DISCRIMINATION BETWEEN SINCERE AND DECEPTIVE ISOMETRIC GRIP RESPONSE USING SEGMENTAL CURVE ANALYSIS

by

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(ABSTRACT)

This investigation was conducted to explore the between trial variability of the measures of the isometric peak force, time to peak force, area to peak force, area under the curve, slope (20%-80%), and the average slope of subjects assigned to perform a series of four isometric grip strength contractions and to develop a discriminant function equation that would predict group membership. Forty-nine college students were instructed to perform either a series of four maximal voluntary contractions (sincere) or a series of four submaximal (deceptive) contractions. The subjects were retested 24-48 hours after the initial test session. Data from both test sessions were recorded, displayed, and analyzed using segmental curve analysis. The coefficients of variation were computed for each test variable. The grand mean coefficient of variation for the sincere condition was $.31 \pm .02$ compared to the grand mean coefficient of variation for the deceptive condition which was $.77 \pm .11$ ($p < .01$). Coefficients of variation were used to predict group membership. The prediction equation accurately classified 92% of the sincere condition and 64% of the deceptive condition.

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TABLE OF CONTENTS

TABLES

FIGURES

CHAPTER 1

INTRODUCTION

The measurement of grip strength is frequently used in an assessment to measure physical work capacity. In addition, a strength assessment can give information about the degree of an individual's rehabilitation progress. There is sometimes, however, a question of an individual's cooperation and motivation with regard to a measurement of maximal effort (Gilbert and Knowlton, 1983).

Deception has been a problem for many years and can be dated back to the middle ages. Deception is defined by the American Psychiatric Association as a voluntary production or gross exaggeration of symptoms with an obvious recognizable goal. It is distinguished from mental disorders and is placed first on a list of 13 conditions not attributable to a mental disorder (ie: marital conflict, occupational problems) (Travin and Potter, 1984). This type of deception is used to encompass all forms of fraud related to health matters.

Detection of a deceptional behavior is a difficult task. At present suspected deceptions are detected through clinicians intuitions rather than objective criteria. When using isometric grip strength as a physical work capacity assessment device several variables have been instrumental in detecting a true versus a deceptive isometric grip contractions. Gilbert and knowlton (1983) suggested using slope to detect a sincere from a deceptive effort when discriminating by sex. The slope measurement represents the slope of the curve from the beginning of the curve to the peak force. Slope was reported to be a significant contributor for males but not for females.

Kroemer and Marras (1980) reported that the onset slope of an individual's strength exertions provides a reliable indication of the actual percent maximal voluntary contraction exerted. The onset of the slope of a deceptive (submaximal) contraction was flatter than the slope of the true maximal contraction.

For many years investigators believed that a deceptive effort could be detected by a greater amount of variability between maximum grip strength responses as well as greater variability across trials. However, Kroemer and Marras (1980), reported that there was no systematic variability among subjects faking a maximal effort. They had 30 subjects who performed elbow flexion strengths at 100%, 75%, 50%, and 25% of maximum voluntary contraction. The coefficients of variation of the strength exertions for the 30 subjects remained constant across the four force levels.

Stokes (1983), suggested that individuals faking an isometric maximal contraction can be detected by a normal curve using different handle positions on the dynamometer.

However in 1987, Niebuhr's and Marion's investigation did not support his findings. Niebuhr and Marion used 25 subjects to measure grip strength at the five standard handle positions. The subjects gave a maximal grip response, held three seconds, then released. The subjects rested one minute then performed a submaximal grip response. They reported that the same shaped curve was found at a lower level of force for individual's faking a maximal contraction.

