a context in which lower functional evaluation outcomes can be construed with greater disability (and resultant award) for the plaintiff or claimant. Given these consequences, many claimants might feel the incentive to perform poorly in order to increase financial compensation, or to merely 'prove' the legitimacy of an injury claim. It would be reasonable then, to doubt that every claimant undergoing such functional testing be performing with full effort.

Rehabilitation professionals in recent years have increasingly used tests for determining sincerity of effort as they expand their clinical roles from traditional areas of biomedical service delivery into the more litigious areas of private practice. Traditional hospital and rehabilitation clinic based service delivery has catered to the patient as client whereby functional performance testing has been used to evaluate patient status and progress to form a basis to plan further rehabilitation intervention. With the growing involvement of therapists in the personal injury litigation and disability insurance adjudication process, lawyers and insurance adjusters have become primary clients instead of patients, bringing about a subtle shift in the purpose and use of functional evaluations. New avenues of referral and funding from the insurance and personal injury litigation sectors of the marketplace have compelled rehabilitation professionals to pay due attention to the needs of their new clients.

Such a shift in service delivery reveals a dilemma that has troubled some therapists. The high costs associated with rehabilitating people with chronic injuries compel insurance companies, their lawyers and workers compensation boards to pay greater attention to functional evaluation outcomes for the purposes of procuring appropriate rehabilitation treatment and minimizing remunerative liability. Determining 'next step' rehabilitation plans, settling injury claims promptly and accumulating evidence to limit liability are additional pressures on therapists when administering functional evaluations. Therefore, in addition to rehabilitation treatment purposes, therapists have found themselves using such tests as the MVE to detect sub-maximal effort and identify the presence of such socially disabling syndromes as 'malingering' and 'symptom magnification'. Therapists, then, employ the MVE and functional evaluations for the dual purpose of rehabilitating the patient-client while servicing the needs of their insurance industry clients.

The MVE Test

Arguably the most common MVE test protocol used in the clinical setting is the Matheson (1984) protocol employing the use of the Jamar hand dynamometer. The Jamar appears to be the instrument of choice for several reasons; it is recognized as the standard instrument for the objective measurement of grip strength (Fess and Moran, 1981), has been shown to be a reliable test instrument for measuring hand grip strength (Hinson, Woodward and Gench, 1990; Mathiowetz, Weber, Volland, and Kashman, 1984), and is relatively affordable. In conventional clinical settings therapists employ the Jamar to measure maximal or peak force that a patient can exert in a voluntary contraction of the muscles of the hand (Niebuhr, Marion and Fike, 1994). Grip strength measurements are taken in order to assess the functional loss of grip strength, or to compare grip strength of the involved hand with the

uninvolved hand and with published norms (Fess and Moran, 1981; Mathiowetz et al. 1985; Mathiowetz, Wiemer, and Federman, 1986).

The Jamar dynamometer has become a familiar instrument of choice for measuring peak handgrip strength (Niebuhr, Marion and Fike, 1994; Fess and Moran, 1981; Mathiowetz et al. 1984), and is now being used for an alternate purpose; measuring repeated voluntary maximal grip strength over a limited duration.

Matheson (1984) recognized the acceptability of including the Jamar hand dynamometer among other selected instruments for his MVE protocol (1986). Matheson's protocol, is based on the assumption that repetitive trial scores within a brief span of time will be stable. Unstable repetitive scores, summarized by higher than normal coefficient of variation (CV) statistics, are interpreted as indicators of sub-maximal effort. In the past decade, this new alternate purpose for the Jamar has flourished and is a standard part of many FCE batteries.

MVE Test Protocol

In the Matheson protocol, the subject is seated and is asked to grip the Dynamometer as hard as possible (Matheson, 1986). The procedure appears not to tax the muscles and structure of the torso- an important factor when testing subjects with spine-related injuries. Figure 1 illustrates the MVE test being administered in a clinical setting.

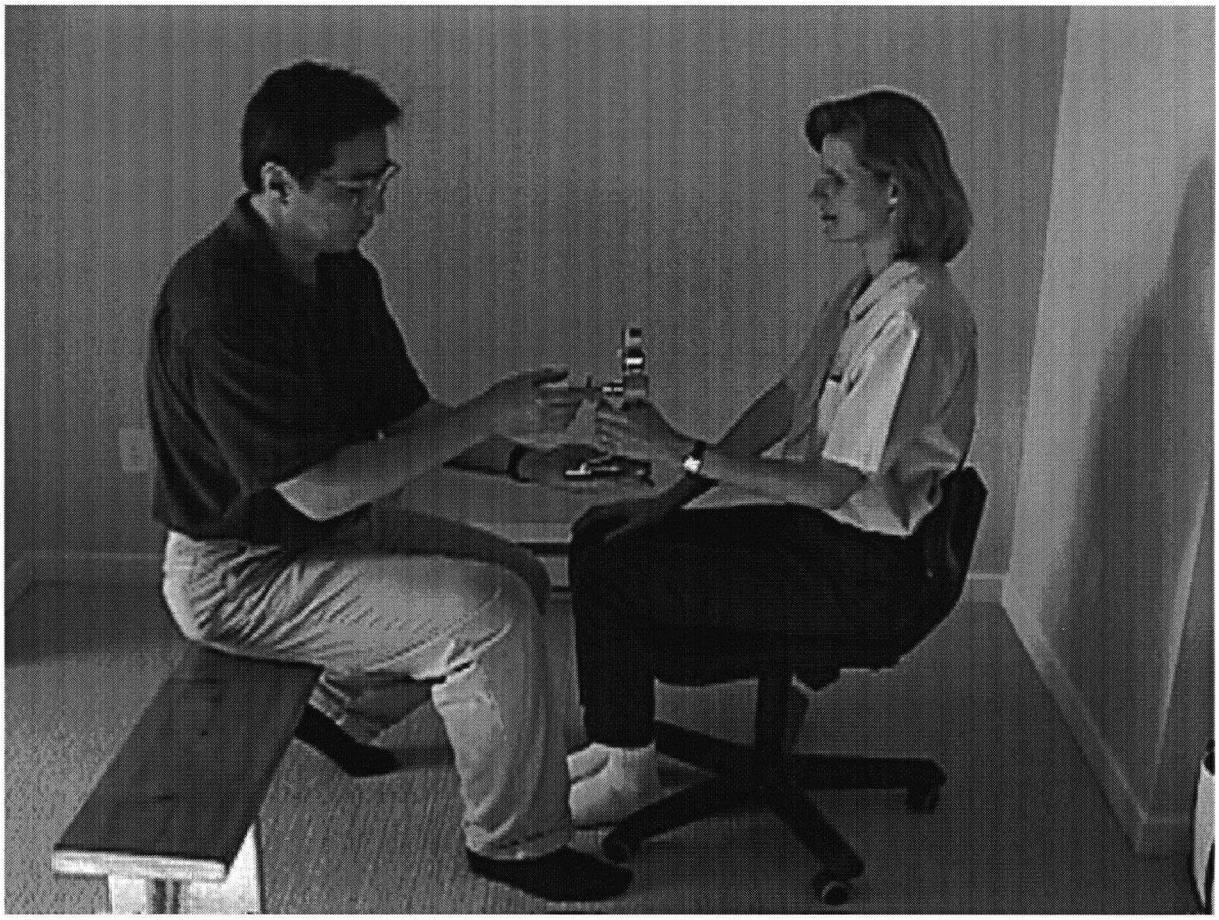

Figure 1. Female subject (right) being administered the MVE test using the Jamar hand dynamometer.

The handgrip device has 5 equally distanced grip size span settings, allowing the tester to change the grip span size to best accommodate the subject's hand size. Under normal grip strength measurement circumstances, the evaluator would approximate the subject's grip size and adjust the handgrip device to the best possible fit.

For the MVE test, the adjustability feature of the Jamar handgrip (over the 5 grip size setting options) is exploited to derive 5 clusters of three repeated scores per grip size setting and per hand tested. Figure 2 illustrates how the Jamar hand dynamometer is held. The handle, which can be easily detached and adjusted for size, is fixed at the middle setting (position 3) in this portrayal.

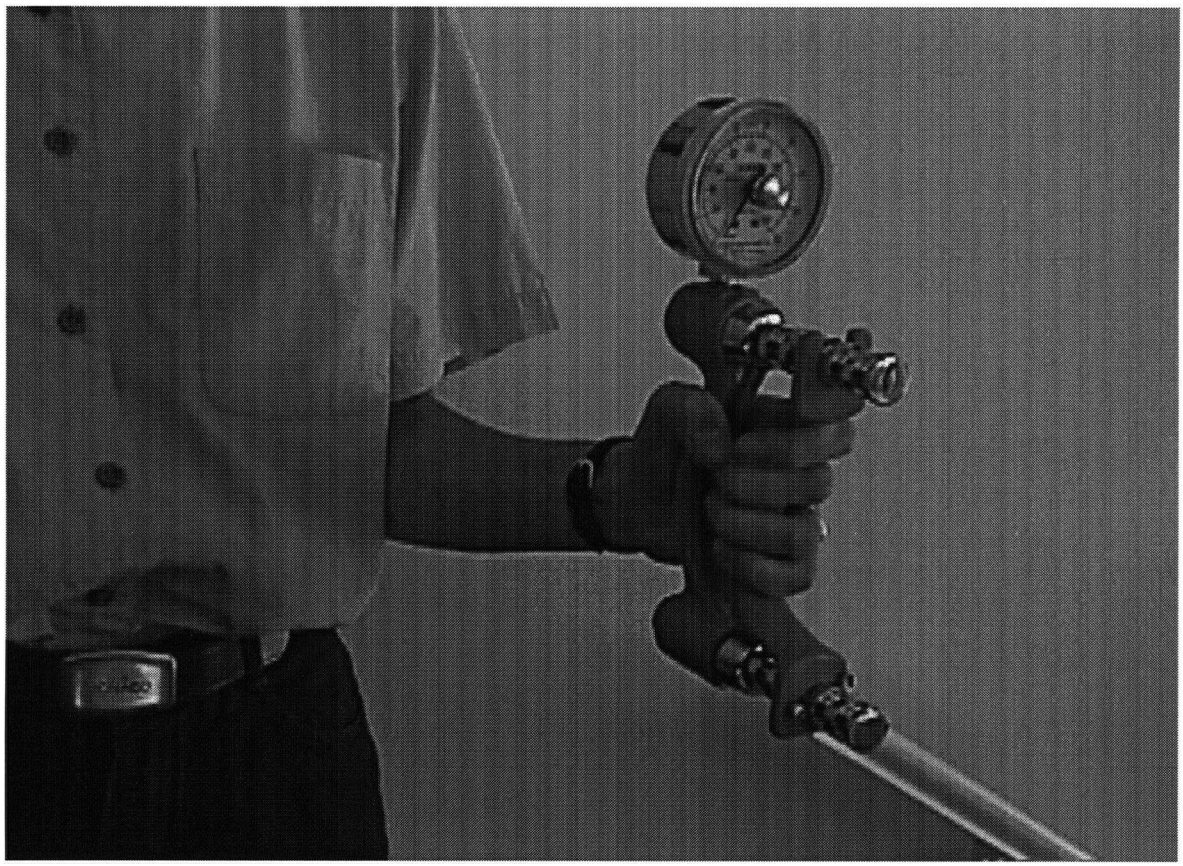

Figure 2. Hand position and grasp of the Jamar hand dynamometer set at position 3.

Each cluster of scores is treated statistically by dividing the standard deviation (SD) into the mean, yielding a total of 10 CV scores (5 per hand). If there are no more than two CVs exceeding a set of predetermined cut-points, the test is considered negative and the subject is usually regarded to be 'sincere' in his/her performance and that he/she indeed was trying his/her best. Because the test is usually an integral part of the larger functional evaluation battery, such an outcome appears to lend support to the validity of the overall functional evaluation outcomes. Two representative cases are presented here to illustrate both negative and positive outcomes.

Example Case of a Negative MVE Test Outcome

Subject A, a 35 year old female was administered the MVE test and her resulting performance is summarized in Table 1.

Table 1

Negative MVE Outcome Measures of Subject A

Subject A: Female, 35 years old										
Hand	Dominant Hand					Non-Dominant Hand				
Grip Setting	1	2	3	4	5	1	2	3	4	5
Trial 1	11	25	19	21	16	13	25	20	19	13
Trial 2	13	22	19	20	15	14	27	25	19	13
Trial 3	15	23	20	19	17	16	23	22	16	14
Mean	13	23.3	19.3	20	16	14.3	25	22.3	18	13.33
SD	1.63	1.25	0.47	0.82	0.82	1.25	1.63	2.05	1.41	0.47
CV	12.56	5.35	2.44	4.08	5.10	8.70	6.53	9.20	2.86	3.54
Maximum Allowable CUT-Point	11.40	8.60	8.30	9.20	9.10	12.00	10.70	8.00	3.54	9.00
Outcome	+	—	—	—	—	—	—	+	—	—
Total + Scores	2/10									
MVE Test Outcome	NEGATIVE Client believed to have performed with full effort									

Since this subject produced just 2 CV scores exceeding the cut-points, her test outcome was negative and so was believed to have given maximal effort during the evaluation.

Example Case of a Positive MVE Test Outcome

Table 2 summarizes the MVE performance outcomes of Subject B, a 27 year-old male, who had a 'positive' test.

Table 2

Positive MVE Outcome Measures of Subject B

Subject B: Male, 27 years old										
Hand	Dominant Hand					Non-Dominant Hand				
Grip Setting	1	2	3	4	5	1	2	3	4	5
Trial 1	8	19	26	15	8	23	36	37	26	24
Trial 2	13	21	18	13	12	20	31	28	20	23
Trial 3	18	20	22	15	12	21	31	28	26	26
Mean	13.0	20	22.0	14.33	10.67	21.33	32.67	31.0	24.0	24.33
SD	4.10	0.82	3.27	0.94	1.89	1.25	2.36	4.24	2.83	1.25
CV	31.40	4.08	14.85	6.58	17.68	5.85	7.22	13.69	11.79	5.13
Maximum Allowable CUT-Point	14.42	9.46	9.39	10.07	10.81	15.24	10.30	9.27	9.73	12.50
Outcome	+	—	+	—	+	—	+	+	+	—
Total + Scores	6/10									
MVE Test Outcome	POSITIVE Client not believed to have performed with maximum effort									

Coefficient of variation cut-points for various forms of maximal effort testing have been reported in the literature. Bohannon, et al, (1989) reported using an overall CV cut-point

of greater than 7.5% for an elbow flexion protocol. Niemeyer et al (1989), using various tasks, including repetitive hand grip strength on the BTE work simulator, recommended that CV scores should not exceed 15% for all subjects. Trossman, et al. (1990) concurred with Niemeyer et al's (1989) recommendation that "sincere" CV scores should not vary less than 15%. All of these studies reportedly utilized samples consisting of young, healthy adult subjects.

One set of CV cut-off points for the Matheson-Jamar protocol was reported to have been derived from a disabled, adult, male population (Matheson, et al, 1989). Table 3 summarizes the means, standard deviations and resultant CV cut-points for each of the five clusters of trials for both dominant and non-dominant hands. Although not explicitly reported, the CV cutpoints appear to be set at 1 SD above the mean CV for each grip setting, per hand.

Table 3

Maximum Allowable Cut-points for Disabled Male Workers (n= 89).

Dominant Hand	**.Position 1**	**Position 2**	**Position 3**	**Position 4**	**Position 5**
Mean	9.01	5.84	5.64	5.62	6.05
SD	5.41	3.62	3.75	4.45	4.76
Maximum Allowable Cut-point	**14.42%CV**	**9.46%CV**	**9.39%CV**	**10.07%CV**	**10.81%CV**
Non-Dominant Hand	**Position 1**	**Position 2**	**Position 3**	**Position 4**	**Position 5**
Mean	8.63	6.26	5.48	5.66	6.74
SD	6.61	4.04	3.79	4.07	5.46
Maximum Allowable Cut-point	**15.24%CV**	**10.30%CV**	**9.27%CV**	**9.73%CV**	**12.20%CV**

Source: Matheson, L., Carlton R., and Niemeyer, L., (1989)

Coefficient of variation cut-points for disabled females are available in proprietary literature (Matheson and Niemeyer, 1990) without the accompaniment of statistical descriptors that would allow further analyses and comparisons. A summary of the CV cut-points for disabled females is listed in Table 4. Mean and SD data were not available.

Table 4

Maximum Allowable Cut-points for Disabled Female Workers (n= 32).

Dominant Hand	Position 1	Position 2	Position 3	Position 4	Position 5
Maximum Allowable Cut-point	11.40%CV	8.60%CV	8.30%CV	9.20%CV	9.10%CV
Non-Dominant Hand	**Position 1**	**Position 2**	**Position 3**	**Position 4**	**Position 5**
Maximum Allowable Cut-point	12.00%CV	10.70%CV	8.00%CV	3.54%CV	9.00%CV

Source: Matheson, L. and Niemeyer, L., (1989)

Subjects who test positive, by producing outcomes resulting in more than two CVs out of ten exceeding the maximum allowable cut-points, are vulnerable to be judged as 'fakers', 'malingerers', and "symptom magnifiers" (Matheson, 1988) or simply individuals whose FCE outcomes cannot be accepted as valid.

Some clinicians have realized the paucity of scientific support for the MVE for its intended purposes and have developed alternate strategies to attempt to contain the validity concerns associated with the MVE and the functional evaluation that it is a part of. Cross-validating performance between each sub-test; by observing consistency in the quality and quantity of actions performed by the evaluee is one common strategy reported by clinicians. This strategy appears to be largely arbitrary and there are no reported studies to support it in the literature. It should be noted here that clinicians might also defer to other professionals such as psychologists to acquire further insight into a subject's motivation and intention during the evaluation procedure.

Clinical and Research Issues/Questions

The MVE test is increasingly being used by rehabilitation clinicians as a means to identify 'malingerers', 'symptom magnifiers' and others who may, deliberately or not, perform functional tests with less than full effort. Thus far, research studies to support the criterion and construct validity of the MVE test are scant. Given the significant rehabilitation decisions that hinge on the outcomes of this test, ascertaining the validity of the MVE is a critical issue.

The MVE test's criterion cut-off scores used to evaluate consistency of repeated maximal trials maybe problematic and therefore represents one of several interesting areas of analyses.

The present cut-off scores, based largely on the performance of healthy adults, maybe inappropriate and unfairly discriminatory for the (disabled) population that typically undergoes MVE testing.

The reported CV cut-point values for general tests for maximal effort using the repeated trials format arose from studies using both healthy and disabled subjects. Earlier maximum effort experiments used protocols which tested muscle groups and actions other than hand-grip strength (Bohanon 1987; Carlsoo 1986; Niemeyer 1990), such as lifting, elbow flexion and hip extension. Almost all of the normative data from which the cut-off values for the MVE test were derived were drawn from young healthy populations. In the field, the MVE test, is commonly administered to a chronically injured population involved in personal injury litigation, insurance and LTD claims settlement. Clinicians could benefit from having access to clearly described group data-particularly those of a disabled population with attributes closely resembling the population that typically undergoes MVE testing.

Does the MVE measure maximum voluntary or sincerity of effort, or does it measure other attributes of the population that routinely undergo this form of testing? Do common evaluee attributes such as; age, sex, occupation, and education account for a significant degree of the variance in MVE outcome scores? Other variables such as: referral source (insurance adjuster, plaintiff counsel, workers compensation board officer), employment status (remuneratively employed or unemployed at the time of injury), prior experience of work stopping injury (number of previous episodes) and depression (Beck Depression Inventory Scores), of a representative population, need also be investigated with respect to relations with MVE outcomes.

While the MVE test appears to be based on reasonable assumptions, the present paucity of research supporting this protocol would appear to make endorsement for its use in scientific and clinical applications difficult.

Statement of the Problem

There are two distinct problems raised for this research. Extensive use of this test in vocational rehabilitation is problematic given the paucity of research concerning the validity of this test and the normative data upon which the criterion measures for the test have been drawn. Not much is known about the performance of a chronically injured population on the MVE test. Criterion measures, in the form of a series of maximum allowable CV cut-points, used in the MVE test have been based largely on non-injured, young adult populations, and may be unreliable and discriminatory for the injured population for which the test is intended.

Further, there is a lack of studies on the construct validity of the MVE test. Is the test measuring 'sincerity of effort' or some other subject-resident attribute? Does the test perform the way it should, by detecting certain attributes consistent with the construct of 'sincerity of

effort' in a reliable way? Before the MVE test can be administered with confidence to measure sincerity of effort, its construct validity needs to be clarified.

Chapter 2

Literature Review

Measurement of hand grip strength using the Jamar Hand Dynamometer (Jamar) has been a familiar practice among rehabilitation practitioners since the early 1950's (Bechtol, 1952). Whereas the usual application for grip strength measurement has been to examine overall body strength, and the functional effects of hand or wrist injuries (Niehbuhr & Marion, 1990), grip strength measurement has been used for the purpose of rehabilitation in a wider context in the past decade. Grip strength measurement is now also used to examine sincerity of effort (Matheson, 1984).

Over the past two decades, the popular MVE test has evolved from a simple procedure, in which the biomechanical performance pattern of a single set of hand grip strength trials was examined (Stokes, 1983), to the present protocol requiring repeated strength trials, and statistical analysis involving coefficient of variation (CV) statistics. This chapter provides a review of the literature surrounding the MVE test (Matheson protocol). The evolution of the MVE is described briefly, followed by a section summarizing empirical support and shortcomings of the test. Owing to a paucity of research that describes the performance of disabled people on the MVE, the review concludes with a summary of normative data and existing knowledge of common human factors and their possible relation to outcomes on the MVE.

Evolution of Tests for MVE

Early approaches to measuring maximal voluntary muscle contraction (MVC) were reported in the occupational physiology and ergonomics fields, for the primary purposes of designing and modifying work environments and selecting suitable employees (Kroemer and

Marras, 1980). In their experiment using load cells to record the rate of muscle fibre recruitment during deliberate maximal and sub-maximal elbow flexion, Kroemer and Marras (1980) hypothesized that the slope of muscle fibre recruitment during an MVC would be steeper than during a sub-maximal trial. They attempted to test the postulate that sub-maximal trials represented a more complex system of neural feedback which would translate into more moderate rates of fibre recruitment and thus, gentler slopes when plotted on a force time-curve. Thirty healthy university students (15 males) were required to sit in a rigid chair and isometrically flex their elbows against a load cell which transmitted exerted torque. All subjects were instructed to exert elbow flexion strengths at 100%, 75%, 59% and 25% of their individual maximal capability with no external feedback about their performance. The male sub-group exerted, on average, higher forces than the female sub-group. The expected relationship between slope and exerted force supported their hypotheses and a model for assessing 'maximal voluntary contraction' was established.

Kroemer and Marras' (1980) experiment was followed by other studies (Gilbert and Knowlton, 1982; Smith, Nelson, Sadoff and Sadoff, 1987; and Chengalur, Smith, Nelson and Sadoff, 1990) which also utilized the use of load cells against which isometric muscle contraction strength was recorded. Unlike Kroemer and Marras' choice of instrumentation, hand-grip dynamometry was used with major modification to provide graphical output data in the form of force-time curves. These studies followed the practice of generating and comparing force-time curves from maximal and sub-maximal trials to detect sincere subjects from those who were faking. Sincere trials were characterized by rapid peak force attainment and plateauing with an average force similar in magnitude to the peak force magnitude. 'Faked' trials also showed rapid peak force attainment but were followed by significant

(>10%) reduction in average force as well as greater variability. Both Gilbert and Knowlton's (1982) and Smith et al.'s (1987) studies used healthy subjects who were instructed to perform both sincere and fake trials. Chengalur et al (1990) tested the previous studies' hypotheses using a similar design on a sample consisting of workers who had unilateral upper extremity injury affecting grip strength in the affected limb. The expected force-time curve patterns for both 'sincere' and 'faking' conditions were reported, supporting the use of Smith et al's (1987) protocol for subjects who had sustained upper extremity injuries. Although theoretically sound and promising, the technical requirements for modifying simple dynamometers to accommodate load cells, needing frequent calibration and the accompaniment of electromyography (EMG), rendered such methods clinically difficult to administer.

Bell Curve

Stokes (1983) presented a model for distinguishing between weakness of grip due to injury and weakness of grip due to "malingering"(p. 683) by exploiting the adjustable hand-grip size setting feature of the Jamar dynamometer. The study attracted much attention owing to the potential for determining sincerity of effort in a simpler manner than the techniques reported by Kroemer and Marras (1980) and Gilbert and Knowlton (1992). Stokes reported that when a sincere subject is required to squeeze the dynamometer maximally at each of the instrument's five incremental size settings, the resulting force-grip size graph should yield a bell-shaped curve. The rationale being that the grip size setting that presents the best mechanical advantage (usually the third setting) should result in the highest score. Conversely, the 'malingering' subject (feigning weakness of grip) would typically exert a minimal amount of force at each of the grip size settings, generating a relatively flat curve. Stokes' research

design employed just two subjects; one sincere and one malingerer. Both subjects demonstrated Stoke's hypothesized force-grip size curve patterns. However Stokes did not report whether the malingering subject was free of upper extremity impairment.

Although clinicians applied Stokes suggestions, studies that followed (Krombholtz, 1985, Niebuhr and Marion, 1987) failed to replicate the expected pattern for sub-maximal effort. Kromholz, in his (1985) study involving a randomly selected, uninjured, college-aged sample, found that subjects could exert, upon instruction, 30, 50, 70, 90 or 100% of their maximum grip strength. His study showed that normal subjects could reliably produce a 'submaximal' effort following the expected 'sincere' or 'maximal' pattern of a bell curve when graphed. Niebuhr and Marion (1987) also tested a sample comprised of healthy college students (9 males and 16 females) who were instructed to either "...squeeze as hard as you can" (p.19), or "...fake a weak grip" (p.19). Both sincere and faking groups consistently produced the typical bell-curve pattern. Significant mean grip strength output differences were documented between the dominant and non-dominant hands. These outcomes pointed to the limitation of using single peak grip strength measurements to predict maximal and sub-maximal effort. A better model to predict maximal effort and 'malingering' was sought.