STATEMENT OF THE PROBLEM

Segmental Curve Analysis (SCA), a software program written by the Mechanical Engineering department at Virginia Polytechnic Institute and State University, has been incorporated in several studies to investigate the between the trial variability of force curves when subjects were instructed to perform isokinetic muscular responses under various conditions (Price, 1988; Fisher, 1989; Snider, 1989; Bogner, 1991). SCA provides a more extensive evaluation and interpretation of isokinetic torque curves than is offered by the standard cybex equipment as well as a more extensive evaluation and interpretation of the isometric grip response curve. In 1988, Earles-Price revealed that isokinetic peak torque of the quadriceps, area to 70 degree angle of knee extension, and area between 20 and 70 degree angle of knee extension were the most reliable parameters across both multiple trials and different days. The results of this study suggested that several measures of isokinetic torque and power were highly reliable in normal subjects using the SCA system (Earles-Price, 1988). Snider investigated the reliability of selected measures of isokinetic torque and power of the knee extensor in subjects who had previously sustained and injury to the knee using SCA. The results of this study suggested that the measures of isokinetic torque and power were also highly reliable in injured subjects as well as uninjured subjects (Snider, 1989). Using SCA, Fisher (1989) reported that there were higher reliability estimates across the three test speeds (60, 180, and 300 degrees/second) and six parameters (peak torque, torque at five degrees prior to peak torque, torque to five degrees beyond peak torque, power to five degrees prior to peak torque, power between plus and minus five degrees of peak torque, and power beyond peak torque plus and minus five degrees of knee extension curves) between subjects assigned to provide a normal response than subjects assigned to provide a deceptive response. Bogner (1991) reported that when subjects were instructed to perform a series of isokinetic contractions as to fake or feign an injury, exhibited significantly greater variability within the selected force curve segments than subjects performing with maximal effort. Then, using discriminate analysis, Bogner was able to discriminate between subjects providing normal and deceptive isokinetic responses.

SIGNIFICANCE OF THE STUDY

For years deceptive responses have been used by workers to relieve them from specific tasks or work. Many insurance companies have been providing compensation for workers unnecessarily. As stated earlier, detection of a deceptive response is primarily a subjective measurement, largely due to the clinicians intuition.

To date, no studies have incorporated SCA to investigate the between trial variability of isometric muscular contractions. The purpose of this study was to measure the between trial variability of isometric force measurements of subjects instructed to perform a series of either four maximal voluntary contractions or a series of four submaximal (deceptive) isometric contractions. In addition, the investigator attempted to discriminate between sincere and deceptive isometric grip responses using the between trial coefficients of variation.

RESEARCH HYPOTHESES

The following research hypotheses was examined in this investigation:

Ho: There is no difference in the between trial variability of the measures of isometric peak force, time to peak force, area to peak force, area under the curve, slope (20%-80%), and average slope between subjects assigned to perform a series of four isometric grip strength responses and subjects assigned to perform a series of four deceptive isometric grip strength responses.

Ho: The discriminant function equation is not able to predict group membership (sincere, S, or deceptive, D) using the coefficient of variation of isometric peak force, time to peak force, area to peak force, area under the curve, slope (20%-80), and average slope.

DELIMITATIONS

The following delimitations were applied in this study:

1. Forty nine (19 male and 30 female) subjects volunteered to participate in this investigation.
2. The experimental task was a series of four maximal isometric grip strength contractions or a series of four submaximal (deceptive) isometric grip strength contractions.
3. The dependent measures included:
    a. Peak force
    b. Time to peak
    c. Area to peak
    d. Area under the curve
    e. Slope (20%-80%)

f. Average slope

LIMITATIONS

The following limitation was recognized by the investigator as a potential weakness in this investigation:

1. The instructions given the deceptive condition regarding the technique to feign an injury during an isometric grip strength test were not explict enough and allowed the subject to produce very short term contractions. Instructions should provide a specific unit of time (ie. 3-5 seconds) to hold the contractions.

BASIC ASSUMPTIONS

The following basic assumptions were accepted by the investigator:

1. The subjects were properly trained to provide a series of either maximal or deceptive isometric grip response.
2. The SCA program correctly displayed and analyzed the isometric strength curves.