In the early 1980's, Matheson (1984) introduced a protocol using the Jamar Hand Dynamometer that intended to directly test an evaluee's ability to give maximal effort. Administered within the battery of tests which comprise the conventional Functional Capacity Evaluation (Velozo, 1993), the MVE served the following purposes: evaluating hand grip strength, establishing reliability of the testee's performance in the FCE (thereby bolstering the reliability of FCE outcomes) and detecting possible sources of submaximal effort such as

Abnormal Illness Behaviour (AIB) (Niemeyer, 1989), Malingering and Symptom Magnification Syndrome (SMS) (Matheson, 1988).

The MVE protocol presented several advantages over its predecessors, adding to its popularity among testers. The test required the use of a familiar and reliable test instrument, was readily available (inexpensive and not requiring sophisticated technical adjustments), did not require gross body movements and could be administered over a relatively short span of time. This protocol, unlike some of its predecessors, required no further need for the use of electronic load cells and EMG accompaniment.

The MVE protocol was based on the assumption that repeated maximal strength trials on the dynamometer over a brief span of time would be relatively consistent. Subjects demonstrating a greater-than-normal variability within a group of repeated trials, more than 2 out of ten times would be regarded as performing with sub-maximal effort.

Although the MVE seems to enjoy popularity in the return to work field in North America, there has been sparse empirical support for its use. Few scientific papers have examined the issue of reliability and validity of the MVE test, and descriptions of the performance of disabled subjects are almost non-existent. Its popularity and support, however, appears to be buoyed by proprietary courses and seminars in industrial rehabilitation.

Presently, the measurement of sincerity of effort by means of testing voluntary maximal muscle strength appears to remain both clinically important and problematic, warranting further research for clarification. The balance of this literature review attempts to summarize the empirical support for the MVE test and to lay a foundation of theoretical support for the questions and hypotheses put forth in this research.

Instrument Reliability

Since its introduction in the literature in 1954 by Bechtol, reliability of the Jamar in measuring grip strength has been reported in several scientific articles (Fess & Moran, 1981; Mathiowetz, Weber, Volland, & Kashman, 1984; Mathiowetz, 1990; Hinson, Woodward & Gench, 1990; and Niebuhr, Marion & Fike, 1994). In regard to test-retest reliability, 2 studies Mathiowetz et al, 1984; Hart and Schauf, 1987) reported coefficients ranging between 0.88 and 0.90 for left and right hands. Mathiowetz et al (1984), in their study of 27 healthy college women, reported test-retest reliability coefficients of 0.87 for the right hand and 0.93 for the left hand. Hart and Schauf reported coefficients of 0.87 and 0.90 for right and left hands, respectively. Their study sample consisted of 63 adults (ages ranging from 29 years to 47 years) experiencing chronic pain.

Along with other similar isometric strength measurement devices, the Jamar dynamometer has noteworthy limitations. Nitz (1995) concurred with others (Kromholz, 1985, Niebuhr Marion and Fike, 1994) in reporting that the Jamar recorded only the maximum grip effort at the instant that it was achieved. It failed to show how long it took to attain peak strength output nor how long maximum grip strength effort could be sustained. Furthermore, the Jamar is incapable of recording grip endurance or fatigue during single or multiple grip efforts (Nitz, 1995).

In regard to the accuracy of the Jamar in measuring peak strength, several studies have reported measurement error data. Niebuhr, Marion and Fike (1994), using the Jamar instrument calibration method recommended by Fess (1987), on a Jamar model PC503OPT, determined that the instrument was accurate within +/- 1.4%. Recalculation checks conducted during their research regarding the reliability of grip strength with the Jamar (Niebuhr et al,

1994) yielded a correlation coefficient of 0.99, suggesting highly consistent output. Niebuhr and Marion (1990) reported measurement accuracy of the Jamar (Model 1), during calibration trials with known weights, to be within +/- 5%. The same investigators (1987), in another experiment using the Jamar, reported approximately 1.5% error in some readings between 0-200lbs. The exact Jamar hand dynamometer model used was not reported. Fairfax, Balnave and Adams (1995) reported instrument measurement error of less than 1%. Although a Jamar dynamometer was reportedly used, the model was not reported.

Protocol

While within-instrument and inter-rater reliabilities of the Jamar Dynamometer have proven acceptable for the purpose of measuring hand strength, the same cannot be assumed for its use in measuring sincerity of effort. Measurement of hand grip strength involves merely observing instantaneous peak output in a single trial whereas the MVE protocol examines the stability of *repeated* peak hand grip trials administered during a *limited span of time.*

Procedural Reliability

Perhaps the first evidence of maximum effort testing in North American work rehabilitation was witnessed in a pre-employment screening device that tested isometric strength among prospective workers. Keyserling, Herrin and Chaffin, (1980) introduced a lifting measurement device which consisted of a handle attached by cable to a force gauge at floor level. The subject was required to gradually exert a force over 2 seconds, then follow with a 3 second maximal effort. Coefficients of variation (CV) over repeated trials in a brief span of time were found to vary between 10 and 13 percent. The assumption of repeated maximal effort over a brief span of time being stable, began to take hold in the field of work rehabilitation.

Blankenship (1988) would eventually introduce the device and the concept of stable repeated strength measures for clinical use. The consistency of an injured worker's effort over 3 to 5 repeated trials, measured by the CV statistic, should not exceed 15% (Blankenship, 1988) to be deemed a 'sincere' effort. The criterion 'cut-off' or 'cut-point' CV statistic appears at times to be arbitrarily set to the test author's interpretations of 'normal' boundaries. Blankenship did not report any study or sample data from which the cut-off could have been derived.

Carlsoo (1986) attempted to examine with what degree of precision a voluntarily exerted force could be repeated, when the subjective experience of previous trials alone serve as the only clue in guiding force application. Seven subjects (6 female) were instructed to perform isotonic and isometric repetitive tasks with the same amount of force per trial. Participants were not permitted to see any recording instruments nor any measuring devices during the trials. The tasks consisted of a two-hand lift during standing, foot pedal extension during sitting, and an isometric thigh-raise task while sitting. The capacity for repeating a voluntary force several times in a row within short time intervals was reported to have a substantially low degree of precision of about 10% (Carlsoo, 1986).

Stratford (1992), using the Smedley hand grip meter reported that within-subject strength measurements were normally distributed. Stratford's sample consisted of 10 randomly selected subjects from a pool of 40. All were diagnosed with having lateral epicondilitis; a soft-tissue condition commonly known as tennis elbow. Subjects participated in 4 static tasks; hand grip, knee extension and flexion, shoulder abduction, hip extension. In all experimental conditions, within-subject strength measurements were foun

0 percent were achieved at trials 100 and 200, respectively.

In theory, there appears to be substantial support for the stability of repeated maximal strength trials. However, it should be noted that all of these studies, except Stratford's (1992), employed healthy, younger adult subjects.

Coefficient of Variation (CV)

If repeated maximal trials exerted by a 'sincere' subject are expected to be stable with a minimal amount of variation, what constitutes an acceptable degree of variation for a subject's performance to be deemed sincere? In the literature, strength variability appears to be most commonly measured using the coefficient of variation (CV) which is calculated by dividing the standard deviation of a series of strength values by the mean of the same series (Matheson 1988). Several maximum allowable variation cut-off values are reported in the literature for use with hand-grip dynamometers (Bechtol, 1952, Blankenship, 1989; Matheson and Niemeyer, 1990; Niemeyer, Matheson and Carlton, 1989), and are summarized in Table 5. Some CV cut-off values appear to have been derived arbitrarily by the author(s) (Blankenship 1989; Matheson and Niemeyer, 1988), while others can be deduced to correspond to + 1 SD from the mean of an experimental sample (Matheson, Carlton and Niemeyer, 1989).

Table 5

Coefficient of Variation cut-off points reported in the literature.

Authors	Coefficient of Variation (CV) Cut-off Points	MVE Task
Matheson LN, Niemeyer L, & Carlton, R., 1990	9.27% - 15.24% [Males]	Hang-grip [Jamar]
Trossman PB, Suleski KB, & Li PW., 1990	<15%	Hand-grip [BTE]
Matheson L. and Niemeyer L, 1989	10% (Males) 12% (Females)	Hand-grip [Jamar]
Niemeyer L, Matheson LN, & Carlton R., 1989	<15%	Hand-grip [BTE]
Matheson LN., 1988	8% - 12%	Hand-grip [Jamar]
Bohannon R, 1987	< 7.5%	Elbow Flexion [custom device]
Chafin DB, Herrin GD, Keyserling WM, Garg W., 1977	<15%	Lifting [custom device]

In all cases, except the male norms reported in Matheson et al. (1989), descriptions of the normative samples from which various cut-off CV values have been reported are lacking. Since key reliability and validity studies to support such crucial cut-off values have not been delineated, the interpretations of MVE test's outcomes, at this juncture, cannot be confidently applied for either clinical or research purposes.

MVE Coefficient of Variation Reliability

Apart from a recent study (Birmingham, Kramer, Speechley, Chesworth and McDermid, 1997), none of the published studies utilizing the Jamar have examined the test-retest reliability of the coefficient of variation (CV) statistic itself. Given the above noted studies, the influence of instrument measurement error on the CV- which is relied upon as the criterion measure in the MVE test, would be of significant interest. Birmingham, et al (1997), utilized isometric leg extension as the basis for examining the stability of the CV as a measure of sincerity of effort. Since CV cut-points are employed as inflexible criteria to separate 'acceptable' from 'unacceptable' variability in repeated trials, the presence and effect of measurement error can pose a significant threat to the validity of MVE outcomes. Measurement error could conceivably inflate one's true CV score to be much higher than normally measured. Birmingham et al, (1997) studied 31 healthy, athletic males between ages 20 and 30. They were required to perform a series of maximal knee extension trials with sincere effort and again with feigned maximal effort. From the two conditions, the investigators were able to generate two sets of data to which the effects of measurement error on CV cutpoints could be examined. They reported that 'sincere' performance trials could vary by +/- 3.2% (1997) as a result of measurement error, thus rendering the true CV unstable as a criterion measure. They found that taking into account a measurement error of 3.2% could result in 45% of subjects previously regarded as 'feigning' being regarded as 'sincere'.

Populations and Normative Data

The majority of studies found in the literature search for this study have utilized samples that differ substantially from those to whom the MVE test is routinely administered the MVE test. Healthy university students, who comprise a large portion of the subjects in the

studies reviewed, arguably demonstrate and represent a very different physical, social and behavioural profile than the typical MVE testee.

Matheson et al's (1989) study, which reported grip strength reliability and normative data, represents the only data available from a disabled population. The sample in Matheson's (1989) study was part of a larger study that examined the behaviour characteristics of participants in a rehabilitation program in California. Subjects were 89 males between the ages of 19 and 64 years. Most subjects had reportedly retained attorneys to help settle their cases with the workers compensation board and had been unemployed for an average of 2.1 years from the time of injury. Eighty-four percent of the subjects reportedly had spine-related impairments. Subjects had taken a fitness test and substantial general physical deconditioning was evident. The effect of deconditioning of this sample was evidenced in lower hand-grip strength when compared with normative data of healthy samples.

Studies have included descriptions of subjects who would typically undergo MVE testing as part of a functional capacity evaluation (FCE) or 'work hardening' rehabilitation program. These samples appear to differ substantially from the normal samples utilized and reported in most of the MVE literature. Kaplan, Wurtele, and Gillis (1996) in their study examining psychological factors and maximal effort during FCEs, reported sample characteristics similar to those reported in Matheson's (1989) study. Kaplan et al's (1996) sample of 64 subjects had a mean age of 39.1 years (range, 21 to 62 years), had been off work since incurring their injuries for an average of 14.9 months, and the majority (77%) were on workers compensation claims. They also reported Beck Depression Index (BDI) scores (mean: 10.09, SD=6.83) which indicated that their subjects, on average were mildly depressed.

The rather lengthy mean duration transpiring from injury to assessment appears to be a factor that might affect performance in maximal strength trials. Ninety percent of the Canadian adult population with low back pain are able to recover function and comfort within 2 to 3 months. The remaining ten percent have a dismal prognosis which results in few who can regain work (Abenhaim and Suissa, 1990). Mayer, Gatchel and Kishino (1985) point out that often deconditioning due to decreased participation in pre-morbid work and leisure activities, rather than a deliberate effort to exaggerate disability, can degrade performance. They suggested that "a progressive pattern of self-limitation from previous work and recreation activities often results in a general deconditioning syndrome. Additionally, it is conceivable that self image and confidence could dwindle due to lessened capacities and social involvement (Hazard, Matheson, Lehmann and Frymoyer, 1991) further degrading physical performance. In regard to possible effect upon variability of repeated maximal strength exertions, it is conceivable that degraded physical performance could result in higher CV scores due to a falling off (progressively degrading) pattern in repeated strength trial scores.

Significant differences in profile and expected performance between healthy, young adult samples and samples of those with chronic disabilities who typically undergo MVE evaluation, underscore the need to critically examine the appropriateness of the MVE test measures. Along with the paucity of grip strength and MVE test norms among a disabled population, there is also a lack of information regarding descriptive factors of this population and how these factors might relate to MVE test outcomes. Factors, such as age, gender, occupation, education and hand dominance comprise a common set of variables often used to describe subjects routinely administered the MVE.

Influence of Demographic Factors

Age Numerous studies have established a relationship between grip strength and age (Agnew and Maas, 1982; Burke, Tuttle, Thompson, Janney and Weber, 1953; Kellor, Frost, Silberg, Iverson and Cummings, 1971; Mathiowetz et al., 1985; Thorngren and Werner, 1979; Hinson and Gench, 1989). Early studies, such as Kellor and associates documented that the relationship between age and grip strength was an inverse linear one, where increasing age corresponded in a general decrease in handgrip strength. More recent studies have questioned the linear nature of strength decline with age, suggesting that the relationship is curvilinear (Agnew and Maas, 1982; Fike and Rousseau, 1982; Mathiowetz et al., 1985 and Hinson and Gench, 1989).

The effect of age on the variability of repeated effort has not been well established in the literature. Carlsoo (1986), in a study involving 7 subjects (6 female) ranging in age from 33 years to 75 years (mean age not reported) performing repeated effort on 4 tasks including hand-grip, could not find any obvious effect between age and precision of repeated physical effort. No other studies have documented a relation between age and variability of repeated maximal effort.

Gender Hand grip strength norms in the literature appear to support a general effect of sex on strength with mean strength scores of males being generally higher than those of females (Mathiowetz, et al., 1985; Fraser & Benten, 1983; Agnew & Maas, 1982; Gilbertson & Barber-Lomax, 1995).

Separate sets of male and female cut-off CV values used in the scoring of MVE outcomes have been reported (Matheson and Niemeyer, 1986; Matheson, 1989). The reported cut-off values used in the scoring of the MVE test were statistically derived from experimental

samples. It is unclear whether the separate male and female cut-off values were derived from the same experimental sample, or whether they were derived from separate samples. Matheson (1989) described the sample from which the CV cut-off values for males were derived. The sample consisted of 108 males aged 19-64 years who were under evaluation at a vocational evaluation facility in California. The cut-off CV values for females are reported in proprietary materials (RMA &Associates, 1996) but a more comprehensive description of the sample, such as Matheson's (1989) report, could not be located in the scientific literature. A sample size of 32 females was reported but there is no reference to occupation, health status, nor any other descriptions.

Occupation and Education The effect of a subject's occupation on hand-grip strength and variability of effort was sparse. The popular assumption that people in clerical and sedentary jobs having less strength than people in manual materials handling jobs is yet to be empirically supported.

The same paucity of studies to support an effect of education on grip strength and effort variability prevails.

Dominance The effect of hand dominance on grip strength and variability of effort remains a controversial subject. Although it is generally believed that dominant hand-grip strength will generally be greater than non-dominant hand grip strength by around 3 to 4%, a few studies indicate that there was no significant difference between the strength patterns of non-dominant and dominant hands (Mathiowetz et al., 1985; Fullwood, 1986; Fraser and Benten, 1983; Reckeras, 1983).

Influence of Diagnostic Factors

Several of the experimental variables to be evaluated for effect on MVE outcomes have yet to be documented and reported in the literature. The effects of: referral source (whether the subject being administered the MVE was referred by the defense or plaintiff side of medical-legal conflict), work status at time of testing, duration of time elapsed between injury date to test date, number of work stopping injury episodes preceding the MVE test, and depression, have not yet been empirically investigated. However, the literature does contain some information which may support, albeit loosely, a trend between some of these aforementioned factors and MVE test outcomes.

Depression Kaplan, Wurtele and Gillis (1996) maintained that depression may affect a patient's performance on the FCE and that the prevalence of depression among pain patients is high. The report of high prevalence of depression among pain patients was well supported in the literature (Hendler, 1984, Wesley et al., 1991, Love, 1987). Though they did not use the MVE protocol in their study of psychological factors effecting maximal effort during FCEs, Kaplan et al., (1996) reported a marginal effect between depression measured by the Beck Depression Inventory (BDI) and sub-maximal performance.

Deficits in attention, interest in social activity and psychomotor retardation as features of depression, all of which could be seen as having a deleterious effect on strength and maximal effort measurements, were well represented in the literature (Turk and Holzman, 1983; Turk, Rudy and Steig, 1987; Haley, Turner, and Romano, 1985; Keefe et al., 1986).

Episodes Kaplan, Wurtele and Gillis (1996) reported that the number of surgeries had a significant effect on maximal and sub-maximal effort. Mean numbers of surgeries, for

subjects (n= 64) who demonstrated maximal effort and sub-maximal effort during an FCE test, were 1.24 (SD=1.25, $p < .05$) and 2.15 (SD=2.11, $p < .05$) respectively.

In summary, there was much anecdotal evidence for the wide use of the MVE test in FCEs. The test, which purports to measure sincerity of effort and contribute to the identification of abnormal illness behaviour, symptom magnification syndrome and malingering, has evolved to be an integral part of many FCEs. While the Jamar dynamometer and its use in the measurement of hand-grip strength was well documented, empirical support for its use in evaluating the concept of sincerity of effort was under developed. There was a paucity of studies documenting the reliability and validity of the MVE test.

Several publications have suggested criterion measurement points for tests of maximum voluntary effort- maximum allowable cut-off points- which are threshold values beyond which the CV scores for each grip-size setting on the Jamar should not exceed more than two out of ten times- to be deemed 'normal'. These cut-off values remain unreliable for several reasons. Many of the suggested sets of cut-off values are supposedly based on the performance of certain populations but descriptions of these populations are sparse. Those few articles that describe the performance of populations had utilized non-injured college student samples. Except for one study of chronically injured male workers (Matheson et al, 1989), there have been no studies to describe the performance of a disabled population on the MVE test. Since the MVE test is routinely performed on people with injuries or chronic disability, there is a need for more studies of disabled populations on the MVE test to produce more appropriate criterion scores. The present paucity of descriptions of MVE test performances from a disabled populations is especially problematic.

In addition, studies that would clarify the MVE test's construct validity are required. Though weak relationships between MVE test outcomes and typical factors and attributes of patients undergoing an FCE can be suggested, studies that can to clarify the relation between the two remains scarce in the literature.

There are 2 purposes to this study. The first purpose of the study is to describe the performance of a chronically injured population and to compare these performances with the performance of Matheson et al's (1989) sample. The second purpose is to examine how certain factors commonly occurring in a chronically injured population relate to outcome measures on the MVE test.

Chapter 3

Methods

There are two purposes for this study. The first purpose (Purpose 1) is to describe the performance of a chronically injured population and compare its performance with the performance of Matheson et al's (1989) sample. The second purpose (Purpose 2) is to determine how certain factors commonly occurring in a chronically injured population relate to the outcome measures of the MVE test.

This chapter outlines the methodology employed to address these stated research purposes. First, the sample and instruments are described. Procedures for the descriptive statistical analyses of the sample's performance are then presented. Finally, the procedures for the study of relationships between independent and dependent variables are presented. Initial data categorizations and transformations of the data are explained, in addition to the statistical analyses used.

Subjects

The research sample consisted of 100 consecutive cases referred to undergo functional capacity evaluation (FCE) testing at a private-practice occupational therapy clinic in the Greater Vancouver region of British Columbia, Canada. Subjects chosen for the study ranged in age from 18 - 66 years (mean = 39.87, SD=11.6, Range= 48). The sample included 68 women (mean age = 39.16, SD = 11.52, range =48) and 32 men (mean age = 41.38, SD = 11.82, Range = 42). Subjects had been referred to the facility for FCEs to determine: their return to work capacity, next rehabilitation plans, and costs for future care. All subjects had been injured and were either actively undergoing disability insurance claims or were plaintiffs in personal injury litigation. All subjects had been tested between November 1, 1996 and

November 1, 1997. During this time interval the facility's test battery procedure and clinical staff remained stable.

Subbjects were also required to have relatively complete data set files. For the purposes of selecting disabled subjects, chart records were initially screened to confirm a physical diagnosis and impaired work status. The physical diagnoses could include orthopedic conditions such as; bone fracture, joint dislocation, soft-tissue injury, and neurological conditions limited to nerve damage in the lower extremities. Since this study looked at maximal voluntary effort, subjects with central nervous system related conditions, such as head injury were excluded. Additionally, subjects with cardio-pulmanory conditions were excluded since decreased fatigue tolerance (Matheson & Ogden Niemeyer, 1987) associated with such conditions could have presented a reliability threat to the MVE test. Four subjects were excluded from the study due to the presence of the following exclusion factors: age under 18 years (n=1); primary diagnosis of head injury and cardiovascular disease (n=2); upper extremity or cervical spine injury resulting in impaired grip strength to one or both hands (n=1).

Confidentiality

Since this study used data from client medical chart files, several procedures were established to preserve the confidentiality of the subjects. Each selected chart file was assigned a consecutive identification number from 1 to 104. A code sheet bearing the identity of the subject and a corresponding identification number was created. This sheet was kept in a sealed envelope and was accessible only by the principal investigator. The purpose of this sheet is to have a record for the purpose of identifying data sets if more data are needed in the future, or if a reliability check is required at any time. Once all of the data had been recorded

(see Appendix A), the identity of the data was blinded from all investigators. At the time this project is accepted as meeting the requirements of the co-investigator's Master of Science degree committee, the code sheet will be destroyed.

Raters

All MVE tests were administered by three occupational therapists registered in the Province of British Columbia and members of the Canadian Association of Occupational Therapists. These occupational therapists had completed the Industrial Rehabilitation Residency Program through Roy Matheson & Associates ltd., and were Certified Work Capacity Evaluators (CWCE). They reportedly administered the MVE test protocol routinely at the facility.

Although the test battery protocol was consistently administered by the 3 evaluators, inter-rater reliability was not established. Subjects were tested once, by one evaluator. To investigate whether there were any systematic differences among the evaluators, an analysis was performed to examine whether there was a relation between each evaluator and MVE test outcomes. A significant relationship could not be found between rater and MVE test outcomes. Refer to Appendix II.

Instruments & Test Administration Procedure

The MVE tests were administered consistently as the first test of physical performance in the FCE protocol utilized by the facility. For the MVE measures, a Model 1 Jamar Hand Dynamometer (Preston, Jackson, Mis) (Jamar) was used throughout this study.

The Jamar is a familiar instrument among rehabilitation practitioners. Its reliability has been well established in the scientific literature. The reliability of the Jamar in measuring peak hand grip strength has been reported as good to excellent in a number of studies (Fess and

Moran, 1981; Mathiowetz, Weber, Volland and Kashman, 1984; Mathiowetz, 1990; Hinson, Woodward and Gench, 1990; and Niebuhr, Marion and Fike, 1994). Studies reporting test-retest reliability and the resulting reliability coefficients are listed in Table 6.

Table 6

Test-Retest Reliability Coefficients of the Jamar Hand Dynamometer

Authors	Hand	Reported Reliability Coefficients
Hart and Schauf, 1987	Left	0.90
	Right	0.87
Mathiowetz et al, 1984	Left	0.93
	Right	0.87

The facility where the study took place reportedly calibrated their Jamar Hand Dynamometers once each month. At the time of data collection, the dynamometer used in this study was checked and yielded a measurement error of 1.25% in force readings across the range of 0-200 lbs.

MVE Test Procedure

Subjects routinely commenced their testing at approximately 9:30 am. They were given 3 self-administered health-related measurement scales to screen for experience of pain (Dallas Pain Questionnaire, and Visual Analog Pain Scale; Langley & Sheppeard, 1985), and symptoms of depression (Revised Beck Depression Inventory; Beck, Rush, Shaw, & Emery, 1979). Following an interview to explain the testing procedure and precautions, the occupational therapist administered the MVE test. The MVE test was administered following the Matheson protocol (1985) with the following instructions.

> "This is a test of maximum grip strength. I would like you to grip this handle as hard as you can for about two seconds and then release it. You will not feel any movement in the handle as you squeeze, but I will be able to read the force of your grip on this dial. We will be taking several measurements of your grip on 5 different sized grip spans. The smallest grip setting may feel awkward, but please grasp it with your whole hand rather than your fingertips. Please try your best, and let me know if you are experiencing any discomfort with this task."

The subject was handed the dynamometer with the handle fixed to the smallest setting. The subject was then required to grip to maximum with the dominant hand first, rest for 10 to 15 seconds, then grip to maximum with the non-dominant hand. This was repeated, alternating from dominant to non-dominant hand, until a total of three measurements are taken for each hand at that grip setting. The sequence was repeated at each of the four remaining grip settings, progressing from smallest to largest. A one minute to two minute break was permitted while the grip size settings were changed.

Subjects were not apprised of the general intent of the MVE test, being told merely that their hand grip strength was being tested, and at no time during the trial were results communicated to the subject. Raw performance scores of each trial were recorded on a data form and then later entered into the facility's proprietary MVE software. For this study, the raw scores were recorded and treated separately and later compared to and verified with the facility's software output. Figure 3 illustrates the general positioning of a test subject performing an MVE trial with a Jamar dynamometer. An important feature of the instrument is the position of the dial-meter, which faces away from the testee, effectively reducing visual feedback of performance during the test.

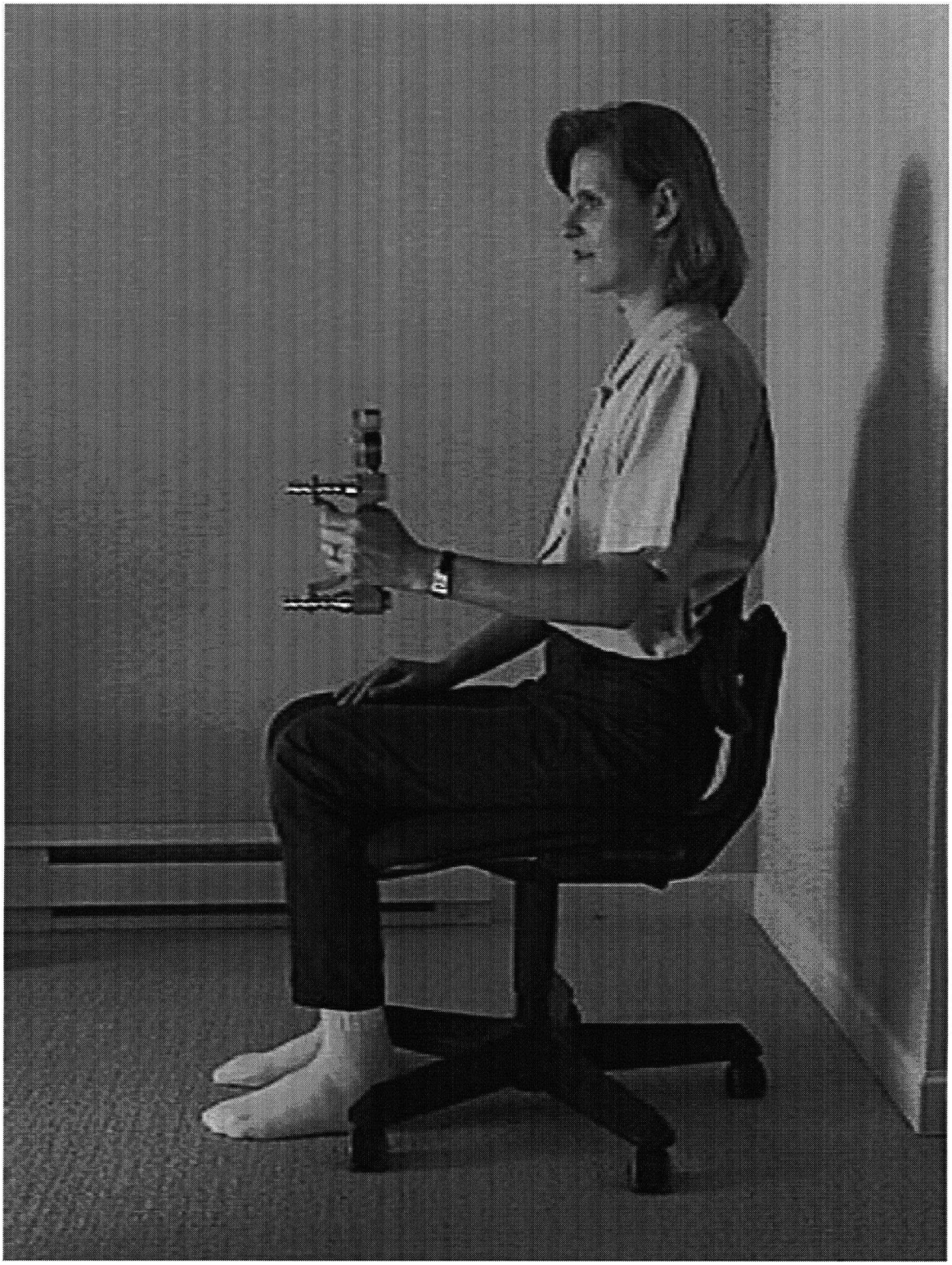

Figure 3. Grip, upper extremity, and body positioning of the testee during the MVE test.

The dependent variable was the outcome of the MVE test- either 'positive' or 'negative'. Following Matheson's (1985) guidelines, the outcome was interpreted as a positive test if the subject's score exceeded 2 Coefficient of Variation (CV) scores out of 10 criterion maximum allowable cut points. A 'positive' test outcome would suggest that the subject was not believed to have given maximum effort.

Revised Beck Depression Inventory

The other standardized instrument yielding data for this study was the revised Beck Depression Inventory (BDI) (Beck, Rush, Shaw, and Emery, 1979) (a copy of the BDI form is in the appendix). The BDI was one of 3 self-administered measurement scales completed by each subject immediately prior to the MVE test. The scale consists of 21 items (see Appendix V) representing problem areas reflecting the presence of cognitive, behavioral and somatic manifestations of depression (Beck and Steer, 1993). The level of intensity of each symptom is rated on a Likert scale from non-existent to severe. Subjects were directed to respond to the items by the tester, who initially read aloud the instructions appearing at the top of the questionnaire sheet:

> "This questionnaire consists of 21 groups of statements. After reading each group of statements carefully, circle the number next to the one statement in each group which best describes the way you have been feeling the past week, including today. If several statements within a group seem to apply equally well, circle each one. Be sure to read all of the statements in each group before making your choice." (Beck and Steer, 1991, p.4 & 5)

The BDI, like its predecessor, the original Beck Depression Inventory is regarded to have fair to excellent reliability and validity. Beck, Steer and Garvin (1988) reported Pearson product moment correlations between pre and posttest administrations of a variety of time

intervals in a psychiatric populations ranged from .48 to .86 among ten studies examining test-retest reliability. In the same study, the authors reported Pearson product moment correlations ranging from .60 to .90 among non-psychiatric patients over 9 reliability studies reviewed. Numerous studies have reported good construct validity in the BDI (Beck and Steer, 1993). Concurrent validity between the BDI and various measures of depression had also been reported in numerous studies. Beck, Steer, and Garbin, (1988) reported a mean correlation of .72 after conducting a meta-analyses of studies that examined correlation coefficients between clinical ratings of depression and the BDI for psychiatric patients.

Procedure

All data were collected from each subject's chart records at the facility. All charts contained the following items, from which the target data were collected: letter of referral and request for services, previous related medical reports, complete copy of the FCE report, MVE test software print-outs, raw data and comments of the evaluator. The letter of referral indicated which referring agency requested the FCE and would be paying the fee for the service. The FCE report and previous medical reports yielded data regarding all of the demographic variables and some of the diagnostic variables, namely, number of previous injury episodes, and chronicity of injury. Maximum voluntary effort software print outs, which contained summary data of each subject's performance, provided mean scores ($\bar{x}$) standard deviations (SD), coefficient of variation scores (CV), and maximum allowable criterion CV cut-points. Raw scores and evaluator comments in the charts provided both MVE and BDI scores, allowing separate calculations to corroborate outcomes reported in the FCE report.

Before data collection commenced, 10 randomly selected chart records were reviewed for content, consistency of data recording and variables to examine in the study. A list of independent and dependent variables were identified and classified according to level of data.

Data Analyses

Purpose 1

The general sample (n=100) was divided into male (n=32) and female (n=68) groups for the purpose of describing the performance of the sample on the MVE test and to compare this sample's performance to that of Matheson's (1989) male and female samples. In order to clarify the general characteristics of this sample, descriptive statistical analyses ($\bar{x}$, SD, Range, Median, CV) were run for each grip setting for both dominant and non-dominant hands. Box plot figures denoting the median (50th percentile), first quartile (25th percentile), and third quartile (75th percentile) were also generated for each grip setting by gender group to graphically summarize and further describe the performance of the samples. These statistical analyses outcomes would be utilized to derive new cut-off scores generated from this 'disabled' sample, which could then be compared with existing performance standards. Though not explicitly explained in his article, Matheson (1988), appeared to derive the MVE's criterion maximum allowable cut-points by combining the mean CV and 1 SD above the mean.

Purpose 2

After a thorough examination of the sample's chart records, 10 independent variables were chosen. These were divided into two groupings; demographic variables and diagnostic variables. The demographic variables were; age, gender, education, hand dominance and

occupation. The diagnostic variables were; diagnosis, depression, referral source, number of previous injury episodes and duration of disability.

Each variable and its coding is described in the following section. Then the initial and subsequent data transformations to prepare the variables for further statistical analyses are explained.

Data were initially recorded onto a tally sheet adhering to certain coding decisions (Please see Appendix III). Data from the tally sheets were entered into a grid matrix constructed in the statistical software program chosen for this study (Systat v. 4.0 for Windows).

The data were then prepared for the analyses of relationships between the experimental variables and MVE outcomes. Before statistical analyses were conducted, each demographic and diagnostic variable category was examined for completeness and errors in data input, including outlying data. Frequency distribution tables, stem leaf plots and graphs of the data were then constructed and examined to ensure that the data were fit for univariate and descriptive statistical analyses. Screening for outlying and missing data, ensuring normal distributions by checking for skewness, linearity, and homoscedacity on the scatter-plot graphs were performed to avoid erroneously inflated or deflated correlations.

The data were then examined by category using standard descriptive statistical techniques to determine; range, mean, median, standard deviation, coefficient of variation, skewness and kurtosis, and to identify naturally occurring distribution patterns. Stem and leaf plots were constructed to clarify the distribution patterns. Naturally occurring disjunctions in the distribution patterns were identified and incorporated into data grouping decisions.

The following section explains the original coding, distribution and transformation of data for each independent (demographic and diagnostic) and dependent variable.

Demographic Variables

Age Age was assigned a numerical code to represent years of age, counted to the day of testing. The initial frequency distribution of the sample was asymmetrical, yielding numerous sparsely populated categories (n=41). Following an examination of the stem and leaf plot graph with particular attention to the range (48), median (37) and upper and lower hinges, a decision was made to transform the data into 4 categories. The final data transformations are summarized in Table 7.

Table 7

Final data transformation categories for age (n=100)

Category/Code	Criteria	Frequency (n)
1	< 30	25
2	31 - 36	26
3	37 - 49	26
4	> 49	23

Gender Males were assigned the code; '0' (n=32), and females were assigned the code; '1' (n=68). Data in this category remained unchanged. Although gender represents just one of many variables to compare with MVE test outcomes, this natural categorization presented an opportunity to explore the occurrence of systematic similarities and differences between groups. Since one particular purpose of the study was to obtain information of heuristic value about the MVE test and the performance of populations on the test, gender differences represented an important aspect of this study.

Education Education was initially coded numerically to represent the number of years of formal education completed by each subject in the sample. This designation was gleaned from the subject's clinical records file, within accompanying medical or vocational reports. The initial frequency distribution of the sample was asymmetrical with more than 20% of the cells sparsely populated. The resulting stem and leaf plot graph and descriptive statistical measures (range (15.0), median (12.0), upper hinge (12.0) and lower hinge (10.0)) were considered. The largest natural cluster was found at 'high school matriculation', with the next robust grouping between grade 8 to High school matriculation. The third largest grouping occurred at 'post high school matriculation'. Outlying values at the low and high ends of the distribution were incorporated into the closest large groupings. The resulting 3 categories are summarized in Table 8.

Table 8

Final data transformation categories for Education (n=100)

Category/Code	Criteria	Frequency (n)
1	Less than High School Matriculation	39
2	High School Matriculation	40
3	At least 1 year greater than High School Matriculation	21

Hand Dominance Manifest hand dominance was defined as the handedness reported by each subject to the examiner at the time of testing. Right handedness was assigned the code

'1' (n= 86), and left handedness was assigned the code '2' (n=14). There were no manifestly ambidextrous subjects in the sample.

Occupation The occupation of the subjects in the sample were originally coded numerically into 11 categories. An occupation categorization schema consisting of 11 categories used by Crockett, Hurwitz, Hart, MacDonald and Welch (1996) in a study of neuro-psychiatric participants in the Province of British Columbia, Canada, was initially used. As can be observed in Table 9, which summarizes the initial frequency distribution, this schema could not be utilized for significance testing due to the asymmetry and sparsely populated cells.

Table 9

Initial Data Transformation Categories for Occupation (n=100)

Category/ Coding	Criteria	Frequency (n)
1	Professional	3
2	Clerical/Sales	8
3	Service	8
4	Agriculture, Fishery, Lumber, Mining	1
5	Skilled Labour	3
6	Semi-Skilled	10
7	Unskilled	34
8	Housewife	0
9	Student/Ward	2
10	Chronically Unemployed	26
11	Retired	5

A stem and leaf plot from this initial distribution was examined, with particular attention given the range (10.0), median (7.0), upper hinge (10.0) and lower hinge (6.0). As can be observed in the previous table, more than a quarter of these cells were sparsely

populated. Given the relatively small sample, and the limitations of the distribution to the proposed statistical analyses, a decision was made to reduce the number of categories to 6. Considering that the main purpose in selecting appropriate categories was to construct a variable that allowed comparison of cases with successful vocational histories with cases with less successful vocational histories, these final categories were sufficient. The data transformation is summarized in Table 10.

Table 10

Final data transformation categories for Occupation (n=100)

Category/Code	Criteria	Frequency (n)
1	Professional & Clerical	11
2	Service	8
3	Skilled/Semi-skilled	13
4	Unskilled	35
5	Chronically Unemployed	26
6	Not in the Workforce	7

Diagnostic Variables

Diagnosis For 'diagnosis', the first diagnosis given to the subject recorded in the chart record was used. After examining the range of diagnoses, and considering the relatively small size of the sample, the coding scheme decided upon for 'diagnosis' was initially set to three categories; Soft tissue injury (category 1), Fracture and Joint Dislocation (category 2), and Neurological Trauma (category 3). The initial frequency distribution along these initial three categories was found to be asymmetrical, yielding as many as 80 counts in category 1 and sparsely 4 counts in category 3. A decision was made to transform the data into a dichotomous grouping (similar to 'gender' and 'handedness') by combining category 3 with category 1. This transformation was not entirely led by statistical reasoning, but also followed clinical

preference, to align neurological trauma with soft-tissue injury rather than with bone and joint trauma. The resulting frequency distribution resulted in 84 counts in category 1 and 16 counts in category 2.

Depression Since symptoms of depression have been reported to affect physical performance and maximal effort (Kaplan et al, 1996, Hendler, 1984, Love, 1987), the inclusion of this variable was necessary to examine its relationship with MVE test outcomes. Depression was initially coded numerically along raw scores on the revised Beck Depression Inventory (BDI) (Beck and Steer, 1979). The BDI has a maximum score of 63. Scores produced by this sample ranged from 1 to 50. The initial frequency distribution was asymmetrical, and sparsely populated in more than a third of the cells. In order to make appropriate data transformation decisions to yield data groupings amenable to further statistical analyses, the subjects' BDI test outcomes along with the test interpretation guidelines were taken into consideration. The BDI test authors (Beck and Steer, 1979) suggest a criterion cut-off point of 17 to separate mildly depressed (BDI=10-16) from moderately depressed (BDI=17-29) patients. Hence, the BDI outcome score of 17 was selected as a cut-off point to separate the sample into category 1 (n=47, Range=15) and category 2 (n=37, Range=33).

Sixteen subjects' chart records did not contain BDI scores, nor outcomes of any other depression inventory. All of these cases had positive MVE test outcomes. The effect of these missing data on the analyses and study in general will be addressed in the results and discussion section.

Referral Source Referral letters contained in the chart record were examined to determine sources of referral for the subjects to undergo evaluation. All subjects were noted to

be involved in active injury insurance claims. Two broad categories were identified. Subjects were relegated to category 1 (n=58) if they were referred for testing from a party representing the interests of the insurance company (which included defense legal counsels and insurance claim adjudicators). Subjects were relegated to category 2 (n=42) if they were referred for testing by a party representing the subject's interests in an injury insurance claim (which included mainly plaintiff legal counsels). The data distribution, being dichotomous and robustly sampled was deemed fit to undergo further statistical analyses and thus remained un-transformed.

Episodes 'Episodes' represented the number of injury episodes leading to time off work, previous to the most recent injury episode for which the subject was referred for testing. The initial distribution was asymmetrical (and positively skewed) with 6 counts identified as outlying values. Outlying values were defined as those data lying 1.5 or more inter-quartile range scores (IQRs) from the median. All 6 outliers were identified as minor outliers, each with 4 previous injury episodes. These were re-confirmed in a review of the chart record and were allowed to remain. The data were transformed to fit 3 categories, reduced from an original 6 categories. Category 1 (n=52) held counts of up to 1 previous injury episode. Category 2 (n=28) held counts of exactly 2 previous injury episodes and category 3 (n=20) held counts of 3 or more injury episodes.

Chronicity Chronicity represented the duration of time transpiring from the time of injury to the time of MVE testing. Duration was initially calculated and recorded in units of weeks. Later, after examining the frequency distribution, this unit of time measure was transformed to months. The initial distribution was asymmetrical with more than 20% of fitted cells sparsely populated. The range (87.0months), median (31.5months), upper hinge (46.0

months) and lower hinge (22.0 months) were considered, resulting in data transformed to fit 4 categories. Categories, criteria and frequencies for Chronicity are summarized in table 11.

Table 11

Final Data Transformation Categories for Chronicity (n=100)

Category/Code	Criteria	Frequency (n)
1	<24 months (1 year)	32
2	25 - 36 months (2 - 3 years)	34
3	36 - 48 months (3 - 4 years)	17
4	> 48 months (4 + years)	17

Dependent Variable

MVE Test Outcome Measures The dependent variable in Purpose 2 of this study was the outcome of the MVE test. The outcome measure of the MVE test was expressed either as 'positive' or 'negative'. All grip strength trials scores (30 trials per subject) from the sample (n=100) were entered into a grid matrix on the statistical software program. MVE scores were calculated by subject to derive Mean (x) Standard Deviation (SD) and Coefficient of Variation (CV) scores for each of the 10 sets of 3 repetitive hand grip trials. Strictly following the test administration and scoring guidelines (Matheson, 1984) each subject's CV scores were compared with the criterion maximum allowable cut-off points. A test outcome was 'positive' if more than 2 CVs generated by the subject exceeded the criterion cut-off points. Two or less CVs exceeding the criterion cut-off points generated by the subject would result in a 'negative' outcome. 'Positive' MVE test outcomes were assigned a code of '2' (n=32), while 'negative' MVE test outcomes were assigned a code of '1' (n=68).

After all of the independent variables were checked and transformed, each was examined to determine if a relationship of significance existed between each of the independent (demographic and diagnostic) variables and the dependent MVE test outcome variable. Chi Square test coefficients were calculated using an alpha level of .05 for the purpose of analyzing relationships between each of the independent variables and the dependent variable.

Chapter 4

Results

This chapter presents the results of the data treatment and analyses. Section 1 reports the outcomes associated with purpose 1, which described the performance of the sample. The performance of the sample is described both as a whole group and divided according to gender. Standard descriptive statistics were used to describe performance of the sample along the parameters of the independent and dependent variables of this study. Maximum voluntary effort test performance data of the total group and along gender groups, with respect to Jamar grip-setting categories (5 for the dominant hand and 5 for the non-dominant hand) follow. Section 2 reports how the independent (demographic and diagnostic) variables related to the MVE test outcome measures.

Section 1: Performance of Chronically Disabled Sample on MVE Test

A statistical description of this sample's performance and criterion measures is presented in this section. First the sample is briefly described. Certain demographic and diagnostic factors selected to serve as the independent variables for purpose 2 were utilized as a framework to further describe this sample and their performance. Separate descriptive statistical analyses of the MVE test performance data along gender groups are then reported, particularly with respect to hand-grip setting specific data categories.

Descriptions of the Sample

The following section presents descriptions of the research sample in addition to the description of the sample presented in Chapter 3 of this manuscript. Descriptions of the sample along two demographic variables and two diagnostic variables are presented first.

Additional descriptions of the sample along the independent variables are summarized and presented in tabular form.

Gender The sizes of respective gender sample groups in this study appear to be reversely proportioned to Matheson's (1989) study (from which the criterion MVE test cut-off points were derived). Matheson reported a sample containing 32 women (23%) and 108 men (77%), whereas this study's sample contained 32 men (32%) and 68 women (68%).

Occupation This study revealed that the most useful (admittedly broad) categories to organize and describe the occupations of this sample were the six categories condensed from the original 11 categories. Table 12 summarizes the proportional contribution of each of the 6 occupational categories to the sample as a whole group and by gender group.

Table 12

Occupational Group Representation in the Sample by Percentage

Category	General Sample (n=100)	Males (n=32)	Females (n=68)
Professional-Clerical	11.0%	3.1%	14.7%
Service	8.0%	9.4%	7.4%
Skilled-Semi Skilled	13.0%	16.6%	11.8%
Unskilled	35.0%	25.0%	39.7%
Chronically Unemployed	26.0%	40.6%	19.1%
Not in the Workforce	7.0%	6.3%	7.4%

Diagnosis 'Soft-Tissue Injuries' (84%) was the more prominent diagnosis than 'Bone Fractures and Dislocations' (16%). Percentage of soft-tissue injuries among the female group

decreased to 82.4%, while the percentage of these diagnoses among the male group rose to 87.5%. The distribution is summarized in table 13.

Table 13

Diagnostic Group Representation in the Sample by Percentage

Diagnostic Category	General Sample (n=100)	Males (n=32)	Females (n=68)
Soft-tissue Injury (including Nerve Injury)	84.0%	87.5%	82.4%
Bone Fractures & Dislocation	16.0%	12.5%	13.6%

Referral Source Fifty eight percent of the subjects were referred for testing to this facility by defense legal counsels (representing insurance companies) or insurance company adjusters. Plaintiff's counsel referred the remaining 42%. When examined according to gender, defense legal counsel or an insurance company adjuster referred 62.5% of the male subjects and 56.0% of the female subjects.

Descriptions of the study sample along the remaining variables are presented in Table 14.

Table 14

Descriptive Statistical Data of the Study Sample of Selected Independent Variables of the Study, by Total Sample and by Gender Group.

Independent Variable	General Sample (n=100)	Female (n=68)	Male (n=32)
DEMOGRAPHIC VARIABLES			
Age (years)			
Mean	39.87	39.16	41.37
SD	11.61	11.52	11.82
Range	48.00	48.00	42.00
Education (years)			
Mean	11.77	12.00	11.28
SD	2.48	2.18	3.01
Range	15.00	10.00	15.00
Hand Dominance ('1' = Right, '2' = Left)			
Median	1.00	1.00	2.00
SD	0.35	0.34	0.37
DIAGNOSTIC VARIABLES			
Depression (BDI-R scores; 0 - 63)			
Mean	16.92	17.50	15.75
SD	9.32	9.92	8.04
Range	49.00	49.00	35.00
Previous Injury Episodes (frequency)			
Median	1.00	1.00	2.00
SD	0.99	0.83	1.22
Range	5.00	3.00	5.00
Chronicity of Current Injury (months)			
Mean	33.22	35.24	28.91
SD	15.83	16.92	12.40
Range	87.00	80.50	48.00

Profiles of Subjects According to MVE Test Outcomes A description of the subjects separated according to MVE test outcomes (positive or negative) is summarized and presented in Tables 15 and 16. Sixty-nine percent of the subjects (n=69) had negative MVE tests while 31% of the subjects (n=31) had positive MVE tests.

Table 15

Demographic Characteristics of Subjects According to MVE Outcomes.

Variable	(-) MVE Test (n = 69)	(+) MVE Test (n = 31)
Age mean (SD)	44.13 (12.14)	37.96 (10.96)
Gender n (%)		
• Men	20 (62.5)	12 (37.5)
• Women	49 (72.1)	19 (27.9)
Education n (%)		
• < High School	28 (40.6)	11 (35.5)
• High School	27 (39.1)	13 (41.9)
• Post Secondary	14 (20.3)	7 (22.6)
Hand Dominance n (%)		
• Right	60 (86.9)	26 (83.9)
Occupation n (%)		
• Professional Clerical	9 (13.0)	2 (6.5)
• Service	6 (8.7)	2 (6.5)
• Skilled, Semi-skilled	11 (15.9)	2 (6.5)
• Unskilled	28 (40.6)	7 (22.6)
• Chronically Unemployed	11 (15.9)	15 (48.4)
• Not in the Workforce	4 (5.8)	3 (9.7)

Note: This table shows that the subjects with lower educational achievement often have a greater tendency to produce abnormal MVE test results.

Table 16

Diagnostic Characteristics of Subjects According to MVE Outcomes.

Variable	(-) MVE Test (n = 69)	(+) MVE Test (n = 31)
Diagnosis n (%)		
• Soft Tissue / Neurological	56 (81)	28 (90)
• Bone Fracture / Dislocation	13 (19)	3 (10)
Referral Source n (%)		
• Defense Legal / Insurance	29 (42)	29 (94)
• Plaintiff Legal / Self	40 (58)	2 (6)
Episodes Injury mean (SD)	1.4 (0.67)	2.5 (1.15)
Chronicity mean (SD)		
• Months	34 (15.38)	32 (16.93)
BDI-R mean (SD)		
• (n=84, range 6-50)	16.75 (9.51)	17.7 (8.67)

Note, this table shows that subjects with more than 2 previous injury episodes more often had abnormal MVE test outcomes. Further, half of the subjects referred by insurance companies had positive MVE outcomes whereas only 6% of the subjects referred by Plaintiff's legal counsel had positive MVE outcomes.

Performance Outcomes on the MVE Test

Descriptive statistical outcome measures of the sample's performance on the MVE test, according to each of the 5 Jamar dynamometer grip settings per hand, are reported in the following section. Summaries of descriptive statistical outcomes of the total sample, female sample and male sample, are presented tabular form. Box plot diagrams summarizing the distribution of individual scores by grip size setting follow.