DEFINITIONS AND SYMBOLS

1. <u>Area to peak</u> (AP): The area under the curve from the beginning to the peak force.
2. <u>Area under the curve</u> (AC): The total area under the curve or the force time interval.

3. Average slope (AS): The average slope of the curve.

4. Maximal voluntary contraction (MVC): The maximum amount of force developed from a muscular contraction of which a subject is physically and consciously capable of producing.

5. Peak force (PF): The greatest amount of force exerted during the isometric contractions.

6. Segmental curve analysis (SCA): Computer software used to analyze the experimental variables.

7. Slope (SL): The slope of the curve from 20% of the peak force to 80% of the peak force.

8. Time to peak (TP): The amount of elapsed time from the beginning of the curve to the peak force.

Summary

The measurement of grip strength is frequently used to assess a person's physical work capacity. It can provide information about the degree of an individual's injury or the progress of an individual's rehabilitation program. However a weakness of this measurement is that an individual's cooperation and motivation with regard to a maximal effort. The detection of a deceptive effort is difficult to assess. The method most commonly used to date is the subjective intuition of the clinician. As a result of the difficulty in detecting deception many investigators are seeking to develop methods to aid in the detection of a deceptive effort. The results of these studies have been controversial. Prior to 1980, investigators reported that with deceptive efforts a subject would demonstrate greater variability between maximum grip strength responses as well as greater variability across trials. Kroemer and Marras (1980), however, reported no significant variability among subjects who were faking a maximal grip strength and subjects who were performing maximal grip strength responses.

Stokes (1983) suggested that individuals who are performing a maximal hand grip response will display a normal curve using the different handle positions. Fakers will not display a normal curve but instead a straight line. However, in 1987, Niebhur and Marion suggested that subjects performing a deceptive hand grip response will display a normal curve just at a lower force. The present study attempted to develop a procedure that can be used to discriminate between a sincere and a deceptive isometric grip strength response using Segmental Curve Analysis.

CHAPTER II

LITERATURE REVIEW

The purpose of this review is to provide an overview of the measurement of grip strength and malingering. In addition, a review of the literature on the detection of deceptive muscular contractions is presented.

Grip Strength

A suggestion to standardize procedures for static muscle strength testing was reported by Caldwell, Chaffin, Dukes-Dobos, Kroemer, Ing, Laubach, Snook, and Wasserman (1974). They suggested that explicit instructions to subjects were necessary for strength assessments. Thirty four subjects were assessed using 3 different instructions. During the first experimental condition the subjects were instructed to "jerk the handle as hard as you possibly can. When you've reached your maximum release the handle on your own." The second experimental condition involved gradually squeezing the handle until maximum effort then releasing. The third experimental condition was to squeeze and hold while the investigator counted to 7 reaching their maximum by the count of 2. Each experimental condition was a pair of trials separated by a two minute rest period. With the "jerk" instructions 38% of the subjects reached their maximum output with in the first second, 41% within 1-2 seconds 12% within 2-3 seconds and 9% took more than 3 seconds. The increase to maximum instructions led to a more variable performance; 12% attained maximum force with in 1 second 15% took from 1-2 seconds, 21% reached maximum between 2-3 seconds, 21% reached maximum between 3-4 seconds 6% reached maximum between 4-5 seconds and 27% took greater than 5 seconds to reach maximum effort. The third experimental instructions, to hold maximum effort until the count of 7 revealed 3% reached maximum effort in 1 second, 24% reached max between 1-2 seconds, 29% reached maximum between 2-3 seconds, 26% between 3-4 seconds 9% in 4-5 seconds and 9% reached maximum after 5 seconds. The reliability for the three experimental instructions was high r=.94 for the "jerk" instructions, r=.92 for the increase instruction, and r=.95 for the hold instructions. The results of this investigation suggest that with out explicit instructions subjects tend to develop their own strategies for the task. This would create greater variability among subjects especially with their time to maximum effort. Also using different methods to reach maximum effort may involve different muscle masses depending on the method. For instance the jerk or a more explosive method may involve larger muscle masses than a slower (increasing) method which would involve smaller muscle masses (Caldwell, 1974).