Performance by Jamar Grip Setting

Total Sample The mean scores of three trials, across the 5 grip size settings per hand, showed certain general trends. Mean scores for the dominant hand (27.30) were slightly

greater than in the non-dominant hand (25.90). Variance remained similar with CV scores of 43% and 42% for dominant and non-dominant hands, respectively. Across each of the 5 grip settings for both hands, performance reflected a biomechanical effect resulting in a positively skewed bell shaped curve peaking at the second grip setting. Tables 17 and 18 summarize the descriptive statistical outcomes for dominant and non dominant hands. Figures 4 and 5 graphically show the distribution of scores for dominant and non-dominant hands, respectively.

Table 17

Descriptive Statistical Measures of Dominant Hand Grip Performance of the Total Sample Across the 5 Grip Settings on the MVE Test (n=100).

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
Minimum	2.00	4.67	2.33	2.67	2.00
Maximum	57.67	63.33	58.33	52.00	45.00
Range	55.67	58.67	56.00	49.33	43.00
75th Percentile	27.8	39.7	39.5	35.9	30.7
Median	21.50	30.67	29.83	26.67	21.50
25th Percentile	15.8	23.0	21.0	18.4	14.0
Mean	22.42	32.36	31.06	27.65	23.02
SD	9.60	13.31	12.98	11.94	10.49
CV	0.43	0.41	0.42	0.43	0.46

Total Sample / MVE Dominant Hand Mean Grip Strength Scores per Jamar Grip Setting

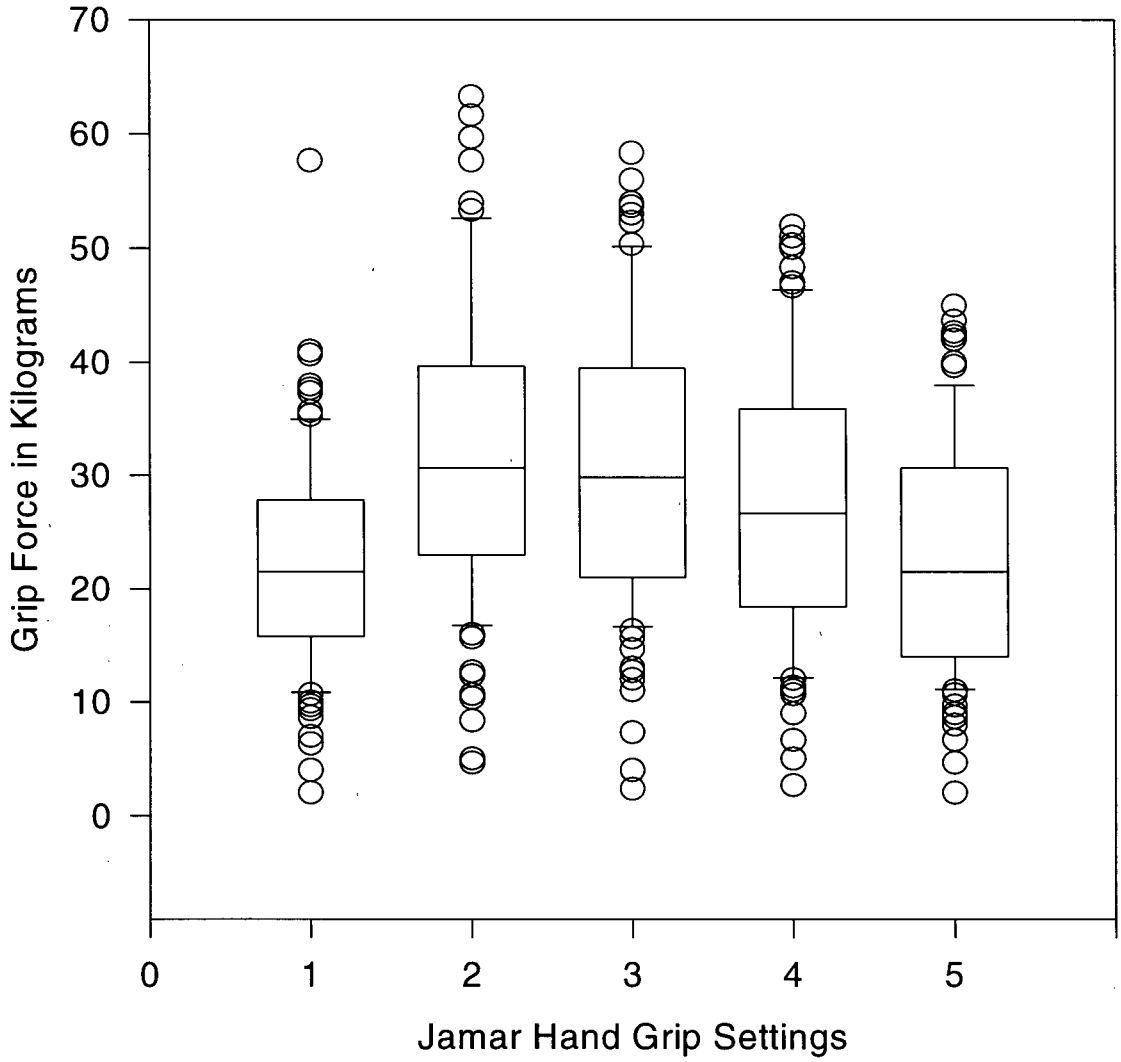

Figure 4. Box plots summarizing dominant hand mean grip strength scores by Jamar hand grip setting among the total sample (n=100).

Note: Positively skewed bell shape distribution with mean CV values peaking at the grip setting 2.

Table 18

Descriptive Statistical Measures of Non-dominant Hand Grip Performance of the Total Sample
Across the 5 Grip Settings on the MVE test (n=100).

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
Minimum	2.00	3.00	3.00	2.67	1.00
Maximum	52.67	61.00	55.33	48.67	43.00
Range	50.67	58.00	52.33	46.00	43.00
75th Percentile	27.7	40.3	36.7	32.0	27.8
Median	20.83	29.00	27.83	24.67	20.33
25th Percentile	15.2	23.5	20.3	17.7	13.9
Mean	21.69	31.22	29.33	25.82	21.41
SD	9.46	12.73	11.85	10.91	9.35
CV	0.44	0.41	0.40	0.42	0.44

Total Sample / MVE Non-Dominant Hand Mean Grip Strength Scores per Jamar Grip Setting

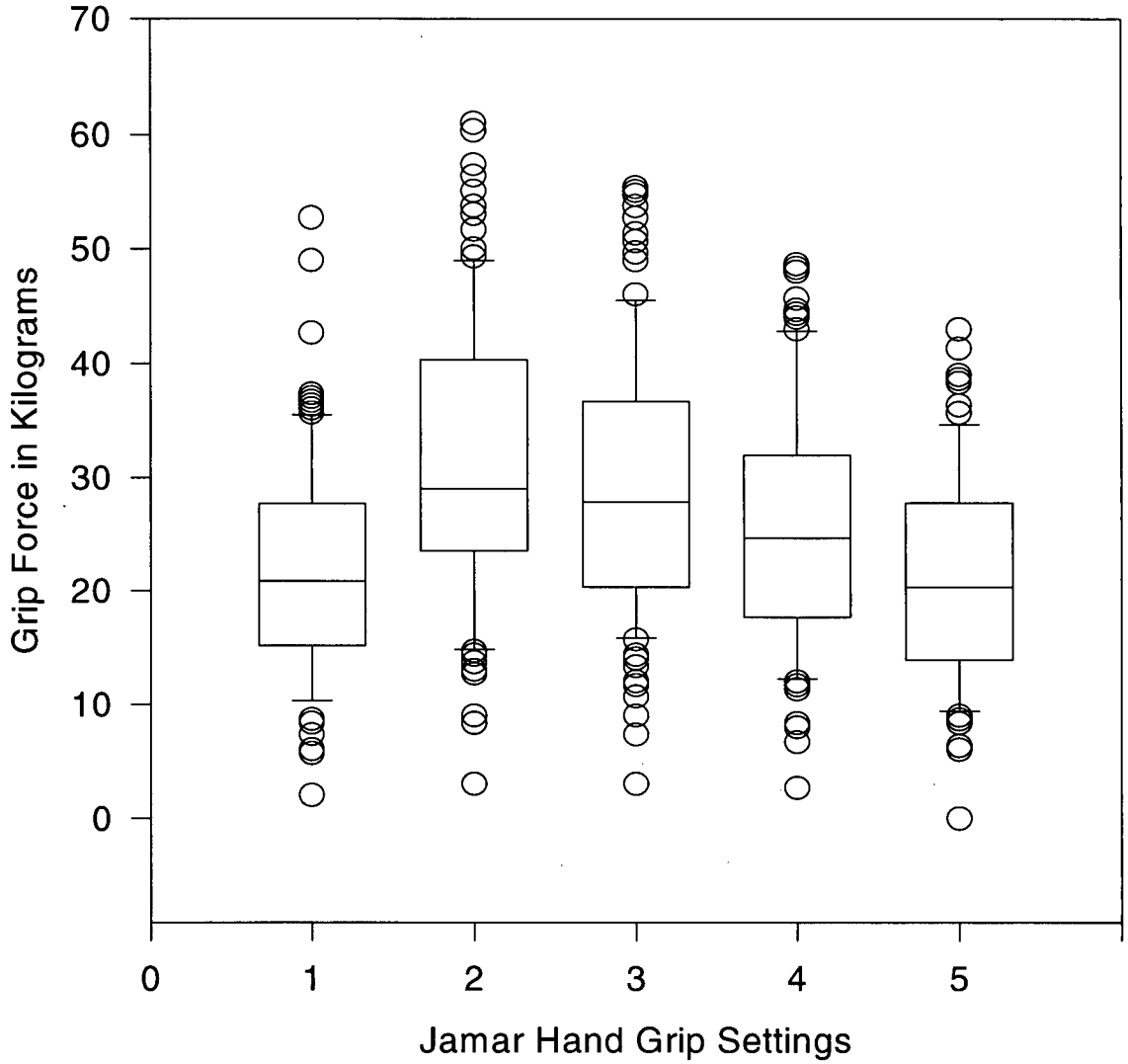

Figure 5. Box plots summarizing non-dominant hand mean grip strength scores by Jamar hand grip setting among the total sample (n=100).

Note: Positively skewed bell shape distribution with mean CV values peaking at the grip setting 2.

Female Sample The mean scores of three trials among the female sample, across the 5 grip size settings per hand, showed trends similar to the general sample. Mean scores for the dominant hand (23.35) were slightly greater than in the non-dominant hand (21.89), while variance scores remained almost identical with CV scores of 40%. Across each of the 5 grip settings for both hands, performance appeared to follow a biomechanical effect resulting in a positively skewed bell shaped curve peaking at the second grip setting. Tables 19 and 20 summarize the descriptive statistical outcomes for dominant and non-dominant hands. Figures 6 and 7 graphically show the distribution of scores for dominant and non-dominant hands, respectively.

Table 19

Descriptive Statistical Measures of Female Dominant Hand Grip Performance Across the 5 Grip Settings on the MVE Test (n=68).

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
Minimum	2.00	4.67	2.33	2.68	2.00
Maximum	41.00	59.67	54.00	48.33	40.00
Range	39.00	55.00	51.67	45.65	38.00
75th Percentile	23.3	33.1	31.0	28.0	23.5
Median	19.00	27.67	26.00	22.67	18.67
25th Percentile	14.3	21.3	19.5	17.0	12.8
Mean	19.65	28.06	26.55	23.42	19.06
SD	7.95	10.57	10.26	9.45	7.93
CV	0.40	0.38	0.39	0.40	0.42

Female Sample / MVE Dominant Hand
Mean Grip Strength Scores per Jamar Grip Setting

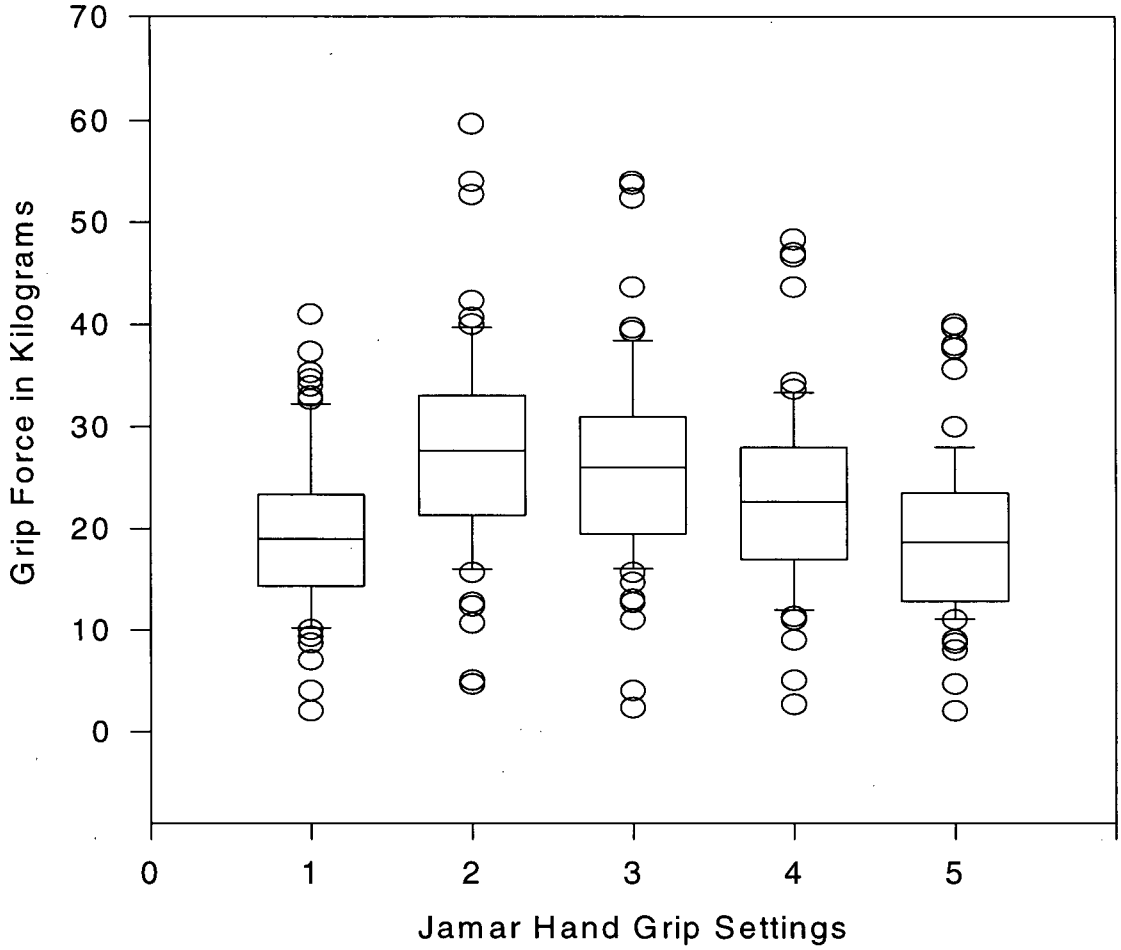

Figure 6. Box plots summarizing dominant hand mean grip strength scores by Jamar hand grip setting among the female sample (n=69).

Note: Positively skewed bell shape distribution with mean CV values peaking at the grip setting 2.

Table 20

Descriptive Statistical Measures of Female Non-dominant Hand Grip Performance Across the 5 Grip Settings on the MVE test (n=68).

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
Minimum	2.00	3.00	3.00	2.67	2.00
Maximum	36.33	55.00	51.33	48.33	43.00
Range	34.33	52.00	48.33	45.67	41.00
75th Percentile	23.7	31.7	29.3	25.5	21.9
Median	18.17	25.00	24.33	21.00	18.00
25th Percentile	13.8	20.8	19.0	16.0	13.0
Mean	18.59	26.67	24.84	21.64	17.69
SD	7.54	9.87	9.02	8.55	7.60
CV	0.41	0.37	0.36	0.40	0.43

Female Sample / MVE Non-Dominant Hand Mean Grip Strength Scores per Jamar Grip Setting

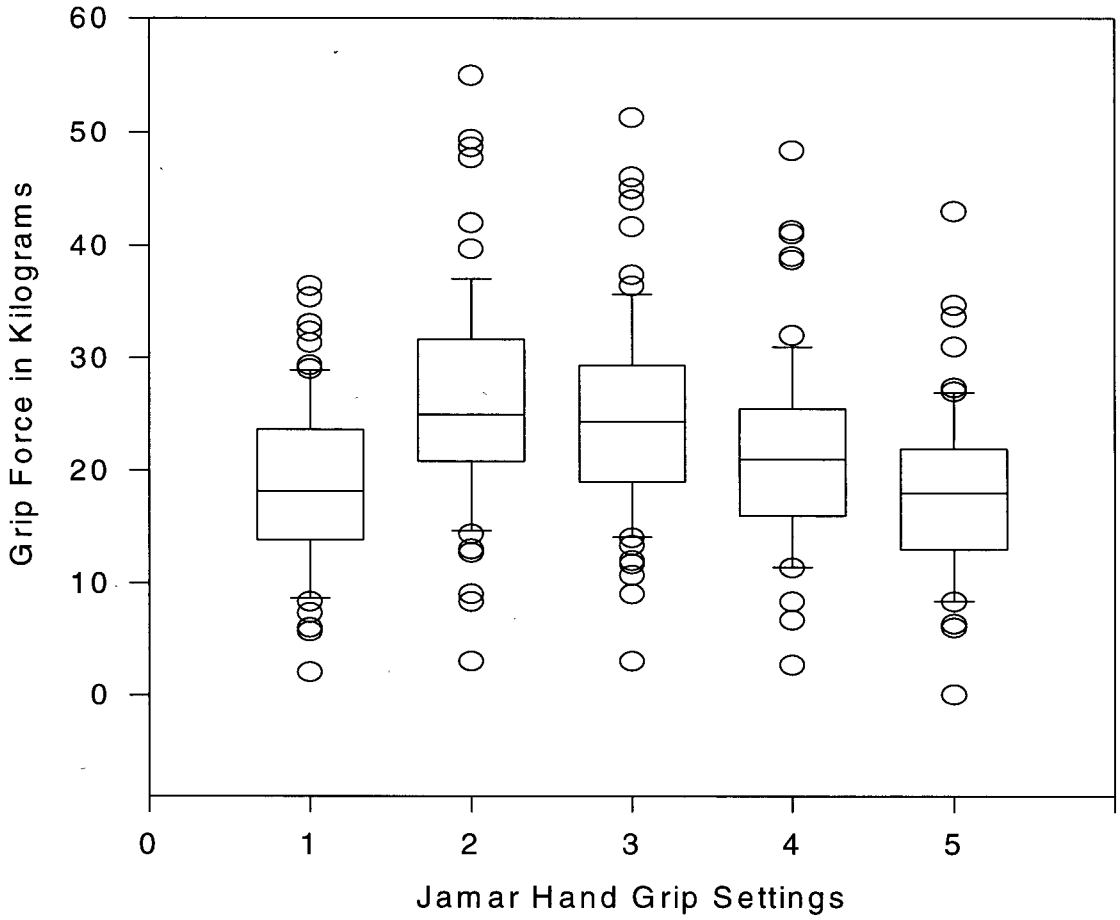

Figure 7. Box plots summarizing non-dominant hand mean grip strength scores by Jamar hand grip setting among the female sample (n=69).

Note: Positively skewed bell shape distribution with mean CV values peaking at the grip setting 2.

In regard to the variance of scores across each set of three trials per grip setting, on which the criterion measures of the MVE test are based, Tables 21 and 22 summarize the CV mean and SD scores. Cut-off point scores for each grip setting, derived from this sample, calculated using Matheson et al's (1988) method (mean CV + 1 SD) are also reported. Across each of the 5 grip settings for both hands, the mean CV scores followed a negative kurtotic trend with the greatest variance in CV scores occurring at the extreme grip settings (setting 1 and setting 5).

Table 21

Female Dominant Hand Coefficient of Variation, Mean and Standard Deviation and Resulting Cut-off Scores Across Grip Settings, for this Sample and Matheson's (1988) Sample.

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
This Sample (n=68)					
Mean CV	8.58%	6.95%	5.37%	5.84%	7.22%
Mean SD	8.28%	5.69%	4.86%	6.65%	7.24%
Derived Cut-off Score	**16.86%CV**	**12.64%CV**	**10.23%CV**	**12.49%CV**	**14.46%CV**
Matheson et al (1988) Sample (n=32)					
Cut-off Score	**11.40%CV**	**8.60%CV**	**8.30%CV**	**9.20%CV**	**9.10%CV**

Note: Matheson et al (1988) published limited descriptive statistical data for males (dominant and non-dominant hands) but reported only final MVE cut-off scores for females in ERIC proprietary materials.

Table 22

Female Non-dominant Hand Mean Coefficient of Variation and Standard Deviation and Resulting Cut-off Scores Across Grip Settings, for this Sample and Matheson's (1988) Sample.

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
This Sample (n=68)					
Mean CV	9.02%	6.50%	5.58%	5.78%	6.83%
Mean SD	8.33%	5.91%	5.53%	4.18%	5.45%
Derived Cut-off Score	**17.35%CV**	**12.41%CV**	**11.11%CV**	**9.96%CV**	**12.28%CV**
Matheson et al (1988) Sample (n=32)					
Cut-off Score	**12.00%CV**	**10.70%CV**	**8.00%CV**	**8.20%CV**	**9.00%CV**

Note: Matheson et al (1988) published limited descriptive statistical data for males (dominant and non-dominant hands) but reported only final MVE cut-off scores for females in ERIC proprietary materials.

Male Sample The mean scores of three trials for males, across the 5 grip size settings per hand showed similar general trends as with the general and female samples. Mean scores for the dominant hand (35.85) were slightly greater than in the non-dominant hand (35.55) for males. Unlike the female sample's performance, variance scores were slightly greater in the dominant hand. Mean CV scores were 33% for the dominant hand and 30% for the non-dominant hand. Across each of the 5 grip settings for both hands, performance appeared to follow a biomechanical effect resulting in a positively skewed bell shaped curve peaking at the second grip setting. Tables 23 and 24 summarize the descriptive statistical outcomes for dominant and non-dominant hands. Figures 8 and 9 graphically show the distribution of scores for dominant and non-dominant hands, respectively.

Table 23

Descriptive statistical measures of male dominant hand grip performance across the 5 grip settings on the MVE test (n=32).

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
Minimum	6.33	8.33	7.33	6.67	6.67
Maximum	57.67	63.33	58.33	52.00	45.00
Range	51.33	55.00	51.00	45.33	38.33
75th Percentile	33.7	52.0	49.5	45.3	38.0
Median	27.83	47.33	46.33	40.00	33.83
25th Percentile	23.5	31.2	33.2	28.4	27.7
Mean	28.312	41.37	40.65	36.91	31.99
SD	10.25	14.09	13.05	11.69	10.13
CV	0.36	0.34	0.32	0.32	0.32

Male Sample / MVE Dominant Hand
Mean Grip Strength Scores per Jamar Grip Setting

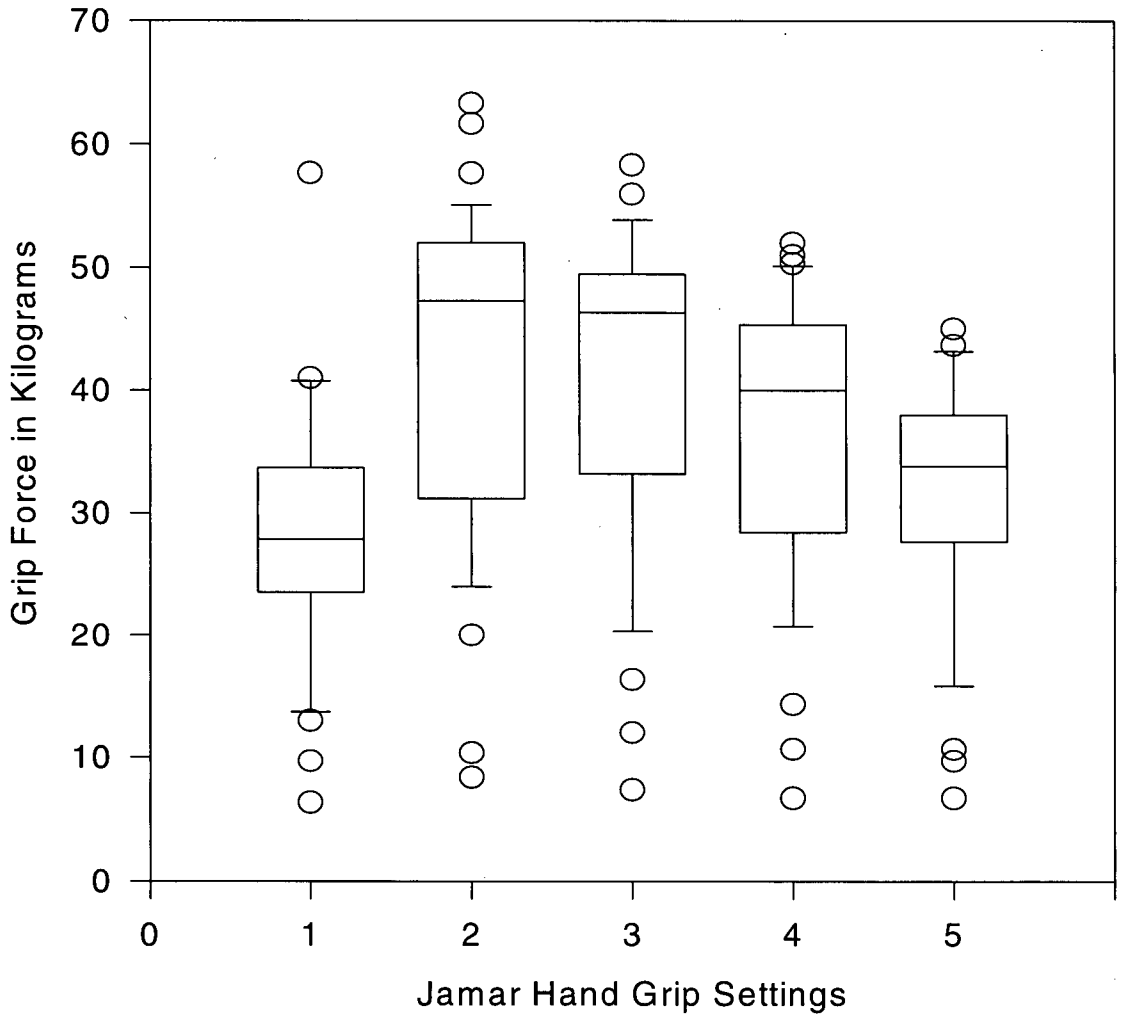

Figure 8. Box plots summarizing dominant hand mean grip strength scores by Jamar hand grip setting among the male sample (n=31).

Note: Positively skewed bell shape distribution with mean CV values peaking at the grip setting 2.

Table 24

Descriptive statistical measures of male non-dominant hand grip performance across the 5 grip settings on the MVE test (n=32).

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
Minimum	8.67	9.00	7.33	8.00	8.33
Maximum	52.67	61.00	55.33	48.67	41.33
Range	44.00	52.00	48.00	40.67	33.00
75th Percentile	35.8	49.3	47.0	43.8	35.7
Median	27.17	44.00	40.83	36.67	30.33
25th Percentile	22.5	33.3	32.5	27.8	26.3
Mean	28.29	40.89	38.88	34.99	29.71
SD	9.84	12.86	11.62	9.98	7.41
CV	0.35	0.32	0.30	0.29	0.25

Male Sample / MVE Non-Dominant Hand Mean Grip Strength Scores per Jamar Grip Setting

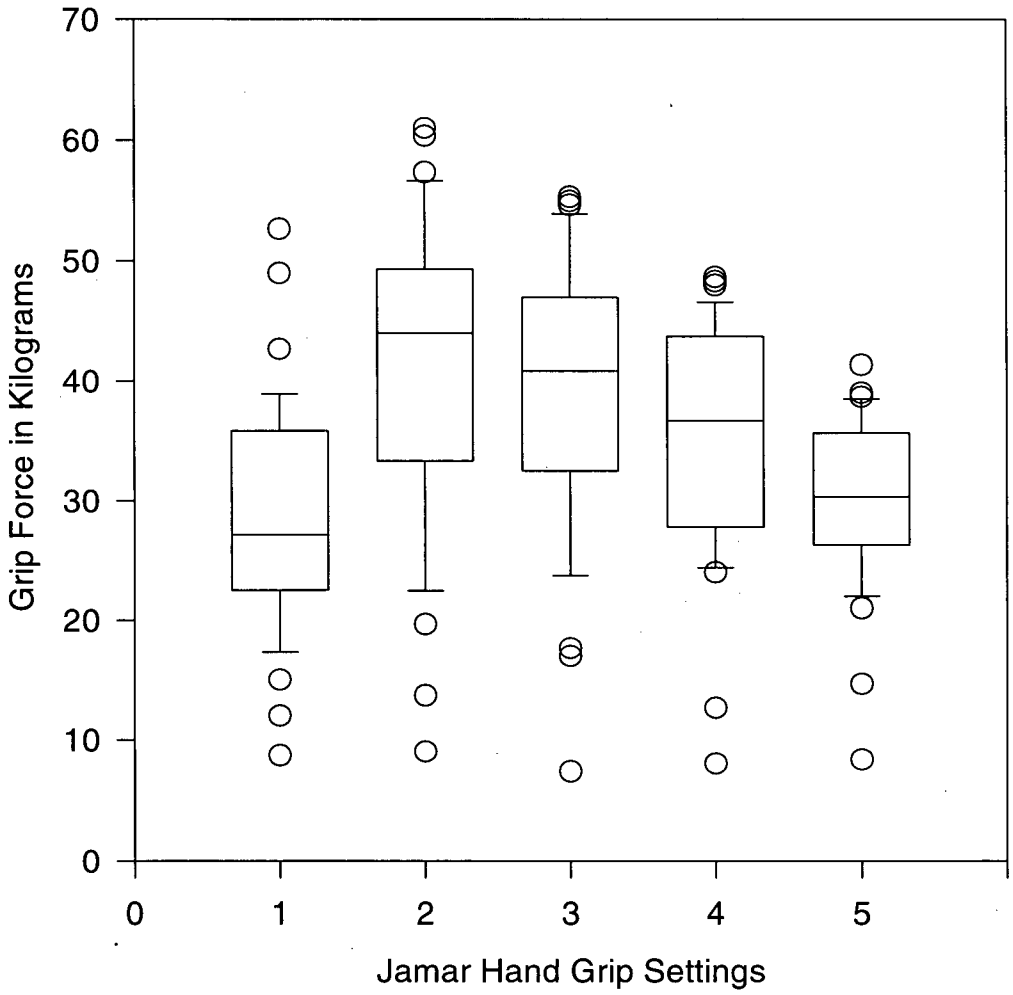

Figure 9. Box plots summarizing non-dominant hand mean grip strength scores by Jamar hand grip setting among the male sample (n=31).

Note: Positively skewed bell shape distribution with mean CV values peaking at the grip setting 2.

In regard to the variance of scores across each set of three trials per grip setting, on which the criterion measures of the MVE test are based, Tables 25 and 26 summarize the CV mean and SD scores. Cut-off point scores for each grip setting derived from this sample, are reported. The tables also display reported descriptive data from Matheson's (1989) sample for comparison.

Table 25

Male Dominant Hand Coefficient of Variation, Mean and Standard Deviation and Derived Cut-off Scores Across Grip Settings, for this Sample and Matheson's (1989) Sample.

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
This Study Sample (n=32)					
Mean CV	8.46%	8.88%	6.74%	5.07%	5.95%
Mean SD	7.54%	8.58%	6.30%	4.58%	6.72%
Derived Cut-off Score	**16.00%CV**	**17.46%CV**	**13.04%CV**	**9.65%CV**	**12.68%CV**
Matheson et al (1989) Sample (n=108)					
Mean CV	9.01%	5.84%	5.64%	5.62%	6.05%
Mean SD	5.41%	3.62%	3.75%	4.45%	4.76%
Cut-off Score	**14.42%CV**	**9.46%CV**	**9.39%CV**	**10.07%CV**	**10.81%CV**

Table 26

Male Non-dominant Hand Coefficient of Variation, Mean and Standard Deviation and Resulting Cut-off Scores Across Grip Settings, for this Sample and Matheson's (1989) Sample.

	Grip Setting 1	Grip Setting 2	Grip Setting 3	Grip Setting 4	Grip Setting 5
This Study Sample (n=32)					
Mean CV	7.07%	5.53%	6.18%	7.08%	5.72%
Mean SD	5.17%	4.89%	5.46%	7.63%	4.73%
Derived Cut-off Score	**12.24%CV**	**10.42%CV**	**11.64%CV**	**14.71%CV**	**10.45%CV**
Matheson et al. (1989) Sample (n=108)					
Mean CV	8.63%	6.26%	5.48%	5.66%	6.76%
Mean SD	6.61%	4.04%	3.79%	4.07%	5.46%
Cut-off Score	**15.24%CV**	**10.30%CV**	**9.27%CV**	**9.73%CV**	**12.50%CV**

Section 2: Analyses of Relationship Between Independent and Dependent Variables

This section reports the outcomes of the analyses of relationship between the independent and dependent variables. The independent variables were separated into two types; demographic and diagnostic. The demographic variables consisted of; Age, gender, education, hand dominance and occupation. The diagnostic variables consisted of; diagnosis, depression, referral source, number of previous injury episodes and duration of disability. The dependent variable was the outcome on the MVE test, expressed simply as either 'positive' or 'negative'. The chi-square statistic was used to examine whether there were significant relationships between each of the independent variables and the dependent variable. Subject Profiles of samples divided according to positive and negative MVE outcomes are reported.

Demographic Influences

Five demographic variables were examined; age, education, gender, hand dominance and occupation. These variables were analyzed with respect to their relation to positive MVE test outcome scores.

Age The age of the subjects was categorized into four groups: less than 30 years (N= 25), 30 to 36 years (N=26), 37 to 49 years (N= 26), and greater than 49 years (N=23). Table 27 displays the distribution of positive and negative MVE test outcomes according to the 4 groups.

Table 27

Distribution of MVE Test Outcomes According to Age (n=100).

Age Category By years	n	(-) MVE test Outcomes	(+) MVE test Outcomes	Percent of (+) MVE test outcomes (%)
<30	25	21	4	16.00
30 to 36	26	18	8	30.77
37 to 49	26	18	8	30.77
>49	23	12	11	47.83
Total	100	69	31	

Note: the increasing trend of positive MVE outcomes with increasing age.

The percentage of subjects with positive MVE test scores who were in the lowest age category (16%) was much lower than the percentage of subjects in the highest age category (48%). Subjects in the 2 intermediate age categories had a similar rate of falling beyond the cut-off points (31%). Although the relationship between age category and positive MVE test outcomes appeared to be strongly linear, the relationship did not achieve significance (Chi-Square = 5.675, df=3, p<.129).

Education For the purpose of examining the relation between positive MVE tests and educational achievement, the amount of educational exposure was categorized into three broad groups; subjects having some high school experience (n=39), subjects with high school matriculation (n=40), and subjects with post secondary education experience (n=21). Table 28 displays the distribution of positive and negative MVE test outcomes according to the 3 groups.

Table 28

Distribution of MVE Test Outcomes According to Education (n=100).

Educational Achievement	n	(-) MVE test Outcomes	(+) MVE test Outcomes	Percent of (+) MVE test outcomes (%)
< High School Matriculation	39	28	11	28.21
High School Matriculation	40	27	13	32.50
At least one year > High School Matriculation	21	14	7	33.33
Total	100	69	31	

Note: Relatively similar rates of positive MVE outcomes among educational categories.

Subjects with the lowest amount of educational exposure had slightly fewer MVE-scores beyond the cut-off point (28.2%) than subjects with some post-secondary educational experience (33.3%). Overall, there was no significant association between the 3 categories of educational achievement and the frequency of abnormal MVE-scores (chi-square = 0.238, df=2, p>.888).

Gender Table 29 displays the distribution of positive and negative MVE test outcomes according to gender.

Table 29

Distribution of MVE Test Outcomes According to Gender (n=100).

Gender	n	(-) MVE test Outcomes	(+) MVE test Outcomes	Percent of (+) MVE test outcomes (%)
Male	32	20	12	37.50
Female	68	49	19	27.94
Total	100	69	31	

Note: Male subjects had a higher rate of positive MVE test outcomes.

The frequency of positive MVE test outcomes did not appear to be related to gender (Chi-Square = 0.930, df=1, p > .335).

Hand Dominance The manual dominance of the subject was compared to the rate of positive MVE test outcomes. Table 30 displays the distribution of positive and negative MVE test outcomes according to right and left hand dominance. A non-significant pattern was observed (Chi-Square = 0.169, df=1, p > .681).

Table 30

Distribution of MVE Test Outcomes According to Hand Dominance (n=100).

Hand Dominance	n	(-) MVE test Outcomes	(+) MVE test Outcomes	Percent of (+) MVE test outcomes (%)
Right	86	60	26	30.23
Left	14	9	5	35.71
Total	100	69	31	

Occupation The occupational status of the subjects was classified in 6 broad categories reflecting; Professional-Clerical (N=11), Service (N=8), Skilled-Semiskilled (N=13), Unskilled (N=35), Chronically Unemployed (N=26), and Not in the Work Force (N=7). Table 31 displays the distribution of positive and negative MVE test outcomes according to the 6 categories.

Table 31

Distribution of MVE Test Outcomes According to Occupation (n=100).

Occupational Group	n	(-) MVE test Outcomes	(+) MVE test Outcomes	Percent of (+) MVE test outcomes (%)
Professional & Clerical	11	9	2	18.18
Service	8	6	2	25.00
Skilled & Semi-skilled	13	11	2	15.39
Unskilled	35	28	7	20.00
Chronically Unemployed	26	11	15	57.69
Not in Workforce	7	4	3	42.86
Total	100	69	31	

Note: Rates of positive outcomes according occupational category were remarkably high for those groups representing limited employment prospects.

Some of the groups were small and with that in mind, it appeared that the Chronically Unemployed (58%) or Not in the Work Force groups (43%) had higher rates of MVE-scores beyond the cut-off points. In comparison, those with Professional-Clerical (18.2%), Service (25%), or Skilled-Semiskilled positions (15%) had much lower rates.

The differences in the rate of positive MVE outcome scores for the 6 broad occupational groups was significant (Chi-Square = 13.562, df=5, $p < .019$). This significant finding should be interpreted with caution given the small size of some of the groups.

Diagnostic Influences

Five diagnostic variables were examined; Diagnosis, Referral Source, Episodes (of injury leading to time off work), Duration (of time between injury date and date of testing) and Depression (as assessed on the BDI-R). These variables were also analyzed with respect to their relation to positive MVE test outcome scores.

Diagnosis Diagnosis was classified into two categories reflecting the primary diagnoses of Soft-tissue injuries (N=84) and Bone fractures and dislocations (N=16). Table 32 displays the distribution of positive and negative MVE test outcomes according to diagnosis.

Table 32

Distribution of MVE Test Outcomes According to Diagnosis (n=100).

Diagnosis Group	n	(-) MVE test Outcomes	(+) MVE test Outcomes	Percent of (+) MVE test outcomes (%)
Soft Tissue & Neurological Trauma	84	56	28	33.33
Fracture & Joint Dislocation	16	69	31	18.75
Total	100	69	31	

It appeared that those with soft-tissue injury as their primary diagnosis (33%) had a higher rate of positive MVE test outcomes, compared to those subjects with bone fractures (19%). However a significant association between diagnosis and positive outcome on the MVE test was not demonstrated (Chi-Square = 1.336, df = 1, $p < .248$).

Referral Source The difference in the rate of positive MVE test outcomes according to the 2 referral source categories was found to be statistically significant (Chi-Square = 23.306, df=1, $p < .000$). Five percent of the category representing referrals from plaintiff legal counsel resulted in positive MVE test outcomes, while 50% of the category representing referrals from defense legal counsel/insurance company adjuster resulted in positive MVE test outcomes. Table 33 displays the distribution of positive and negative MVE test outcomes according to the 2 referral categories.

Table 33

Distribution of MVE Test Outcomes According to Referral (n=100)

Referral Category	(-) MVE test Outcomes	(+) MVE test Outcomes	Total	Percent of (+) MVE Test Outcomes
Insurance Co. / Defense Legal Counsel	29	29	58	50.0%
Self / Plaintiff Legal Counsel	40	2	42	4.8%
Total	69	31	100	

Note: Subjects referred by insurance company interests had a 50% rate of positive MVE outcomes. Conversely, self or plaintiff counsel referrals resulted in a rate of less than 5%

The pattern of differences between the two categories of referring parties in relation to positive MVE is illustrated in figure 10.

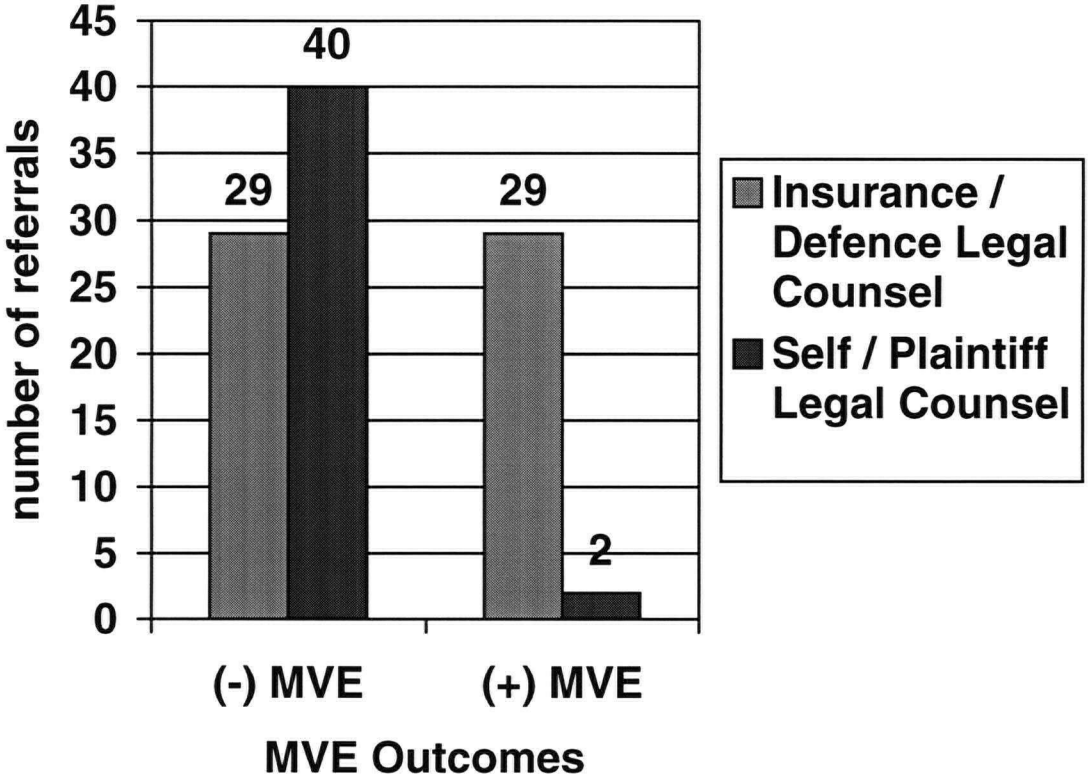

Figure 10. Frequency of positive MVE test outcomes in the sample according to referral.

Note: Subjects referred by insurance company interests had a 50% rate of positive MVE outcomes. Conversely, self or plaintiff counsel referrals resulted in a rate of less than 5%

Episodes There were three categories to describe Episodes, with category 1 (N=52) and category 2 (N=28) representing 1 and 2 injury episodes respectively, and category 3 (N=20) representing 3 or more injury episodes. Table 34 displays the distribution of positive and negative MVE test outcomes according to the 3 categories of episodes. It appeared that as the number of episodes increased, the rate of positive MVE results increased. In the lowest category 6 out of 52 subjects (12%) produced positive MVE outcomes. In the second category, representing 2 episodes, 10 out of 28 subjects (36%) produced positive MVE outcomes. Though the sample comprising the third category was relatively small, 15 out of 20 subjects (75%) scored positive MVE test outcomes.

Table 34

Distribution of MVE Test Outcomes According to Episode (n=100).

Number of Injury Episodes	n	(-) MVE test Outcomes	(+) MVE test Outcomes	Percent of (+) MVE test outcomes (%)
1	52	46	6	11.54
2	28	18	10	35.71
≥ 3	20	5	15	75.00
	100	69	31	

Note: As the number of injury episodes increased, so did the rate of positive MVE outcomes.

The pattern of differences among the 3 categories of episodes in relation to positive MVE outcomes warranted cautious interpretation due to the comparatively small population in category 3. The pattern is illustrated in figure 11.

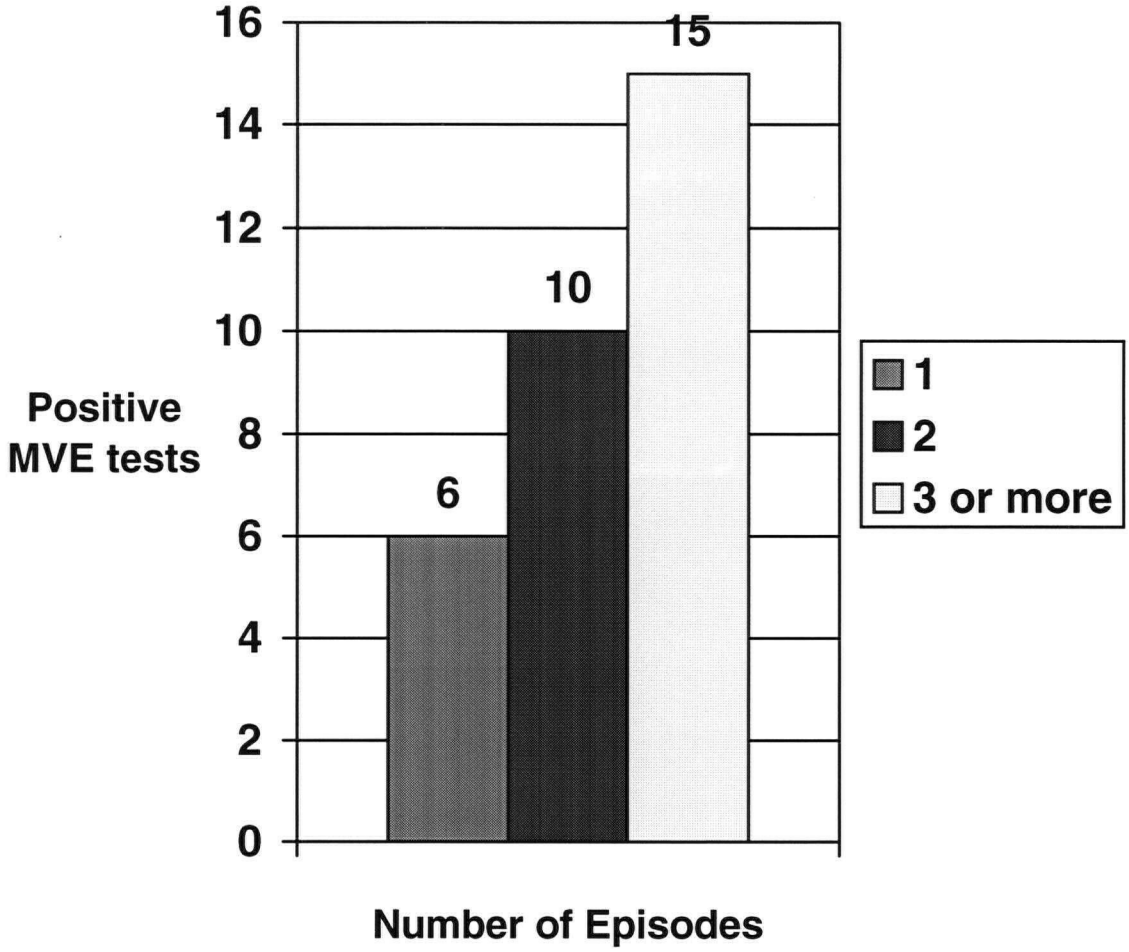

Figure 11. Frequency of positive MVE test outcomes in the sample according to number of injury episodes.

Note: As the number of injury episodes increased, so did the rate of positive MVE outcomes.

The relation between frequency of episodes and frequency of positive MVE test outcomes was found to be statistically significant (Chi-Square = 27.600, df=2, p< .000).

Chronicity The sample was separated into 4 categories. Category 1 (N=32) was comprised of those subjects with up to 24 months elapsed from time of injury to time of this MVE testing. Category 2 (N=34) comprised those subjects with 25 months to 36 months elapsed from time of injury to time of this MVE testing. Category 3 (N=17) comprised those subjects with 31 months to 48 months elapsed from time of injury to time of this MVE testing, and Category 4 (N=17) comprised those subjects with over 48 months from time of injury to time of this MVE testing. Table 35 displays the distribution of positive and negative MVE test outcomes according to the 4 groups.

Table 35

Distribution of MVE Test Outcomes According to Chronicity (n=100).

Chronicity of Disability	n	(-) MVE test Outcomes	(+) MVE test Outcomes	Percent of (+) MVE test outcomes (%)
<24 months	32	21	11	34.38
25-36 months	34	23	11	32.35
36-48 months	17	11	6	35.29
>48 months	17	14	3	17.65
	100	69	31	

Note: The rate of positive MVE test outcomes were similar at between 32.35% to 35.29% for the first 3 categories, then decreased to 17.65% among those subjects with more than 48 months of disability duration.

Subjects in each of the first 3 categories were found to have a similar rate of positive MVE outcomes (34%, 32% and 35%, respectively). The rate of positive MVE outcomes fell to 18% among those subjects with 4 or more months of elapsed time from time of injury to time of this MVE testing.

An association was not found between chronicity of injury and the rate of positive MVE test outcomes, in this sample (Chi-Square = 1.763, df=3, p<.623).

Depression Depression was measured by the self-administered Revised Beck Depression Inventory (BDI-R). On the BDI-R, scores ranging from 0 to 16 are considered to reflect minimal to mild depressive symptoms, while scores ranging from 17 to 64 are considered to reflect moderate to severe depressive symptoms. For the sample that participated in the BDI-R (n=84), the rates of positive MVE outcomes were 15% for the 'minimally' to 'mildly depressed' group and 20% for the 'moderately depressed' group. Table 36 displays the distribution of positive and negative MVE test outcomes according to the 2 categories resulting from the BDI-R cut-off level of 17.

Table 36

Distribution of MVE Test Outcomes According to Depression (n=84).

BDI-R Score	n	(-) MVE test Outcomes	(+) MVE test Outcomes	Percent of (+) MVE test outcomes (%)
< 17	39	33	6	15.39
≥ 17	45	36	9	20.00
Total	84	69	31	

This pattern of difference between these two groups in relation to positive MVE test outcomes were found to be statistically non-significant (Chi-Square = 0.303, df = 1, p< .582).

The sample comprising subjects that had not completed a BDI was remarkable by the rate (100%) of positive MVE results. The pattern of difference between this group and the other groups that had completed the BDI, to positive MVE outcomes was found to be significant (Chi-Square = 42.604, df = 2, p< .000).

The general outcomes of the analyses of relationships between the independent and dependent variables of this study are summarized in table 37.

Table 37

Summary of Analyses of Relationships Between Independent and Dependent Variables.

Independent Variables	Chi Square Value	Degrees of Freedom	α Level (p = 0.05)	Relationship
Demographic Variables				
Age	5.675	3	.129	Non Significant
Education	0.238	2	.888	Non Significant
Gender	0.930	1	.335	Non Significant
Hand Dominance	0.169	1	.681	Non Significant
Occupation	13.562	5	.019	Significant
Diagnostic Variables				
Diagnosis	1.336	1	.248	Non Significant
Referral Source	23.306	1	.000	Significant
Episodes	27.600	2	.000	Significant
Chronicity	1.763	3	.623	Non Significant
Depression*	0.303	1	.582	Non Significant

Note: Among the 10 independent variables chosen for this study, Occupation, Episodes, and Referral Source had significant relationships with positive MVE outcomes.