Isometric grip strength tests are commonly used to assess a variety of diagnoses: i.e. hand injury recovery, rheumatoid arthritis disease progression, and other disorders that may effect strength. However it is difficult to set up norms to be used across all forms of isometric grip strength tests. In 1987, Fiutko compared the grip strength of two separate countries, Kuwait and Poland (Fiutko, 1987). Across several age groups with in 16-65 years of age. Five hundred seventy nine healthy males were divided by age into groups, 19 years and less, 20-24, 25-29, 30-39, 40-49, and 50 and more. The studies were done independent of one another. Fuitko reported that the Polish grip strength responses were higher across all age groups. Also the two countries grip strengths increased across years and then began to decline with age. Interestingly, the Polish peaked between the ages of 20-24 while the Kuwaites peaked at the age group of 25-29 years.

To further illustrate the difficulties in producing norms for the assessment of strength, McGarvey, Morrey, Askew, and An (1984) investigated the reliability of several different isometric evaluations, grip, supination, pronation, and elbow extension and flexion on both the dominant and non dominant sides. Data was collected from three trials of maximum voluntary contractions with a 30 second rest in between trials. The test trials were also administered at different times during the day, 8:30 am, 12:30 pm, and 4:30 pm. The values were expressed as means of the three trials. Forty adult subjects ages 40-70 years participated in the study. They reported a significant difference in the isometric strengths at various times of day in the comparisons of pronation, supination and grip. On the basis of these data, It appears that this variation can probably not be routinely detected in the normal clinical setting. However, the study further defines the reliability of isometric strength testing and should be considered in further attempts at more accurate measurement of elbow function. The small variations of strength, approximately 5%, that can be measured universally with sensitive testing equipment, are clinically relevant. However, when attempting to determine an impairment state, in order not to place too much importance on small differences, care should be exercised interpreting strength measurements. This investigation demonstrated how the application of sophisticated biomechanical techniques may be employed to provide useful objective information in the difficult clinical area of disability assessment. Disability judgements may be made more accurate as more is learned of the normal variables influencing objective measurement. The only consistent trend for strength was in grip strength. Both the dominant and non dominant grip strength responses were stronger at 12:30 pm and at 4:30 pm , than at 8:30 am. And the fourth consideration was that although significant changes did occur the variations should probably be considered negligible in the clinical setting. The reason for this being the average value (5.5%) of change in strength falls within the range 5%-12% of dominant/non dominant differences in strength, which is commonly used to normalize strength data. McGarvey, et al. concluded that the variation of isometric strength with time of day can not be routinely detected in the normal clinical setting (McGarvey, et al. 1984).

Stratford, Norman, and McIntosh (1989) reported on the ability to generalize hand grip strength responses across different conditions, repetitions, and on different occasions. The study was conducted using 35 subjects (19 males, 18 females) with extensor carpi radialis brevis tendinitis. A repeated measures study design was adopted that provided three measurements during the same test session and three additional measurements at a second test session. Test measurements were obtained on the involved limb as well as the uninvolved limb. The reliability coefficients for maximum grip strength interrepetition for maximal grip response with the involved limb is r=.99 same day and r=.97 on separate days. The interoccasion reliability for the involved limb was r=.99 on same day and r=.95 on separate days. Maximum grip strength responses for the uninvolved limb (MGU) was r=.99 on the same day and r=.97 on separate days for the interrepetition and the interoccasion reliability was r=.98 and r=.93 for the same day and separate days respectively. Stratford et al. (1989)

concluded that a clinicians need to collect data on the same day to see the same day variability to be able to correctly measure change across time or on separate occasions. (Stratford, Norman, and McIntosh, 1989).