Among the independent variables, Occupation, Referral Source and Episodes were found to have significant associations with MVE test outcomes. The interpretation of Occupation requires some caution due to sparse numbers in more than 20% of the categories. Further, although Depression was shown to have an overall relationship of non significance

* Sixteen subjects were not administered the BDI. Those 16 subjects all scored positive MVE tests.

with MVE outcomes, 16% of the sample were not administered the BDI-R test. These same subjects all attained positive MVE test outcomes.

CHAPTER 5

Discussion

This chapter presents a more detailed discussion of the results of this study. The results are discussed in relation to issues raised in the literature review (chapter 2) and findings derived through the statistical analyses of the data. Methodological issues, particularly the limitations presented by the research design, are presented with recommendations for further studies on this topic. The chapter concludes with a discussion of the study's theoretical and clinical relevance.

There were two purposes to this research. The first purpose was to describe the performance of a disabled population on the MVE test and to compare the performance of this population to the performance of Matheson et al's (1989) population. The second purpose was to determine how certain demographic and diagnostic factors of this sample related to outcome measures of the MVE test. This chapter is organized into two main discussions according to these two purposes. The chapter begins with a summary of the sample's performance. Patterns of MVE performance and profiles of subjects achieving positive and negative MVE outcome scores are presented first. Additionally, the performance of this study sample is compared with the performance of the population from which the MVE test criterion measures were derived. The chapter then moves to a discussion of the analyses of relationships between the independent and dependent variables.

Purpose 1; Performance of a Disabled Sample on the MVE Test

Research to date relating to the MVE test conveys an assumption that the performances and amount of variability expected in repeated maximal grip-strength trials between disabled and non-disabled people are homogenous. However, closer consideration of

those previous studies reveals a scarcity of MVE test performance descriptions of disabled people. The majority of reported MVE test CV cutoff scores do not delineate separate criterion scores for disabled and non-disabled people. Without further studies to confirm the homogeneity of MVE performance between these two groups of testees, applying MVE criterion scores drawn from healthy populations to evaluate disabled people may be problematic.

Since the MVE test is usually administered to disabled people, some clinicians have likely questioned the appropriateness of applying criterion measures derived from the performance of healthy populations, to evaluate the performances of their chronically disabled clients. Clinical experience would suggest that certain social and physical features of an individual's state of disability could decrease their maximal repetitive physical performance. Economic and social influences related to the issue of disability could lead the participant to purposely give less than full effort in order to maintain his or her disability status. On the other hand, non-deliberate features of chronic disability, such as depression, and decreased physical conditioning due to lengthy periods of inactivity could conceivably effect poor physical performance.

Do disabled people perform differently on the MVE test than non-disabled people? If disabled people do perform differently, do they tend to demonstrate greater variability in repetitive maximal strength trials, and therefore yield greater CV scores on the MVE test than non-disabled people? With these issues in mind, a disabled sample's performance on the MVE test is discussed. Given the scarcity of literature describing MVE test performance patterns of a disabled population, it was important to describe the sample's performance and compare those with known performance standards. The following comparisons pertain to general grip

strength standards. Following this, the descriptions of performance move toward comparisons of the degrees of variation of repeated maximal grip-strength trials on the MVE test with those of other studies.

Grip Strength Performance The mean grip strength performance patterns of the study sample, with regard to age, gender, and hand dominance were examined and found to fit expected distribution patterns.

Previous studies of hand grip strength have reported a curvilinear relationship between grip strength and age. Mathiowetz, et al's (1985) study, to establish clinical norms for hand strength involving 628 healthy subjects spanning 20 to 75+ years of age, reported a curvilinear relationship peaking within the 30 to 34 year-old cohort. Hinson and Gench (1989) reported a similar curvilinear response pattern, peaking within their 30 to 39 year-old cohort. Both of these well-known studies also demonstrated generally higher mean scores for males and dominant hands than for females and non-dominant hands, respectively. The distribution of maximal grip strength scores in the current study sample according to age was also curvilinear, with mean grip strength scores peaking at age category 2 (31 to 36 years) for both male and female groups. The mean grip strength score for males (77.77lbs) was greater than mean grip strength scores for females (49.99lbs). Mean grip strength scores for the dominant hand (60.33lbs) was greater than for the non-dominant hand (57.22lbs).

To determine whether this disabled sample's strength differed at all from non-disabled group standards, a comparison was made with normative data from Mathiowetz, et al's (1985) study of normal adults. Median peak grip-strength scores from the strongest cohorts of both male and female groups (category 2; 31 to 36 years) from the current study compared similarly to cohort groups situated between 50 to 64 years of age in Mathiowetz et al's sample.

Table 38 summarizes mean peak dominant hand and non-dominant hand grip scores for this sample's strongest male and female cohort groups along with the corresponding cohort groups in Mathiowetz, et al (1985).

Table 38

A Comparison of Mean Peak Dominant Hand and Non-dominant Hand Grip Scores for this Sample's Strongest Male and Female Cohorts (Category 2; 31-36 years) and Corresponding Cohorts in Mathiowetz, et al (1985).

Condition	Mean Grip Score (lbs.)	Corresponding Cohort in Mathiowetz, et al (1985) and Grip Score (lbs.)	
Male			
(Category 2; 31-36 years)			
Dominant	91.37	60-64 years	89.7
Non-Dominant	90.37	55-59 years	83.2
Female			
(Category 2; 31-36 years)			
Dominant	62.01	55-59 years	57.3
Non-dominant	58.94	50-54 years	56.0

These substantially weak hand grip strength outcomes indicate a significant diminution of hand-grip strength and endurance among this disabled sample compared with Mathiowetz, et al's (1985) normal adult sample. Although this study sample's hand grip strength performances demonstrated some normal tendencies, in such instances as with age, gender and handedness effects, the remarkable diminution of hand-grip strength performance would appear to suggest a general deconditioning effect among this disabled sample population. This finding underscores the need to further examine whether disabled people perform tests of

maximal effort differently than non-disabled people and if separate norms and performance criteria are thus warranted.

At least two explanations for the degradation in maximal hand-grip strength performances can be offered. One explanation would be that a significant portion of the sample was 'malingering' or purposely trying to perform the tests of hand strength sub-maximally. On the other hand, the discrepancy could be due to other less deliberate reasons, such as general physical deconditioning due to decreased activity (Hoenig & Rubenstein, 1991). Muscle strength loss due to inactivity, for example, has been reported to be lost at a rate of one to 5 percent for each day of bed rest (Rubin, 1988). Given the chronicity of the sample's overall experience of disablement (mean= 33.22months), it is conceivable that secondary influences of lessened activity could have a degrading effect upon physical strength and endurance. A standard measure of physical conditioning was not available for each of the subjects in this study but should be required in future studies on this issue to clarify physical conditioning factors and their possible effect upon MVE test outcomes.

To further investigate the possibility of general physical deconditioning in the study sample and its possible expression in degraded grip strength, the pattern and consistency between repetitive maximal grip strength trials of the subjects on the MVE test were examined. A fatigue effect pattern of gradually eroded strength performance between the initial trial and the second and third trials under each of the 10 conditions was detected in the overall sample as well as when divided by gender. The order in which the 10 different grip size conditions were presented to the testees were reportedly randomized but the presence of a fatigue pattern of progressively degrading scores contained within each series of 3 repeated

hand grip trials could be observed. Figure 12 illustrates the pattern of mean maximal hand grip scores according to the three serial repetitions of the MVE test.

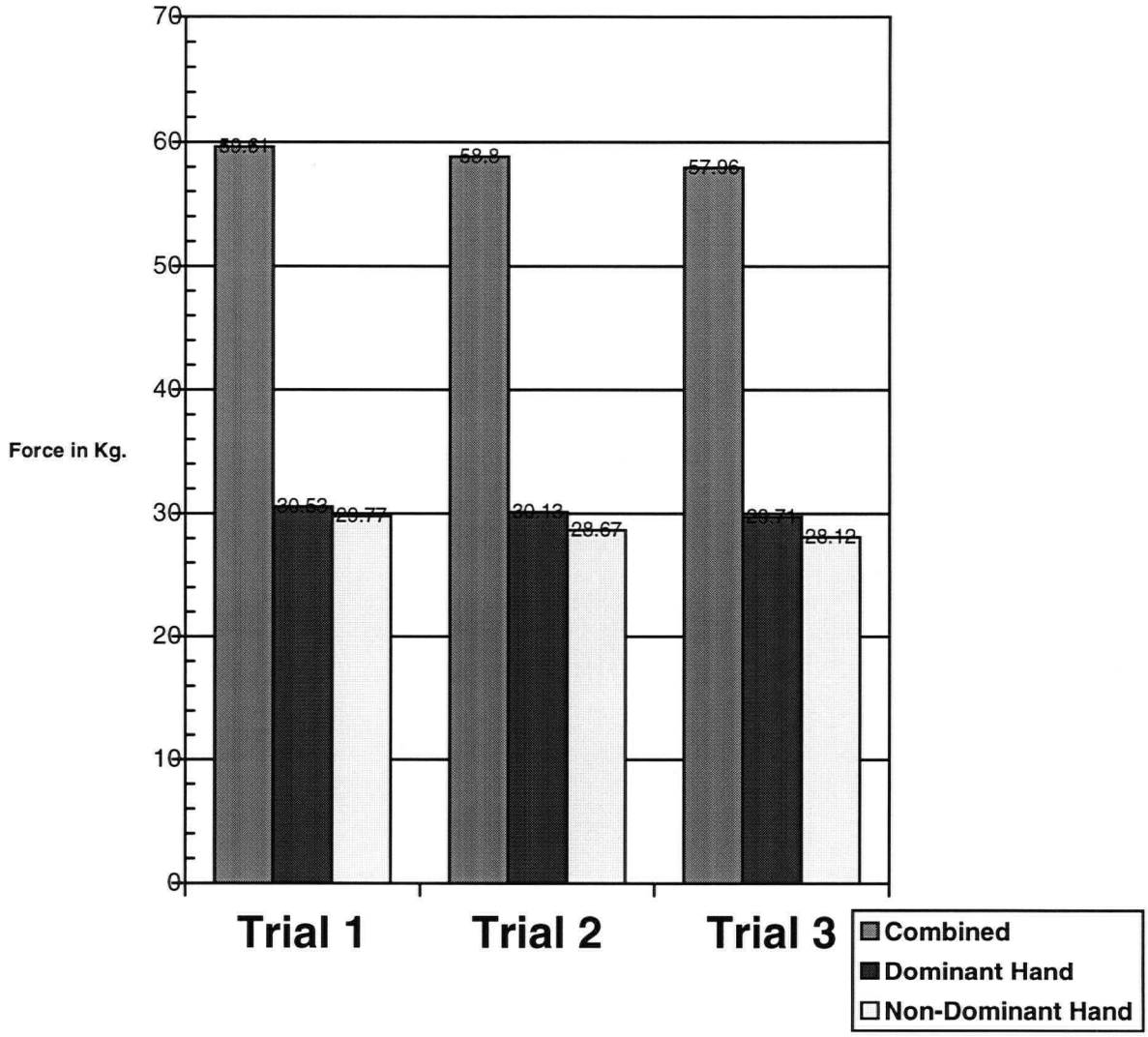

Figure 12. Serial combined, dominant and non-dominant maximal hand grip score (lbs.) means listed according to the three trials of the MVE test.

Note: A consistent degradation of grip strength scores from the first trial, to the second trial, and to the third.

The same pattern of degrading repetition mean scores, with the first trial always yielding the highest score, followed by a lower second trial score and a still lower third trial score was observed across genders and handedness. This finding raises some concern for sincere but deconditioned testees demonstrating higher variability in MVE trial scores, increasing the likelihood of false positive MVE tests. To investigate the effect further, the entire sample's data was reanalyzed using new cut-off scores comprised of this sample's CVs and SDs, and additionally where possible, with Matheson et al's (1989) CVs and this sample's SDs. The resulting analyses outcomes are presented further forward in this chapter.

Such a consistent overall pattern suggesting a fatigue effect had not been reported in previous studies (employing both disabled and non-disabled samples), and warrants greater attention in future studies of disabled subjects on the MVE test. If this effect is unique to disabled samples, clinicians may consider increasing the rest interval between repeated grip strength trials to reduce possible degrading of serial scores due to diminished physical conditioning on MVE scores. In addition, clinicians analyzing peak hand grip strengths of chronically disabled people may consider utilizing the single highest score (likely the first trial) in a particular series of trials rather than calculating the mean of a series of repeated trials.

One other grip strength comparison was made to determine the performance pattern of this sample. As mentioned earlier, the most current criterion scores for the MVE test were derived from Matheson's (1989) studies[1]. Mean grip strength scores taken during MVE testing

---

[1] Matheson, L., Carlton, R., & Ogden-Niemeyer, L., reported the performance of a male disabled sample in their 1989 article in the Industrial Rehabilitation Quarterly, titled; Grip Strength in a Disabled Sample: Reliability and Normative Standards. Separate criterion MVE CV cut-off scores were later reported for males and females in proprietary MVE test manuals without descriptions of the samples from which the scores were derived. Descriptions and performance of the male sample were inferred from the above-mentioned article. There are no

from the current study sample were compared with similar data from Matheson's (1989) sample to determine congruency of these two disabled samples. Since Matheson reported data from his male sample only, the following comparison is limited to an examination of performance of male cohorts. Table 39 presents a comparison of median (50th percentile) scores between this study sample's and Matheson's (1989) sample.

---

known descriptions of the characteristics and performance of the female sample. It is also not certain whether the female sample was disabled.

Table 39

Comparison of Median Hand Grip Scores (kgs) Among Males Across 5 Grip Settings on the MVE test.

Dominant Hand	Grip 1	Grip 2	Grip3	Grip4	Grip5
This Sample (n=32)	**62.54**	**91.49**	**89.93**	**81.55**	**70.72**
Matheson et al (1989) Sample (n=108)	61.48	93.57	95.25	86.88	76.02
Difference	**+1.06**	**-2.08**	**-5.32**	**-5.33**	**-5.30**

Non-Dominant Hand	Grip 1	Grip 2	Grip3	Grip4	Grip5
This Sample (n=32)	**62.54**	**90.39**	**85.97**	**77.35**	**65.64**
Matheson et al (1989) Sample (n=108)	53.46	84.05	83.54	79.36	69.35
Difference	**+9.08**	**+6.34**	**+2.43**	**-2.01**	**-3.71**

Note: Relatively small differences in strength performance between this study sample and Matheson's sample.

When the male cohorts were compared, the median grip strength scores across all 5 grip settings differed by an average of 4.27lbs, indicating reasonable similarity in grip strength performance between the two samples.

Bell Curve Apart from comparing grip strength performance, the study sample's overall repetitive grip-strength pattern over the 5 Jamar grip size settings (per hand) were compared with known performances of disabled and non-disabled populations. The

biomechanical pattern typically observed when mean strength scores are graphed according to the five grip size settings, as reported in previous studies of non-disabled and disabled participants (Stokes 1983; Fairfax, Balnave & Adams 1995; Niebuhr & Marrion 1987), was also clearly observed in this sample. Figures 4 through 9 in chapter five graphically demonstrate these patterns. All of the resulting biomechanical curves of mean grip strength graphed according to the five equally spaced grip size settings were positively skewed with the highest magnitude consistently occurring at the second grip setting on the Jamar dynamometer (1-7/8 in). Matheson's (1989) sample also achieved their highest peak scores at the second grip setting.

Variability of Repeated Scores Several publications in the last decade have either reported or suggested acceptable variance in repeated maximal strength trials in the form of maximum allowable CV threshold scores. Table 5 in chapter 2 summarizes the ranges of these CV cut-off scores. Among the 7 reported ranges just 3 employed the Jamar hand dynamometer. Further, among these noted studies, only one study (Matheson et al, 1989) employing a male sample, reported limited descriptive data from which a set of criterion cut-points were derived. The same author (Matheson, 1989) later reported a set of criterion cut-points for females, without describing the sample from which the scores were derived. In both cases the criterion cut-off values appeared to have been derived by the same method. The authors combined mean CV scores for each of the grip size settings with corresponding SD scores to generate 5 dominant hand and 5 non-dominant hand MVE criterion scores. The same method was applied to the performance outcomes of this study's sample. A set of criterion cut-off scores was therefore similarly generated from the performance of this study's sample to allow comparisons of MVE test performance with Matheson's and others' samples.

A general comparison of reported MVE cut-off scores between this study sample and others' is presented in Table 40.

Table 40

A Comparison of Reported Ranges of Maximum Allowable CV Cut-off Points Utilizing the Jamar Dynamometer

Study / Author	Type of Sample	Suggested Criterion CV Cut-off Scores/Ranges
This Study (1998)	Disabled (Injured automobile insurance claimants)	(males) 9.65% - 16.00% (females) 9.96% - 17.35%
Matheson L.N., Niemeyer L., & Carlton R. (1989)	Disabled (Injured workers on active WCB claims)	(males) 9.27% - 15.24%
Matheson L.N. (1989)	(Sample not described)	(females) 9.96% - 16.86%
Matheson L.N. (1990)	Unknown	(females) 8% - 12%
Matheson L. & Niemeyer L. (1987)	Unknown	(males) 10% for all grip settings (females) 12% for all grip settings
Blankenship K. (1988)	Unknown	Less than 15% for all grip settings, male and female

Examination of the resultant CV cut-off ranges show that this sample's performance, in general, varied greater than other previously reported performances. These findings, showing as much as 6% difference in allowable CV scores, would further challenge the reliability of existing CV cut-off standards. Of the listed studies and ranges of criterion CV cut-point scores, only the first two studies (including this study) explicitly report CV cut-off scores derived from the performances of disabled people.

The representativeness of Matheson et al's (1989) and Matheson's (1989) samples were not clear, weakening the validity of the criterion cutoff points derived from those studies. Nevertheless these CV cutoff scores have been accepted in the field and are considered the standard measure for assessing sincerity of effort in return to work occupational therapy practice. Despite the lack of empirical support for these standard measures these figures continue to serve as important clinical measures and therefore presented interesting points of comparison for this sample's performance.

The specific amounts by which this sample's performances differed or concurred with Matheson et al's (1989) and Matheson's (1989), measured in terms of derived maximum allowable CV cut-points (expressed by the %CV statistic) were summarized and presented in tables 21, 22, 25, and 26 in Chapter 4. The derived maximum allowable CV cut-points, segregated along hand grip position, gender and hand dominance were compared to the MVE test's cut-points and showed differences ranging between a low of -3.00%CV and a high of +5.46%CV. Both this total sample and Matheson et al's (1989) male sample were convenience samples limiting the extent of comparative analyses. These figures can only suggest that variability can occur within and between samples on the MVE test and further questions the reliability of the test's cutoff points.

An additional set of analyses to investigate the effect of varied sets of MVE cutoff scores derived from the cohort to which the testees belonged was performed. Initial comparisons between Matheson's samples' and this study samples' performances revealed similar hand grip strength data, as well as CV scores across the 10 hand grip dynamometer positions. The samples' SDs differed remarkably, however, across the 10 hand grip dynamometer settings. With these similarities and differences in mind, the raw MVE trial

scores from all 100 subjects in the sample were reanalyzed according to 2 new schema. As mentioned earlier, the MVE scoring criteria in the form of CV cut-off values, were derived from the sum of mean CVs and mean SDs of each of the 10 hand dynamometer positions of Matheson et al's (1989) male and Matheson's (1989) female samples. This study sample's data were recalculated using a new set of cut-off values combining the mean CV scores from Matheson et al's (1989) sample and the mean SD scores from this study sample. Additionally, the study sample's data were recalculated using its own mean CV and mean SD scores. Figures 13, 14, and 15 summarize the number of positive MVE test outcomes identified using each of the three sets of MVE cut-off scores. Figures 1 and 3 report only 2 conditions due to the absence of mean CV scores of Matheson's (1989) female sample.

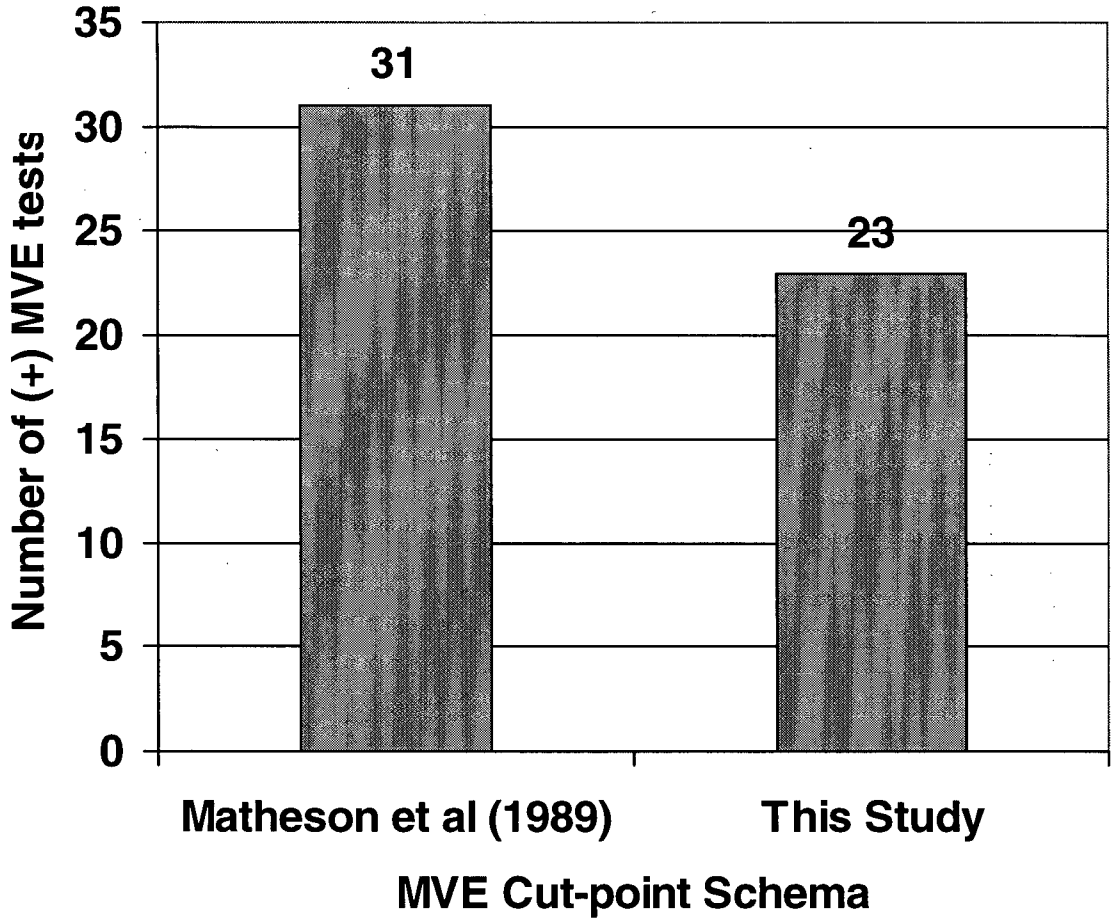

Figure 13. Number of total sample scoring (+) MVE tests according to 2 separate sets of CV cut-off values; Matheson et al (1989), and This study.

Note: The rate of positive MVE test outcomes dropped by almost 1/3 when cut-off values from this study were applied.

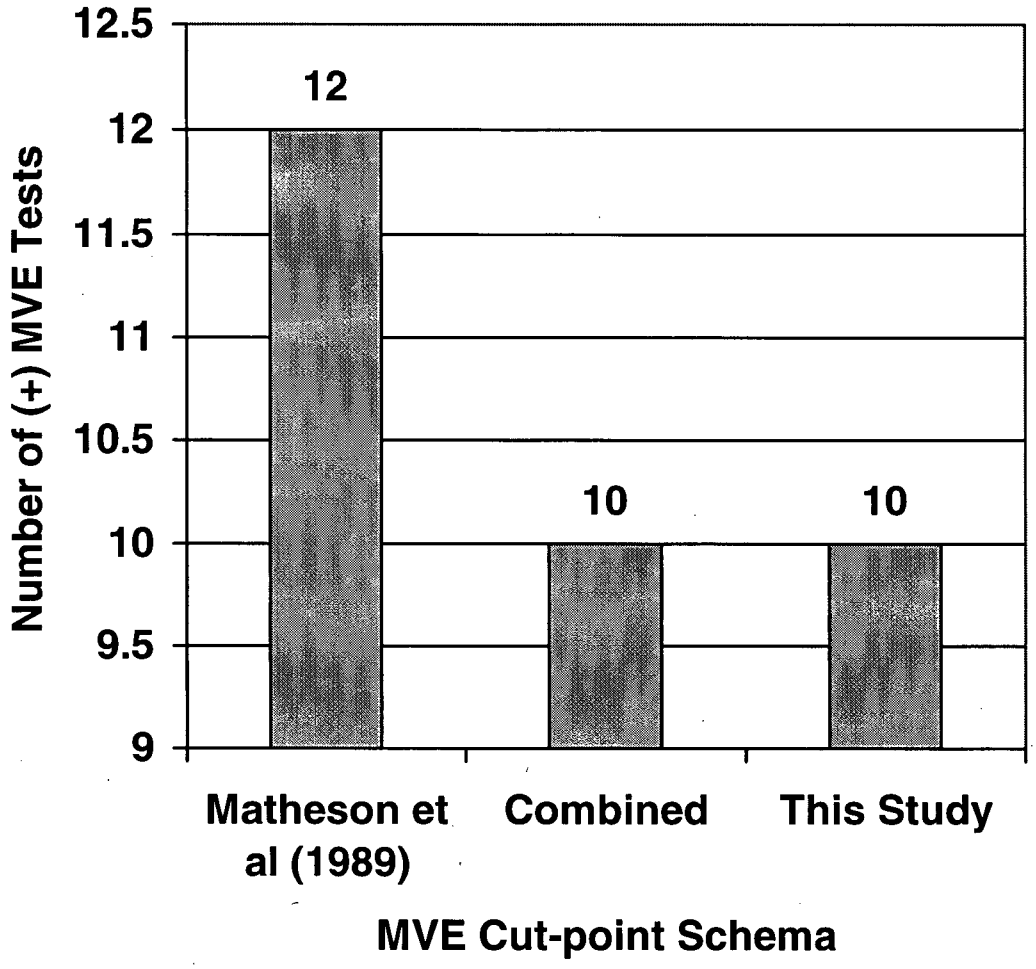

Figure 14. Number of males from study sample scoring (+) MVE tests according to 3 separate sets of CV cut-off values; Matheson et al (1989), Combined (using mean CVs from Matheson et al (1989) and mean SDs from this study), and This Study (using both mean CVs and mean SDs from this study).