In addition to standardizing the instructions and the time to day for strength testing, Balogun, Akomolafe and Amusa (1991) reported that there was greater strength results when in the standing position as compared to the sitting posture. They tested 61 college students 16-28 years of age in the four experimental conditions using grip strength responses with different elbow flexion, sitting position elbow 90 degree flexion, sitting position elbow in full extension, standing position elbow in 90 degree flexion, and standing position elbow in full extension. Subjects were instructed to "squeeze the handle of the dynamometer as hard as possible and to hold it in place for five seconds." In each experimental condition two attempts were made with a minimum of five minutes rest in between trials and no longer than one hour. The highest measurement was recorded for the test. The results of the analysis of variance for grip strength revealed that there was no significant difference between gender in the specific treatments there was however a significant difference in the grip strength with the different experimental postures and joint angles. It has been suggested that a standard posture should be used when measuring grip strength and it is difficult to compare values across different postures Balogun, et al, 1991).

Several studies have reported standardized positioning and instructions for measuring grip strength. One such study used 27 apparently healthy adults ages 20-39 years (Mathiowetz, Weber, Volland, & Kashman, 1984). Mathiowetz et al., were investigating the possibility of establishing norms for positioning and instructions to evaluate inter-rated reliability, to compare test-retest reliability for one trial, two trials, three trials, and the highest score, and to report on the calibration accuracy of the test instruments. Calibrations were done using known weights and suspending them from the center of the hand pieces and from the center of the finger grooves for the pinch devices.

Hand dominance was determined by questioning the subject "Are you left or right handed?" Subjects were seated with their shoulders abducted and neutrally rotated, elbow flexed at 90 degrees, forearm in neutral position and the wrist between 0-30 degrees dorsiflexion and between 0-15 degrees ulnar deviation. The subjects performed three successive trials. The maximum value readings were recorded by two independent investigators to be compared with one another later.

The handle position was set at the second position for all subjects. The following instructions were given and the task was demonstrated by the examiner. All of the experiments had the same instructions; squeeze the handle as hard as you can, the examiner gave encouragement during the test. The same instructions were given for the second and third trial. Prior to each test the examiner demonstrated the exact position and activity that was to be tested.

The results produced an extremely high correlation between the two raters on the first test session grip, right .996, left .999; palmer pinch, right .979, left .995; key pinch, right .989, left .987; and tip pinch, right .991, left .996. The test-retest reliability (Pearson Product Moment correlation) was used to assess the correlation across the two trials. The highest of the correlations was achieved when the means of three trials was used. Grip, right .822, left .915; palmer pinch, right .749, left .830; key pinch, right .748, left .829; and tip pinch, right .754, left .689. This study suggest that high inter-rater and test retest reliability can be achieved by using standardized positioning and instructions. Mathiowetz et al. (1984) also suggest that the mean of the trials should be used rather than the highest score.

Malingering

Malingering has been defined as conscious act of simulating or exaggerating physical or psychological disease

(Travin and Protter, 1984), and is especially troublesome in cases of workmen's compensation. It has been estimated that approximately $289 million was paid for fraudulent claims in 1982 alone (Edwards, 1983).

Malingering is thought to be an adaptive response to both internal and external factors with an obvious goal in mind. This assumes that the subject is consciously aware of his fictitious performance, and is therefore responsible for his actions from a medical and legal standpoint. This category of malingering is called an other-deceiver. Other malingering-like behaviors have been discussed in the literature, in which varying degrees of psychoses may contribute to their manifestation (Travin and Protter, 1984).

Malingering is usually thought of as a "higher order task" in a psychological sense. A given task, whether it be physical or psychological, is made up of interactions between demands and capabilities. Performance of that task increases as demand increases, but is ultimately limited by one's inherent capabilities. The basic capabilities we possess to meet the demands of everyday life include physical strength and endurance, the five senses, proprioception, visualization, and the ability to perform actions in series, which are essential to sensori-motor skills (Welford, 1978). If demand exceeds capability by developing a strategy or approach to a problem. Higher order skills require the capability to instantaneously interpret events, memory retention, and verbal communication as well as the ability to apply knowledge acquired from one situation to a new one (Welford, 1980). Subjects lacking the capability to perform a task based on sensory feedbacks may have to rely on higher-order mental capabilities to perform such a complex task as faking an injury. Hence, conscious attempts at malingering may require higher levels of processing than reflexive performances regulated by sensory inputs of pain, discomfort and fatigue (Welford, 1978).

It is probably not inaccurate to say that most limitation of activity as a result of injury is due to the presence of pain. At any given moment, more than two million workers are inhibited by pain at a cost of over $2 million annually (Kandel and Schwartz, 1985). The way a subject responds to pain will ultimately influence the pattern of behavior he exhibits. The source of most information about pain arises from free nerve endings. All muscular activity is controlled based on the contributions of sensory and motor neurons, also known as afferent and efferent neurons. Sensory neurons provide information to the central nervous system (CNS) about the external environment or internal events that may influence activity; motor neurons transmit information from the CNS to muscles to stimulate activity. In a simple two-stage system, this is all that is required. "Behavior," if it can be called that, is simply a response to internal or external stimuli. Higher order activities require higher levels of processing within the central nervous system, either through interneurons, ganglia, or the brain. This higher level of processing results in more complex behavior patterns than in a two-stage system (Darley et al., 1981). Hence, Malingering and malingering-like behavior can be considered in a physical sense as well. Kroemer and Marras (1980) theorized and demonstrated that submaximal efforts would require a longer build-up phase than a maximal effort because of the amount of mental processing required for a submaximal effort. Deceptive behavior by a subject is usually manifested as a submaximal effort. Therefore, one would expect that a true maximal effort, whether limited by pain or not would require less processing than a deceptive effort, since the feedback loop required in processing the information that mediates the behavior would be much shorter in the case of the truly injured patient compared to the malingering subject.

Detection of Deceptive Muscular Contractions

The detection of malingering in the past has been mainly based on subjective findings. Subjective evidence of malingering usually involves complaint of discomfort or injury with out any supporting objective findings as to the source of the complaint. In our increasingly litigious society, it has become necessary to develop objective means to identify malingering. Previous methods used to detect malingering have included the use of psychological tests like the Minnesota Multi-Phasic Personality Inventory (MMPI) (Grow, McVaugh, and Eno, 1980), and isometric hand grip testing.

Kroemer and Marras (1980) hypothesized that one method for detecting a deceptive effort was using the slope of the curve created by the exercise. They suggested that the steeper the slope the higher the probability that the subject was performing a sincere maximal voluntary contraction. They suggested that there was a longer build up period for submaximal efforts than for a maximal effort. Kroemer's and Marras's research however, did not support previous reports that there would be greater variability for submaximal efforts than for maximal voluntary contractions. Using 30 subjects, they used the Caldwell regimen which requires the subject to increase the muscle tension smoothly to the desired level with in about 2 seconds and to maintain this level for at least 3 seconds. The average value for the 3 seconds is calculated and accepted as the strength score provided the actual exertion during this time period did not vary by more than $\pm$ 10% of the average value. In addition to the average force levels, the onset slopes and the slope of the force build up were read for the records and expressed in terms of force per units per seconds. All subjects were instructed to exert force at 100%, 75%, 50%, and 25% of their individual maximal capacity. Each subject exerted 10 contractions under each condition. This investigation reported coefficients of variation which were remarkedly constant for all subjects at all four force levels.

Stokes believed that the loss of grip strength is a rateable factor in determination of permanent disability by compensation boards. In 1983, Stokes, tested two patients using the five different handle positions first with a normal hand then using an injured hand to determine if there was a pattern that would aid in the detection of a submaximal effort. The patient was instructed at each handle position to apply a maximal grip. The readings were recorded and graphed forming a slightly skewed bell shaped curve with the lower readings at the extreme handle positions and the highest reading at the middle position. He suggested that a subject who is injured and has a loss of strength will demonstrate the same bell shaped curve only at lower strength levels where as a subject who is attempting to fake an injury or perform a submaximal contraction will not demonstrate a bell shaped curve but instead will show a straight line graph.