Note: The effect of the SD from this study sample on the rate of positive MVE test outcomes. The rate of positive MVE test outcomes dropped by almost 1/3 when cut-off values from this study were applied.

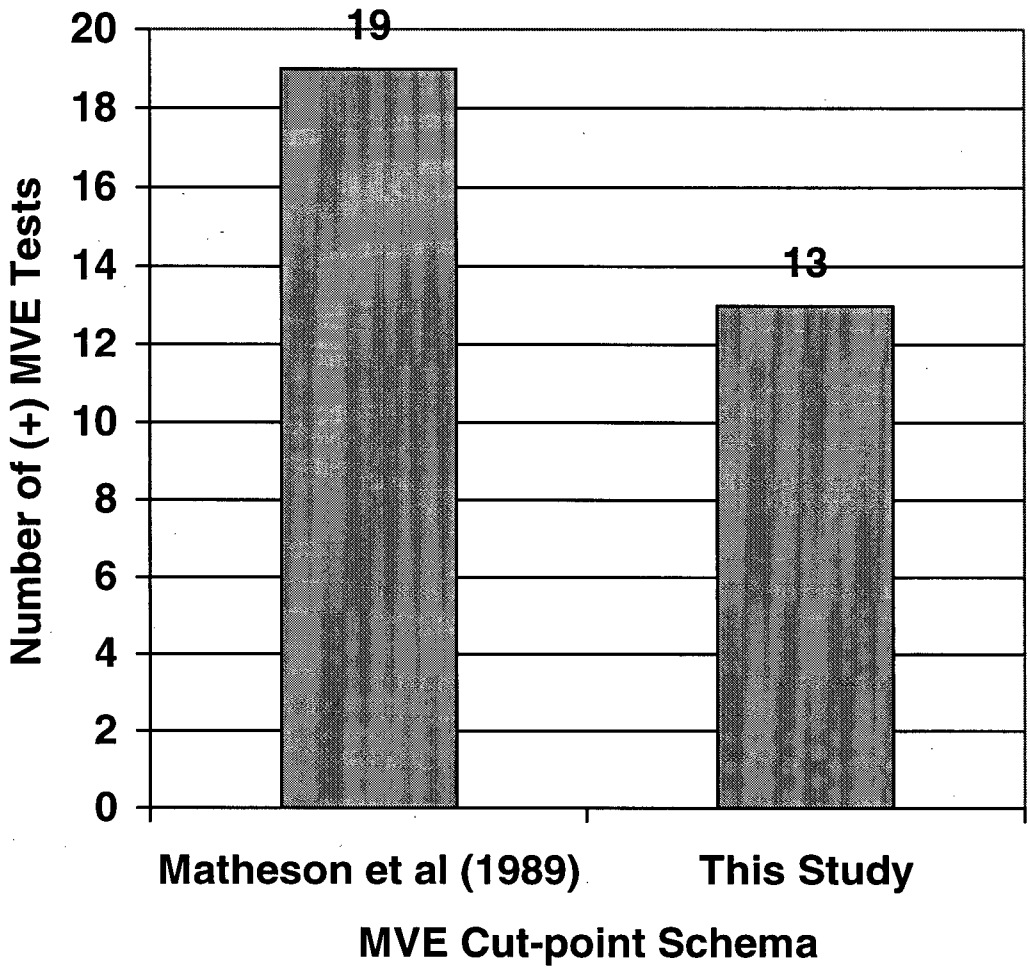

Figure 15. Number of females from study sample scoring (+) MVE tests according to separate sets of CV cut-off values; Matheson et al (1989), and This Study.

Note: Similar to the findings from the male sample data, the rate of positive MVE test outcomes dropped by almost 1/3 when cut-off values from this study were applied.

The effect of using cut-off values derived from this sample (to evaluate its members) was remarkable, resulting in 26%, 17%, and 32% fewer positive MVE outcomes for the total, male, and female sample groups, respectively. The resultant yield of positive MVE outcomes using both sets of new CV cutoff values for this study's male sample was the same at 17% fewer than when using the standard MVE cut-off scores.

When possible instrument measurement error is also considered, the overall effect on the selectivity and sensitivity of the MVE test's cut-off points become apparent. How do we know if the cut-off points are situated in the most 'fair' positions? At present, it cannot be known for certain. The paucity of research on the MVE test, particularly concerning the validity and reliability of the cut-off points, further underscores the need to exercise caution when interpreting the outcomes of the test. At present, MVE test outcomes should not be solely relied upon to determine the sincerity of an individual's effort.

The data analyses of this chronically disabled study sample revealed similarities and performance patterns expected of normal distributions. The relation between age and strength was curvilinear. Generally, male and dominant hand grip strength scores was slightly greater than female and non-dominant hands, respectively. Peak hand grip strength for both male and female cohorts were similar to Matheson et al's (1989) and Matheson's (1989) cohorts, demonstrating substantial diminution comparing with older, weaker cohorts in Mathiowetz, et al's (1986) normative scales of normal adults. When grip strength performance was observed over the 5 grip size settings on the Jamar dynamometer, the previously reported biomechanical curve effect pattern was consistently demonstrated across genders and age groups.

Dissimilarities in performance were also remarkable. A greater degree of variability within serial maximal hand grip trials in the MVE test was observed. The between trial variance was greater in this study's samples when compared to Matheson et al's and Matheson's (1989) samples, from which current MVE cut-off scores had been derived. Another remarkable finding was the pattern of degrading grip strength scores between repeated trials on the MVE test, suggestive of a general fatigue or deconditioning effect, which could account for a certain degree of the increased between-trial variance.

Purpose 2; Relationship of Factors of a Disabled Population to MVE Test Outcomes

A fundamental characteristic of a fair test is that it demonstrates construct validity. The MVE test is meant to measure what it's title implies; maximum voluntary effort. Any evidence to demonstrate that the test measures attributes of the subject that are not logically related to or have reasonable effect on that concept could pose a threat to the test's validity.

Prior to examining the performance of this sample on the MVE test, several expectations existed regarding how the demographic and diagnostic variables would correlate with MVE test outcome measures. If the MVE test was to effectively separate 'sincere' testers (or those individuals capable of demonstrating maximal effort) from 'insincere' testers (or those individuals incapable of demonstrating maximal effort), we could expect to observe certain MVE outcome patterns with respect to the independent variables of this study. Significant relationships between common demographic characteristics such as; age gender, educational level, handedness and occupation, and positive MVE test outcomes would not be expected. These are, after all, attributes that are expected to possess no direct bearing on consistency of effort and therefore should not each contribute a significant portion of the variance in a MVE test outcome.

On the other hand, significant relationships between another type of subject resident characteristics-the 'diagnostic' variables chosen in this study; diagnosis, subjective depressive symptoms, referral source, number of injury episodes, and chronicity of disability, might be expected to contribute more to the variance in an MVE test outcome. These are attributes seen to have viable relationships to factors that could account for less than maximal performance on the MVE test. In the following section, a discussion of the expected and observed

relationship patterns between the independent variables and MVE outcomes is discussed by variable.

Demographic Influences

A review of the literature revealed a paucity of studies suggesting relationships between the common variables selected for this study and the variability of repeated maximal strength trials. As expected, the results from this study sample generally failed to demonstrate any significant relationships between each the five demographic factors and the pattern of positive MVE test outcomes. All but one of the Chi-square tests comparing the demographic variables to the rates of positive MVE test outcomes failed to achieve statistical significance ($p \leq .05$).

The one exception was 'occupation' (Chi-square=13.56, df=5, p=.019). Caution in interpreting this statistic needs to be exercised given that two (Service, Not in the Workforce) of the six categories were relatively sparsely populated. Within the categories for occupation, relatively large percentages of subjects in the 'Chronically Unemployed' (58%) and 'Not in the Workforce' (43%) categories scored positively in the MVE test.

The expected and observed performance of this disabled population on the MVE test, with respect to certain demographic factors, appears to lend support towards the MVE test's validity. The MVE test performed as expected with respect to this sample's demographic attributes.

Diagnostic Influences

Contrary to the pattern of relationships to MVE test outcomes observed among the demographic variables, only one of the diagnostic variables failed to demonstrate statistical significance ($p \leq .05$). This was 'diagnosis'. Expected and observed outcomes of relationship

between the diagnostic independent variables that showed significance and MVE test outcomes is discussed by variable.

Referral Source A significant relationship found between referral source and MVE test outcome measures warrant further consideration. Subjects referred for functional evaluation at this facility by lawyers or claims adjudicators representing the disability insurance carrier had a significantly higher rate of positive MVE tests (Chi-square=23.306, df=1, p<.000). One explanation for this observation may lie in the decision-making influences that lead to referrals for functional capacity evaluations (FCE). Often, especially 'difficult' or persistent insurance claims cases are referred for FCEs as a final, rather than initial step in the subject's course of rehabilitation. The relatively long duration transpiring between injury episode and testing date (mean=32months) attests to this observation. The majority of this sample consisted of relatively minor diagnoses of soft tissue injury (84% of total sample, and 90% of positive MVEs) but with relatively lengthy terms of disability (mean =33.22 months, SD=15.83). These were claims cases which, for a variety of reasons, could not be settled early.

The likely explanation for the persistence of these 'troublesome' claims is that these subjects were malingering and purposely elongating their claims in a quest to receive greater assistance and compensation. The functional capacity evaluation (FCE), of which the MVE test is a part, at this late stage of the claimant's rehabilitation, appears to provide more of a decisive measure for claims adjudication and case closure for the insurance company rather than for setting further rehabilitation plans for the claimant. Therefore, the insurance company claims adjudicators or lawyers could have been especially selective in their referrals for FCE and MVE testing by sending clients they considered troublesome and likely to be 'caught' malingering, to this facility.

For this explanation to be viable, a concurrent explanation for the performance of the other subjects, referred by self or parties representing the plaintiff, on the MVE test would be required. One explanation would be that the motive behind plaintiff and self-referrals for FCEs is to exonerate the subject from being labeled as a 'malingerer' and to validate him or her to be a sincere testee, genuinely suffering from a legitimate disabling condition. The pattern of results for this analysis would support these general explanations.

A possible rebuttal to this explanation would be that some plaintiffs, in seeking a verdict warranting greater compensatory award, could deliberately perform tests of physical performance sub-maximally to further legitimize their injury and disability claims. A malingerer would be expected to deliberately perform weakly, leading to greater variability in repeated strength trial scores. The low rate of positive MVE tests among the plaintiff-referred subjects (2%) failed to support this latter explanation.

Another explanation for the pattern of positive MVE test outcomes according to referral source could have been bias among the raters. A tendency to report positive MVE tests was not observed among each of the three raters related to this study. However, an effect of agency bias in this study toward positive MVE tests, for cases referred to the agency by parties representing the interests of insurance companies, was evident.

Given the litigious context in which the MVE test is performed, the likelihood that 94% of all referrals from one specific group resulted in positive MVE tests being a random effect is remote and problematic. Had the study been performed across numerous agencies, the effect of rater bias could have been made clearer. Further studies are required to clarify this pattern and should incorporate a prospective design that can control for such potential bias.

Episodes The number of previous injury episodes resulting in time off work was observed to have the strongest relationship, among independent variables, to positive MVE test outcomes. As the number of episodes increased, the rate of positive MVE test outcomes was observed to increase. Assuming that the MVE test is effective in separating 'sincere' and 'non-sincere' efforts, certain interpretations can be offered. The most immediate interpretation is that those subjects with more experience with compensated injury become better 'game-players'- testees who have learned that sub-normal performance in rehabilitation examinations translates into stronger disability claims. Profiles of subjects with 2 or less injury episodes and three or more compensated injury episodes is presented in table 34 in chapter 4 for comparison.

Subjects with 3 or more injury episodes tended to be older (mean age=47.6 years), represented approximately equally by male and female subjects, and with lower than high-school educational achievement (50%), than subjects with two or less injury episodes. Half of the subjects in the current study were chronically unemployed at the time of their most recent injury episode with mainly (95%) soft-tissue injuries. Although they had a similar mean term of chronicity (approximately 33 months) with subjects with 2 or less episodes, the majority (80%) was referred for MVE testing by insurance company representatives. These subjects tended to report symptoms of moderate depression, and had twice the rate of positive MVE test outcomes of subjects reporting symptoms of mild to minimal depression.

The strength of the positive relationship between 'episodes' and greater variability in MVE test performance was evident and concurs with the general pattern seen in another recent study. Kaplan, Wurtele, & Gillis (1996), in their study of psychological factors and maximal effort reported a similar relationship with respect to number of surgeries (resulting in

time off from work). Subjects in the maximal effort group had a mean number of surgeries of 1.24, while subjects in the sub-maximal effort group had a mean number of surgeries of 2.15. If 'surgeries' were assumed to be an indicator of an 'episode' resulting in time off from work, the likelihood of a relationship existing between 'episodes' and sub-maximal effort would be strengthened.

Since it is still unknown how or if injury episodes resulting in work loss relate to maximal effort, further research using a more rigorous design to clarify the nature of the effect is warranted.

Chronicity Chronicity of disability indicated by the duration of work loss was chosen for its possible association with maximal and submaximal effort. Various studies in the past decade have drawn associations between chronic disability, especially due to soft-tissue injuries, and increased costs for rehabilitation and compensation. One such study of note conducted in the province of Quebec, Canada, involved people with soft tissue spinal injuries on Workers Compensation claims. Spitzer, et al (1987) reported that 92.6 percent of all soft-tissue injuries resolve within 6 months of injury. The remaining 7.4% of the chronic cases reportedly account for 75.6% of WCB claims costs due to soft tissue injuries (14% medical care, 86% salary replacement).

Since soft-tissue injuries are generally regarded to be of minor medical concern, such a pattern of return to work rate could suggest that the economically taxing 7.4% who take longer than 6 months to recover are prolonging their term of disability gainfully. A greater rate of feigned weak or sub-maximal grip strength trials could be expected with this sample, given the remarkably chronic terms of disability (mean=33.22 months). This expectation was not supported by the rate of positive MVE test outcomes of this sample.

Depression Depression is common among chronically disabled people (Love, 1987). This variable presented unforeseen problems mainly due to missing BDI scores among 16% of the sample. Since all of the cases lacking BDI scores resulted in positive MVE tests, the statistical analysis of the relationship between this independent variable and the dependent variable was weakened.

Statistical analyses to acquire insight into relationships between depression and other independent variables, was also consequently weakened. For example, a thorough analysis of relationships between depression and the independent variable- 'chronicity', and MVE test outcomes could have rendered information of heuristic value about depression and its possible influence on MVE performance as a feature of lengthy periods of disability. We are consequently left wondering how much of the variance in MVE test outcomes related to chronicity could have been attributed to depression. Obvious limitations of data analyses interpretation were presented by the missing Depression data. These fundamental limitations require a careful review of the relationship between self reported symptoms of Depression, measured by the BDI, and the MVE test outcomes.

Of the subjects who completed the BDI, the Chi-square analysis showed no significant relationship between the severity of depressive symptoms and MVE test outcomes. This finding ran counter to explanations drawn from previous studies reporting the relationship between depression and physical performance. The presence of depressive symptoms, such as psychomotor retardation (Turk & Holzman, 1983), decreased motivation (Haley, Turner & Romano, 1987), and lower fatigue tolerance (Turk, Rudy & Steig, 1987), is regarded as a possible threat to the reliability of repeated maximal voluntary strength trials (Kaplan, Wurtele & Gillis, 1996). If symptoms of depression were to be considered threats to the

reliability of the MVE test, then perhaps a proportional (linear) relationship between increasing BDI scores and positive MVE tests might be expected. Revised Beck Depression Inventory scores that identified subjects as being at least 'moderately depressed' (BDI score of 17 or higher) were not significantly associated with positive MVE scores. Before any conclusions regarding the relationship of depression to MVE performance can be accepted, the problem of the missing BDI data from 16 cases warrants further review and discussion. Table 40 presents a comparison of descriptive profiles between those cases with intact and missing BDI scores.

Table 40

Profiles of Subjects with Reported and Missing BDI Data

Variables Mean (SD)	Subjects with Reported BDI Data (n=84)	Subjects with Missing BDI Data (n=16)
Age mean (SD)	39.20 (11.29)	43.38 (12.98)
Education n (%)		
• < High School	36 (42.86)	3 (18.75)
• High School	32 (38.10)	8 (50)
• Post Secondary	16 (19.05)	5 (31.25)
Sex n (%)		
• Male	28 (33.33)	4 (25)
• Female	56 (66.67)	12 (75)
Dominance n (%)		
• Right Hand	72 (85.71)	14 (87.50)
• Left Hand	12 (14.29)	2 (12.50)
Occupation n (%)		
• Professional, Clerical	10 (11.91)	1 (6.25)
• Service	7 (8.33)	1 (6.25)
• Skilled, Semi-Skilled	12 (14.29)	1 (6.25)
• Unskilled	31 (36.91)	4 (25.00)
• Chronically Unemployed	18 (21.43)	8 (50.00)
• Not in the Workforce	6 (7.14)	1 (6.25)
Diagnosis n (%)		
• Soft tissue / Neurological	71 (84.52)	13 (81.25)
• Bone fracture / Dislocation	13 (15.48)	3 (18.75)
Referral Source n (%)		
• Defense Lgl./ Insurance	43 (51.19)	15 (93.75)
• Plaintiff Lgl./ Self	41 (48.81)	1 (6.25)
Episodes Injury mean (SD)	1.68 (0.99)	2.19 (0.83)
Chronicity mean (SD)		
• Months	34.30 (16.28)	27.50 (12.11)
BDI mean (SD) (n=84, range 6-50) [17+=Moderate Depression]	16.92 (9.32)	N/A
MVE Cut-points Exceeded mean (SD)	1.19 (1.50)	5.50 (1.55)

Note: Subjects with missing BDIs tended to be more; female, chronically unemployed with soft-tissue injuries, and had more injury episodes and were referred by insurance company/ defense legal counsel.

Subjects with missing BDI scores tended to be older and have greater experience with injury leading to time off from work and to be referred by insurance companies. The most remarkable differences between those with and without BDIs were a greatly differing rate of MVE cutpoints exceeded (more than 4 times higher) and a surprising lower mean duration of disability at time of testing among those missing BDI scores. This comparison between means demonstrated that these 16 cases with missing BDI scores differed enough from the other subjects to suggest that their exclusion being due to a random occurrence was less likely.

Why were 16 cases, all of who happened to have positive MVE test outcomes, and most of who had been referred by insurance company interests, excluded from taking the BDI? The agency, from where the data was received, reported that none of the 16 subjects in question had abstained from taking the test. Rather, the agency had reportedly excluded the BDI from its FCE test battery for a brief period of time while considering their policy of including a screening tool for depression. This explanation runs counter to the notion that the raters in 'excusing' subjects with obvious symptoms of depression from taking the BDI could have exercised extraordinary bias. At this point the role of Depression remains unclear and problematic; the possible influences of the missing BDI scores remain for further research.

In regard to the relationship of factors of a disabled population and outcomes of the MVE test, this sample performed as expected, yielding no significant associations between selected demographic features of this sample and the rate of positive MVE test outcomes. On the other hand, associations among certain diagnostic variables; referral (source) and (number of injury) episodes, with positive MVE outcomes were found to be significant. A pattern showing subjects referred by parties representing insurance companies had a 50% chance of

scoring a positive MVE test was evident. Additionally, subjects with more than one previous injury episode had a greater tendency (36%) to have positive MVE test outcomes.

Clinical Relevance and Implications for Future Research

To fully understand the clinical implications of the study outcomes, a broader look at the context in which the MVE test is administered is required. Stone (1984), in her discussion of the disability state, wrote that "all societies have at least two distribution systems, one based on work and the other based on need, whose coexistence is a thorny problem in social policy and social theory (p15)". Society decides what constitutes 'need' and who is excused from work and who is therefore entitled to receive compensation. Stone (1984) refers to the requirement of a 'validating device' (p21) for the process delineating which of the two systems is operative in each case of disability. A 'validating device' is the mechanism by which society obtains knowledge about an individual for the purpose of deciding whether to give social aid (p21). The device is counted upon to yield two types of information; the needs of the individual (whose needs are not being met by the work distribution system) and whether the individual has a valid reason for being in need. Naturally, for the validations to be 'fair' the devices need to be based upon 'objective' rather than 'subjective' information (p23).

Functional Capacity Evaluations (FCE) and the Maximum Voluntary Effort test (MVE) have become two current 'validating devices' used to objectively determine the needs of the individual and whether he or she has a valid excuse for being in need. Occupational therapists, among other rehabilitation professionals, have become increasingly involved in being primary administrators of these tests and thus have become unwitting partners with the medical community and the insurance industry in the disability validation process.

People with either 'genuine' or 'artificial' disabilities (p. 28) often discover that they must navigate their way through a morass of social and medical procedures to determine whether they qualify to be exempt from the 'work based' system of distribution and gain entry to the 'need based' system. Invariably, each must 'prove' their right to access the need-based system.

There appears to be substantial support (based on use) in the field for the MVE test to differentiate between those who are genuinely disabled and thereby have the right to insurance benefits and disability benefits and those who are merely faking poor function and thereby should be denied those benefits. In this litigious context and for the 'validating' role given to the MVE test, it would be better if the MVE test was indeed a valid and fair test. From a clinical perspective, OTs and other rehabilitation professionals participating in the process of validating the client's disability status (through the use of such tests as the FCE and MVE) should be aware of their role in this process and exercise care in selecting their instruments. Since the outcomes of these tests can profoundly effect the fate and future circumstances of the client, OTs need to be informed about the empirical integrity of their instruments and the moral and ethical implications of their evaluations.

At present, OTs should approach this test with greater care. Clinicians should consider the issues illuminated by this research, namely the distinct differences in performance between disabled populations and non-disabled populations, evaluee-resident characteristics that may have a bearing on MVE performance outcomes, variability of MVE outcome scores and utility of current criterion cut-off points, and problems concerning the concept of maximum voluntary effort. These outstanding issues underscore the need for further research on the MVE test.

Occupational therapists involved in administering FCEs and the MVE test could benefit from understanding some of the common factors and characteristics of a chronically disabled population that could affect performance in these tests. Testees who have been chronically disabled for more than 6 months should be evaluated for their general fitness level. Their hand grip scores in particular should be screened against available norms to determine whether the subjects are fit to be evaluated with the same standards used for normal, healthy adults. Lower fatigue tolerance and substantial deconditioning could have a bearing on serial or repetitive maximal strength trials and therefore threaten the reliability of the MVE test and the greater FCE of which it is part.

The subjects in this research sample generally demonstrated significantly diminuted grip strength when evaluated against healthy adult grip strength norms. Performance variation among the typically chronically disabled population undergoing this test compared with non-disabled populations would also bring into question the appropriateness of using general performance standards derived from large groups to evaluate individual performance.

Clinicians also need to be vigilant about which set of criterion cut-off scores they select to use with the MVE test. This study discovered that several sets of available CV cut-off scores are incongruent, differing by as much as 60%. In addition, most of those reported cut-off measures have failed to describe the original sample's characteristics and performances. Studies examining the validity and reliability, as well as the sensitivity and selectivity of these various standards remain scarce. Not knowing exactly at which levels the CV cut-off scores should be fixed, to conclusively identify 'malingerers and symptom magnifiers' is indeed problematic and clinicians should exercise the utmost care in the interpretations of this test. At the very best, until more studies using more rigorous research

designs and methods are conducted on this topic, clinicians should not rely on this test solely to evaluate maximum voluntary effort during the FCE, but corroborate their analyses with other test performances in the battery.

Heeding these cautions, clinicians should also be vigilant about certain diagnostic attributes of the evaluee. Chronic unemployment at time of injury, referral source, and chronicity of disability, among the 10 chosen research factors were each found to account for a significant degree of the variance in positive MVE scores. Perhaps a judgement on these and other diagnostic variables and their relationship to sincerity of effort should be deferred to other professionals such as clinical psychologists, who can take a more comprehensive approach to evaluating behavioural issues.

Finally, the litigious context in which this test is usually applied should not be overlooked nor underestimated in future studies. Maximum voluntary effort test measurements often occur in a context in which individuals are required to undergo the test as one of a series of procedures that will define or 'validate' the subject's level of need. The social and financial consequences serve as strong motivating factors that could conceivably affect such tests of voluntary effort. Coercion, both from an environmental context, from the test administrators, and referring parties may also have a determining effect on performance.

To clarify the construct validity of the MVE test, future studies may attempt to delineate whether differences in MVE performance are associated with natural aspects of disability (for example, deconditioning, depression, and anxiety), or due to some deliberate attempt to perform insincerely. It would be particularly informative to perform a similar study on a group of 'validated' disabled people who are not involved in litigation or insurance

claims. Asking potential subjects with disabilities to participate rather than be required as a process of litigation or claims adjudication, to submit to testing might also be considered.

Conclusion

The performance characteristics of this sample on the MVE test revealed certain patterns that suggest disabled people perform differently from non-disabled people. While those in the study sample in the 30 to 36 age category scored highest in regard to peak grip-strength, overall strength performance of this age group was similar to the 50 to 64 year-old cohorts in Mathiowetz, et al's (1985) norms. Such a general diminution in hand grip strength performance, which was also reported by Matheson et al (1989), underscores the notion that differences in physical performance may exist between disabled and non-disabled people that may in turn have a bearing on MVE test performance. The observed general pattern of gradually degrading grip strength scores across the three repetitions in each of the ten conditions (5 dominant and 5 non-dominant) suggests a possible fatigue effect among disabled populations which, may in turn effect MVE test performance (by effecting increases in variability in repeated maximum voluntary effort trials).