In 1987, Neibuhr and Marion used 25 subjects, all apparently healthy with no upper extremity dysfunction, to perform sincere and deceptive hand grip responses in the five handle positions with their dominant and non dominant hand.

The subjects were instructed to squeeze as hard as they could after 3 seconds they were told to relax. For the faking trial the subjects were told to "fake a weak grip", after 3 seconds they were told to relax. Neibuhr and Marion reported the sincere trials revealed greater strength for both the dominant and non dominant hand at the different handle positions reflecting a bell shaped curve. The faking trials also revealed a bell shaped curve although the strength scores were considerable less.

Gilbert and Knowlton, (1983) also used grip strength effort as a method to discriminate between sincere and deceptive efforts. However, these investigators decided to concentrate on variables drawn from individual force curves generated by each subject. Gilbert and Knowlton used 36 subjects to attempt to establish a simple method to determine the legitimacy of a maximal voluntary grip contraction (MVGC). The subjects were assigned to an experimental condition (sincere or deceptive) but their group association was not know to the investigators until after the group predictions. The subjects were instructed to "jerk" to their maximum grip force as rapidly as possible and to hold for 5 seconds. The procedure was repeated after a 2 minute rest. Data was represented by an average of the two trials. It was assumed that the slope (SLP) would be greater for the sincere group than for the deceptive group. Another assumption was that the ratio of average force to peak force (DEV) would be greater for the sincere group than for the faking group as well as the ratio of peak force to body weight (WTRATIO). Group prediction was made by assigning the highest 50% of the z score sums to the sincere group and the lowest 50% of the z score sums to the faking group. Classification resulted in correct placement of 87.5% of the females and 80% of the males. For females SLP was the only variable to be a significant discriminator but for the males DEV and SLP variables were significant discriminators. It was concluded that sincere and faking subjects can be identified from the results of maximal isometric grip strength test based upon the analysis of an isometric force curve (Gilbert and Knowlton, 1983).

In 1990, Niebuhr and Marion, investigated the degree of voluntary control that normal uninjured subjects have over submaximal effort and their ability to feign weakened grip responses. Three experiments were conducted to determine if 1) subjects, instructed to exert a specific amount of effort, would produce feigned efforts consistent with Stokes (1983) hypothesis, 2) the ability of subjects to produce varying amounts of submaximal effort on demand, and 3) if subjects, with proper instruction as to the amount of effort to exert, can produce feigned submaximal efforts similar to the sincere, maximal efforts of injured people. The first experiment used

30 subjects all apparently healthy to perform grip strength test using their dominant hand at three handle positions (small, middle, and wide) at different levels of effort (50%, 100%) two trials. The results reported that the subjects were able to produce feigned efforts that were reasonably accurate 50% accounts therefore producing a similar curve to the maximal efforts at the different handle positions.

Experiment two involved 20 subjects, none of them had participated in experiment one. The subjects were instructed to exert different levels of force on an isometric hand grip dynamometer. The levels were 30, 50, 70, 90, and 100% of a maximal contraction using both the left and the right hands. The results indicated no difference between the left and the right hand. This experiment suggested that the best estimate of performance was the 70% level. The subjects tended to overexert at the 30 and 50% levels and underexert at the 90% level. It is suggested by the results of this experiment that subjects can control grip force on demand to a reasonably accurate degree.