These observations leave us to ponder if and to what extent the apparent hand grip strength performance differences between disabled and non-disabled people translate into differences in MVE test performance. These observed differences in performance further challenge the appropriateness of using decisive criterion cut-off scores derived from groups to evaluate individual performances. If criteria derived from groups are to be used, then it remains to be determined just how much variability is tolerable. More rigorous studies are required before such measures can be applied fairly and confidently.

The overall variability in repeated maximal hand-grip trials demonstrated by this sample exceeded all of the previously established norms. Of particular note, despite similarity in general hand-grip strength performance between this study's and Matheson's sample, the former demonstrated greater variability in MVE test scores than the latter. The discrepancies in MVE score variability further questions, rather than supports, the appropriateness of the current MVE test criterion cut-off values. Based on the current evidence, the MVE test's maximum allowable cut-off points remain problematic and could be discriminating against the disabled population.

The preliminary analyses of relationships between common independent factors and MVE test outcomes yielded a pattern expected of a test purporting to measure the concept of sincerity of effort in individuals. Demographic factors studied in this research (age, gender, occupation, education and handedness) were found not to have significant relationships with the pattern of MVE test outcomes. Certain diagnostic factors (referral source, number of injury episodes) were found to have significant relationships with the pattern of MVE test outcomes. Clients referred by the adjudicator or legal counsel representing the insurance company had a greater chance of scoring a positive MVE test. As the number of injury episodes leading to time off work increased, the rate of positive MVE tests increased. No significant relationships were observed with regard to diagnosis, duration and depressive symptoms.

The outcomes of this study (as well as similar studies that employed a disabled sample) need to be evaluated with caution due to several factors related to the limits of the research design and recruitment of cases. Clinical experience would suggest that the sample was representative of the typical population undergoing this test in this region. However,

convenience sampling limited the generalization and interpretation of the outcomes. Without a more robust, randomly recruited sample, generalizability of the outcomes is limited. At best, relationships between factors can be suggested but ultimately need to be explored further with a more rigorous research design.

Weaknesses in the sampling method and control over the variables were more than apparent in the problem of missing BDI data that affected 16% of the sample. Since all of the subjects missing BDI scores scored positive MVE tests, the strength of the significance tests of relationship between independent and dependent variables required careful interpretation. Greater caution was also reserved for the interpretation of depressive symptoms and duration of disability, as these variables were seen to have had a greater link with the attributes measured by the BDI.

Despite its wide use in return to work rehabilitation as a standard measure of sincerity of effort and malingering, the MVE test needs further empirical study to establish its validity. In particular, the use of CV cut-off scores needs to be further clarified. Without such clarification, it is not known what an acceptable limit on variability of repeated maximal trials, amongst a disabled population should be. Since none of the studies to date have been tied to other validated criterion measures of sincerity of effort or malingering, the MVE test's utility as a screening measure for these attributes remains questionable and should not yet be relied upon to separate 'fakers' from sincere testees. Until further rigorous research is performed on the MVE test, clinicians with the intention to use this test should be aware of the test's present shortcomings and should continue to use every caution to corroborate MVE test outcomes with other more reliable and valid measures.

References

Abenhaim, L.L., & Suissa, S. (1987) Importance and economic burden of occupational back pain: A study of 2500 cases representative of Quebec. Journal of Occupational Medicine, 29, 670-674.

Agnew, P.J., & Maas, F. (1982). Hand function related to age and sex, Archives of Physical Medicine and Rehabilitation, 63, 269-271.

Beck, A.T., Rush, A.J., Shaw, B.F., & Emery, G. (1979). Cognitive therapy of depression. New York, NY: Guilford Press.

Beck, A.T., & Steer, R.A. (1993). Beck Depression Inventory manual. San Antonio, TX: The Psychological Corporation, Harcourt Brace and Company.

Beck, A.T., Steer, R.A., & Garbin, (1988). Psychometric properties of the Beck depression inventory: twenty-five years of evaluation. Clinical Psychology Review, 8, 77-100

Bechtol, C.O. (1954). Grip test: the use of a dynamometer with adjustable hand spacings. Journal of Bone and Joint Surgery, 36A, 820-832.

Birmingham T.B., Chesworth B.M., Kramer J.F., MacDermid J., & Speechley M. (1997). Test-retest reliability of the coefficient of variation as a measure of sincerity of effort during isometric testing. Physiotherapy Canada, (Summer), 184-190.

Blankenship, K.L. (1989). Industrial rehabilitation. Macon, CA: American Therapeutics, Inc.

Bohannon, R.W. (1987). Differentiation of maximal from submaximal static elbow flexor efforts by measurement variability. American Journal of Physical Medicine and Rehabilitation, 66, 213-218.

Bohannon, R.W. & Smith, M.B. (1988). Differentiation of maximal and submaximal knee extension efforts by isokinetic testing. Clinical Biomechanics, 3, 215-218.

Burke, W.E., Tuttle, W.W., Thompson, C.W., Janney, C.D., & Weber, R.J. (1953). The relation of grip strength and grip-strength endurance to age. Journal of Applied Physiology, 5, 628-630.

Carlsoo, S. (1986). With what degree of precision can voluntary static muscle force be repeated. Scandinavian Journal of Rehabilitation Medicine, 18, 1-3.

Chaffin, D., Herrin, G, & Keyserling, W. (1979). Pre-employment strength testing,: An updated position. Journal of Occupational Medicine, 20, 403-408.

Chaffin, D., Herrin, G, & Keyserling, W. (1978). Pre-employment strength testing. Journal of Occupational Medicine, 20, 403-409.

Chaffin, D.B., Herrin, G.D., Keyserling, W.M. & Garg, A. (1977). A method for evaluating biomechanical stresses resulting from manual materials handling jobs, American Industrial Hygiene Association Journal, 38, 662-675.

Chengalur, S.N., Smith G.A., Nelson R.C., Sadoff S.J. & Sadoff, A.M. (1990). Assessing sincerity of effort in maximal grip strength tests. American Journal of Physical Medicine and Rehabilitation, 69, 148-153.

Crockett, D.J., Hurwitz, A.H., Hart, S.D., MacDonald, J. & Welch, S. (1996). Prevalence of WAIS-R prototypal groups in neuropsychiatric participants. Archives of Clinical Neuropsychology, 11(8), 637-650.

Fairfax, A.H., Balnave, R. & Adams, R.D. (1995). Variability of grip strength during isometric contraction. Ergonomics, 38(9), 1819-1830.

Fess, E.E. (1987). A method for checking Jamar dynamometer calibration. Journal of Hand Therapy, 1, 28-32.

Fess, E.E. & Moran, C.A. (1981). Clinical assessment recommendations. Garner, NC: American Society of Hand Therapists.

Fraser, C. & Benton, J. (1983). A study of adult hand strength. British Journal of Occupational Therapy, 46(10), 269-271.

Fullwood, D. (1986). Australian norms for hand and finger strength of boys and girls aged 5-12 years. Australian Occupational Journal, 33(1), 26-36.

Garg, A., Mital, A. & Asfour, S.S. (1980). A comparison of isometric strength & dynamic lifting capability, Ergonomics, 23, 13-27.

Gilbert, J.C. & Knowlton, R.G. (1983). Simple method to determine sincerity of effort during a maximal isometric test of grip strength. American Journal of Physical Medicine, 62, 135-144.

Gibertson, L., Barber-Lomax, S. (1994). Power and pinch grip recorded using the hand-held Jamar dynamometer and B+L hydraulic pinch gauge: British normative data for adults. British Journal of Occupational Therapy, 57(12), 483-488.

Haley, W.E., Turner, J.A. & Romano, J.M. (1985). Depression in chronic pain patients: Relation to pain, activity, and sex differences. Pain, 23, 337-343.

Hamilton, A.M., Balnave, R., & Adams, R.D. (1994). Grip strength reliability, Journal of Hand Therapy, 7, 163-170.

Hazard, R.G., Matheson, L.N., Lehmann, T.R. & Frymoyer, J.W. (1991). Rehabilitation of the patient with chronic low back pain. In M.H. Pope, G.B.J. Andersson, J.W. Frymoyer & D.B. Chaffin (Eds.), Occupational Low Back Pain (pp. 194-208). St.Louis, MO: Mosby.

Hendler, N. (1984). Depression caused by chronic pain. Journal of Clinical Psychiatry, 45, 30-36.

Hinson, M, Gench, B.E. (1989). The curvilinear relationship of grip strength to age. The Occupational Therapy Journal of Research, 9(1), 53-60.

Hinson, M., Woodard, J., & Gench, B. (1990). Reliability of the Jamar digital dynamometer model 2A. The Occupational Therapy Journal of Research, 10, 108-110.

Hoenig, H. & Rubenstein, L. (1991). Hospital-associated deconditioning and dysfunction. JAGS. 39, 220-222.

Jacobs, K. (1991). Occupational therapy: work-related programs and assessments, Boston, MA: Little Brown and Company.

Kaplan, G.M., Wurtele, S.K. & Gillis, D. (1996). Maximal effort during functional capacity evaluations: An examination of psychological factors, Archives of Physical Medicine and Rehabilitation, 77, 161-164.

Keefe, F.J., Wilkins, R.H., Cook, W.A., Crisson,, J.E. & Muhlbaier, L.H. (1986). Depression, pain and behavior, Journal of Consulting and Clinical Psychology, 54(5), 665-669.

Kellor, M., Frost, J., Silberberg, N., Iversen, I. & Cummings, R. (1971). Hand strength and dexterity. American Journal of Occupational Therapy, 25, 77-83.

Keyserling, W., Herrin, G. & Chaffin, D. (1980). Isometric testing as a means of controling medical incidents on strenuous jobs. Journal of Occupational Medicine, 22(5), 332-336.

Kroemer, K.H. & Marras, W.S. (1980). Towards an objective assessment of the 'Maximal Voluntary Contraction' component in routine muscle strength measurements. European Journal of Applied Physiology, 45, 1-9.

Kroemer, K.H., & Marras, W.S. (1981). Evaluation of maximal and submaximal static muscle exertions, Human Factors, 23, 643-653.

Krombholz, H. (1985). On the association of effort and force of handgrip. Perceptual and Motor Skills, 60, 161-162.

Langley, G. & Sheppeard, H. (1985). The visual analogue scale: its use in pain measurement. Rheumatology International, 5, 145-148.

Love, A.W. (1987). Depression in chronic low back pain patients: Diagnostic efficiency of three self-report questionnaires. Journal of Clinical Psychology, 43(1), 84-89

Matheson, L.N. (1984). Work capacity evaluation: Interdisciplinary approach to industrial rehabilitation, Anaheim, CA: Employment and Rehabilitation Institute of California.

Matheson, L.N., (1994). Basic requirements for utility in the assessment of physical disability. APS Journal, 3(3). 193-199.

Matheson, L.N. (1986). Work capacity evaluation: Systematic approach to industrial rehabilitation, Anaheim, CA: Employment and Rehabilitation Institute of California.

Matheson, L.N. (1988). How do you know that he tried his best? The reliability crisis in industrial rehabilitation, Industrial Rehabilitation Quarterly, 1, 10-12.

Matheson, L.N., Carlton, R. & Niemeyer, L.O. (1989). Grip strength in a disabled sample: reliability and normative standards. Industrial Rehabilitation Quarterly, 3, 4-9.

Matheson, L.N. & Niemeyer, L.O. (1990). Industrial rehabilitation resource book: work capacity evaluation training manual (Performance Assessment and Capacity Testing . Trabuco Canyon).

Matheson, L.N. & Niemeyer, L.O. (1987). Symptom Magnification Syndrome: Casebook, Anaheim, CA: Employment and Rehabilitation Institute of California.

Mathiowetz, V., Weber, K., Volland, G. & Kashman, N. (1984). Reliability and validity of hand strength evaluations. Journal of Hand Surgery, 9A, 222-226.

Mathiowetz, V., Wiemer, D.M. & Federman, S.M. (1986). Grip & pinch strength: Norms for 6- to 9-year olds. American Journal of Occupational Therapy, 40, 705-711.

Mayer, T., Gatchel, R. & Kishino N. (1985). Objective assessment of spine function following industrial injury: A prospective study with comparison group and one-year follow-up. Spine 10, 482-493.

Montazer, M.A. & Thomas, J.G. (1991). Grip strength as a function of repetitive trials, Perceptual and Motor Skills, 73, 804-806.

Montazer, M.A. & Thomas, J.G. (1992). Grip strength as a function of 200 repetitive trials, Perceptual and Motor Skills, 75, 1320-1322.

Niebuhr, B.R. & Marion, R. (1987). Detecting sincerity of effort when measuring grip strength among normal subjects. American Journal of Physical Medicine, 66, 16-24..

Niebuhr, B.R. & Marion, R. (1990) Voluntary control of submaximal grip strength, American Journal of Physical Medicine & Rehabilitation, 69(2), 96-101

Niebuhr B.R., Marion R., & Fike M.L., (1994). Reliability of grip strength assessment with the computerized Jamar dynamometer, The Occupational Therapy Journal of Research, 14(1), 3-19.

Niemeyer, L.O. (1989). The issue of abnormal illness behavior in work hardening. In L.O. Niemeyer & K. Jacobs (Eds.), Work hardening: State of the art (pp.67-109). Thorofare, NJ: Slack.

Niemeyer, L.O. & Jacobs, K. (Eds.), (1989). Work hardening: State of the art, Thorofare, NJ: Slack.

Niemeyer, L.O., Matheson, L.N. & Carlton, R.S. (1989). Testing consistency of effort: BTE work simulator, Industrial Rehabilitation Quarterly, 2, 1-8.

Nitz, J.C. (1995). How to evaluate hand grip. Australian Physiotherapy, 41(1), 49-51

Reckeras, O. (1983). Bilateral differences of normal hand strength. Archives of Orthopedic and Traumatic Surgery, 101, 223-224.

Rubin, M. (1988). The physiology of bed rest. American Journal of Nursing. 50-51.

Smith G.A., Nelson R.C., Sadoff S.J., & Sadoff, A.M. (1989). Assessing sincerity of effort in maximal grip strength tests. American Journal of Physical Medicine and Rehabilitation, 68, 74-80.

Stokes, H.M. (1983). The seriously uninjured hand-weakness of grip. Journal of Occupational Medicine. 9 (25), 683-684.

Stone, D. (1994). The Disabled State. Philadelphia, PA: Temple University Press.

Stratford, P.W. (1992). Summarizing the results of multiple strength testing trials: truth or consequence. Physiotherapy Canada, 1(44), 14-18.

Thorngren, K.G. & Werner, C.O. (1979). Normal grip strength. Acta Orthopaedica Scandinavica, 50, 255-259.

Tramposh, A. (1990). The measurement of disability in disability compensation systems: Current perspectives. Journal of Evaluation, 1, 37-41.

Tramposh, A.K. (1992). The functional capacity evaluation: Measuring maximal work abilities, Occupational Medicine: State of the Art Reviews-, 7(1), 113-124.

Trossman, P.B., Suleski, K.B. & Li, P.W. (1990) Test-retest reliability and day-to-day variability of an isometric grip strength test using the work simulator. Occupational Therapy Journal of Research, 10, 266-279.

Turner, J.A. & Romano, J.M. (1984). Self-report screening measures for depression in chronic pain patients. Journal of Clinical Psychology, 40(4), 909-913.

Turk, D.C. & Holzman, A.D., (1983). Chronic Pain: Interfaces among physical, psychological and social parameters. Pain and Behavioral Medicine: A Cognitive-Behavioral Perspective. New York: Guilford Press, 1983.

Turk, D.C., Rudy, T.E. & Stieg, R.L. (1987). Chronic pain and depression. I. "Facts". Pain Management, 1, 17-26.

Velozo, C.A. (1993). Work evaluations: Critique of the state of the art of functional assessment of work. The American Journal of Occupational Therapy, 47(3), 203-209.

Wesley, A.L., Gatchel, R.J., Polatin, P.B., Kinney, R.K. & Mayer, T.G. (1991). Differentiation between somatic and cognitive/affective components in commonly used measurements of depression in patients with chronic low-back pain: Let's not mix apples with oranges. Spine, 16(S2), 213-215.

Appendices

Appendix I

MVE Study Data Record Sheet

MVE Study University of British Columbia CASE DATA TALLY SHEET

1. Identification Number	
2. Age	
3. Sex	
4. Occupation	
5. DX	
6. Education	
7. Dominance	
8. Referral	
9. Episode	

MVE Dominant	Trial 1	Trial 2	Trial 3	Mean	SD	CV	Cut-Point
Cluster 1	DMVE11	DMVE12	DMVE13				
Cluster 2	DMVE21	DMVE22	DMVE23				
Cluster 3	DMVE31	DMVE32	DMVE33				
Cluster 4	DMVE41	DMVE42	DMVE43				
Cluster 5	DMVE51	DMVE52	DMVE53				
MVE Non-Dom	Trial 1	Trial 2	Trial 3	Mean	SD	CV	Cut-Point
Cluster 1	nMVE11	nMVE12	nMVE13				
Cluster 2	nMVE21	nMVE22	nMVE23				
Cluster 3	nMVE31	nMVE32	nMVE33				
Cluster 4	nMVE41	nMVE42	nMVE43				
Cluster 5	nMVE51	nMVE52	nMVE53				

Duration [months]		Rater	
BDI		Test date	
Work Status		Record date	

Appendix II

Raters and Relationship with MVE test Outcomes

Distribution of MVE outcomes according to three raters used in this study.

Rater x MVE Outcomes

Rater	Negative MVE	Positive MVE	Total
1	37	16	53
2	24	9	33
3	8	6	14
Total	69	31	100

	Value	Df	Probability
Pearson Chi-square	1.151	2.00	0.562

Relationship between raters and MVE outcomes was statistically non-significant.

Appendix III

Coding Guidelines for MVE Study

DataCoding Definitions & Instructions / MVE Study, UBC, SRS, M. Iwama 1997

[1] Identification Number	Enter consecutive numbers starting with 001 to 999
[2] Assessment Date	Numerical Format 00-00-00. I.e.: 12-17-96 (Dec. 17, 1996)
[3] Gender	Enter M (male) or F (female)
[4] Date of Birth	Enter Subject's Date of Birth in Numerical Format. 00-00-00
[5] Age	Calculate subject's age in years by subtracting the subject's date of birth from the date of assessment and enter double digit #.
[6] Occupation	Enter job at time of injury
[7] Occupational Category	Choose one from the following categories and enter full title: A) Clerical A) Service B) Maintenance C) Construction D) Managerial F) Technical G) Professional
[8] Referring Party	Enter referral party
[9] Referring Party Type	Choose the most appropriate type from the following list: A) Law/Plaint (Lawyer representing the plaintiff-client) B) Case Coor (Rehab Case worker for Insurance company) C) Law/Defen (Lawyer representing the Defendant-insurance company) D) Adju/ Insu (Adjuster, Insurance Company)
[11] Date of Injury	Enter date of injury in numerical format: 00-00-00
[12] Weeks Elapsed	Calculate number of weeks from the date of injury to the day of assessment, and enter number.
[13] Diagnosis	Enter primary diagnosis, for which the assessment is being requested. Choose from the following alternatives: A) Soft-tissue Injury (Includes muscle, ligament, cartilage and intervertebral disc) B) Fracture (Bone fractures) C) Neurological (damage to nerve tissue and plexi)
[14] Previous time loss	Enter number of reported episodes of injury leading to time off work (prior to current injury episode)
[15] Education	Enter number of years of education completed (excluding K) Ie. Completed 3rd year of University in Ontario: 13 (HS) + 3=**16**
[16] MVE Cut-points	Enter number of MVE CVs exceeding the allowable cutpoints (according to Matheson Protocol)
[17] MVE Outcome	Enter 'Positive' when # of CVs exceeding the max. allowable cut-points exceeds 2. 'Negative' if 2 or less.
[18] Hand Dominance	Enter 'R' or 'L'
[19] Mean Max. Grip	Enter the mean maximum grip score during MVE test
[20] Normal grip mean	Enter value for normal grip strength for age and gender group. Refer to Mathiowetz data.
[21] Difference	Enter 'Negative' if MVE max mean and Norm concur within 20% Enter 'Positive' if MVE max mean is lower than norm by greater than 20%
[22] Rapid Grip Exchange	Enter 'Positive' if REG exceeds MVE max score by more than 16%. Enter 'Negative' if REG concurs with MVE scores.
[23] MVE-REG Concurrence	Enter 'Positive' if REG outcomes support validity of MVE Enter 'Negative' if REG outcomes are inconsistenet with MVE
[23] BDI Raw Score	Enter raw score for BDI
[24] BDI Classification	Enter category title: Minimal (0-9) Mild (10-18) Moderate (19-29) Severe (30-63)
[25] Rater	Enter '1' for WE Enter '2' for GK Enter '3' for MK

Appendix IV

Certificate of Approval, Committee Clinical Research Ethics Board

Appendix V

Revised Beck Depression Inventory (BDI) Test Sheet

BDI™

Date: _____

Name: _____ Marital Status: _____ Age: _____ Sex: _____

Occupation: _____ Education: _____

This questionnaire consists of 21 groups of statements. After reading each group of statements carefully, circle the number (0, 1, 2 or 3) next to the one statement in each group which **best** describes the way you have been feeling the **past week, including today.** If several statements within a group seem to apply equally well, circle each one. **Be sure to read all the statements in each group before making your choice.**

1
- 0 I do not feel sad.
- 1 I feel sad.
- 2 I am sad all the time and I can't snap out of it.
- 3 I am so sad or unhappy that I can't stand it.

2
- 0 I am not particularly discouraged about the future.
- 1 I feel discouraged about the future.
- 2 I feel I have nothing to look forward to.
- 3 I feel that the future is hopeless and that things cannot improve.

3
- 0 I do not feel like a failure.
- 1 I feel I have failed more than the average person.
- 2 As I look back on my life, all I can see is a lot of failures.
- 3 I feel I am a complete failure as a person.

4
- 0 I get as much satisfaction out of things as I used to.
- 1 I don't enjoy things the way I used to.
- 2 I don't get real satisfaction out of anything anymore.
- 3 I am dissatisfied or bored with everything.

5
- 0 I don't feel particularly guilty.
- 1 I feel guilty a good part of the time.
- 2 I feel quite guilty most of the time.
- 3 I feel guilty all of the time.

6
- 0 I don't feel I am being punished.
- 1 I feel I may be punished.
- 2 I expect to be punished.
- 3 I feel I am being punished.

7
- 0 I don't feel disappointed in myself.
- 1 I am disappointed in myself.
- 2 I am disgusted with myself.
- 3 I hate myself.

8
- 0 I don't feel I am any worse than anybody else.
- 1 I am critical of myself for my weaknesses or mistakes.
- 2 I blame myself all the time for my faults.
- 3 I blame myself for everything bad that happens.

9
- 0 I don't have any thoughts of killing myself.
- 1 I have thoughts of killing myself, but I would not carry them out.
- 2 I would like to kill myself.
- 3 I would kill myself if I had the chance.

10
- 0 I don't cry any more than usual.
- 1 I cry more now than I used to.
- 2 I cry all the time now.
- 3 I used to be able to cry, but now I can't cry even though I want to.

11
- 0 I am no more irritated now than I ever am.
- 1 I get annoyed or irritated more easily than I used to.
- 2 I feel irritated all the time now.
- 3 I don't get irritated at all by the things that used to irritate me.

12
- 0 I have not lost interest in other people.
- 1 I am less interested in other people than I used to be.
- 2 I have lost most of my interest in other people.
- 3 I have lost all of my interest in other people.

13
- 0 I make decisions about as well as I ever could.
- 1 I put off making decisions more than I used to.
- 2 I have greater difficulty in making decisions than before.
- 3 I can't make decisions at all anymore.

_____ Subtotal Page 1

CONTINUED ON BACK

THE PSYCHOLOGICAL CORPORATION®
HARCOURT BRACE JOVANOVICH, INC.

Copyright © 1978 by Aaron T. Beck. All rights reserved. Printed in the U.S.A.
BDI is a trademark of The Psychological Corporation.

9-018359

14
- 0 I don't feel I look any worse than I used to.
- 1 I am worried that I am looking old or unattractive.
- 2 I feel that there are permanent changes in my appearance that make me look unattractive.
- 3 I believe that I look ugly.

15
- 0 I can work about as well as before.
- 1 It takes an extra effort to get started at doing something.
- 2 I have to push myself very hard to do anything.
- 3 I can't do any work at all.

16
- 0 I can sleep as well as usual.
- 1 I don't sleep as well as I used to.
- 2 I wake up 1-2 hours earlier than usual and find it hard to get back to sleep.
- 3 I wake up several hours earlier than I used to and cannot get back to sleep.

17
- 0 I don't get more tired than usual.
- 1 I get tired more easily than I used to.
- 2 I get tired from doing almost anything.
- 3 I am too tired to do anything.

18
- 0 My appetite is no worse than usual.
- 1 My appetite is not as good as it used to be.
- 2 My appetite is much worse now.
- 3 I have no appetite at all anymore.

19
- 0 I haven't lost much weight, if any, lately.
- 1 I have lost more than 5 pounds.
- 2 I have lost more than 10 pounds.
- 3 I have lost more than 15 pounds.

I am purposely trying to lose weight by eating less. Yes _____ No X

20
- 0 I am no more worried about my health than usual.
- 1 I am worried about physical problems such as aches and pains; or upset stomach; or constipation.
- 2 I am very worried about physical problems and it's hard to think of much else.
- 3 I am so worried about my physical problems that I cannot think about anything else.

21
- 0 I have not noticed any recent change in my interest in sex.
- 1 I am less interested in sex than I used to be.
- 2 I am much less interested in sex now.
- 3 I have lost interest in sex completely.

_____ Subtotal Page 2

_____ Subtotal Page 1

_____ Total Score