Finally in Experiment three, Neibuhr and Marion proposed to determine whether healthy people could, by exerting differential effort at the various handle positions, emulate the grip of an injured person. Thirty apparently healthy, females none of which had participated in experiment 1 or 2 were tested to determine if for both sincere and feigned conditions the middle handle position would be greatest amount of force and if grip strength for the feigned would be uniformly less at each handle position than the corresponding grip force in the sincere conditions thus producing parallel force curves for the conditions. The handle positions were labeled 1, 2, 3, 4, and 5 that were associated with efforts of 30, 70, 70, 50, and 40% of a maximal contraction. The results indicated that the curves of grip force as a function of handle position would be parallel for the sincere and feigned condition. In summary, the results suggested that when subjects were instructed to perform sincere and feigned efforts at the different handle positions a flatter curve will help determine the sincere effort from the feigned effort and that subjects are able to in a reasonably accurate degree control the amount of grip force exerted on the dynamometer. When these two experiments were combined the results suggested that the curves of grip force as a function handle position would be parallel for the sincere and feigned condition.

The use of Segmental Curve Analysis has been incorporated in several studies to investigate the between trial variability of force curves when subjects were instructed to perform isokinetic muscular responses under various conditions (Earles-Price, 1988; Snider, 1989; Fisher, 1989; Bogner, 1991) A recent study (Earles-Price, 1988) examined both stability reliability and internal consistency reliability of selected measures of isokinetic torque and power of the knee extensors in subjects using a unique software program called Segmental Curve Analysis (SCA). The SCA program was designed to provide a more extensive interpretation, evaluation, and analysis of isokinetic torque curves than can be obtained from the standard Cybex equipment. Of the selected torque and power variables utilized in this study, peak torque, area to 70 degree angle of knee extension, and area between 20 and 70 degree angles of knee extension were the most reliable parameters across trials and days. Thus, the results of this study revealed that several measures of isokinetic torque and power of the knee extensors were highly reliable in normal subjects when using the SCA system (Earles-Price, 1988).

Another study using Segmental Curve Analysis (SCA) was in 1989. Seventeen subjects who had previously sustained an injury to the knee were instructed to perform five maximal reciprocal contractions of the knee extensors/flexors at the speeds of 60 degrees/second and 180 degrees/second for the involved limb using a Cybex II isokinetic dynamometer. During the testing, all torque and angle data from the cybex were digitized, sampled between 71 and 200 Hz and stored on a disk for later analysis. The SCA system displayed, then analyzed each knee extension torque curve for the following variables: Peak torque, torque at five degrees prior to peak torque, and torque at five degrees beyond peak torque of knee extension curves, and also the area to five degrees prior to peak torque, area between plus and minus five degrees of knee extension curves. Intraclass reliability was calculated using a two way ANOVA for repeated measures. Intraclass correlation coefficients were extremely high for all of the torque and power parameters in each of the testing conditions ranging from R=.96 to .99. It was concluded that measures of isokinetic torque and power from the SCA system were highly reliable in both injured and uninjured subjects.

Fisher attempted to use isokinetic testing to compare the reliability of 76 injury free subjects performing knee extensions on a Cybex II isokinetic dynamometer. These 76 subjects were randomly divided into either sincere (S) or deceptive (D) conditions. Deceptive subjects were trained to fake an injury after being presented with a standardized injury scenario they were to follow in simulating a knee injury. Sincere subjects were trained to give true isokinetic MVCs. Both groups were tested at speeds of 60, 180, and 300 deg/sec, and performed five repetitions at each speed. During testing, the data was transmitted to a 286 computer interfaced with a DT2801 series data translation board. The computer was equipped with the Segmental Curve Analysis program which analyzed the torque curves generated during testing. Each curve was analyzed for the following six variables: Isokinetic peak torque (PT), torque at five degrees joint angle prior to PT (TN5), torque at five degrees beyond PT (TP5), power (area under the torque curve) to five degrees prior to PT (PN5), power between negative and positive five degrees around PT (A55), and power from five degrees beyond PT to the end of the curve (PP5). Coefficients of variation and intraclass reliability were calculated for each of these variables to compare their reliability across four of the five repetitions. The first repetition was omitted from the analysis. The analysis revealed that sincere subjects produced higher measures of reliability across all three test speeds and for all six variables than did the deceptive subjects. Intraclass correlation coefficients were higher at 60 deg/sec than at 180 or 300 deg/sec in both condition. Variables of torque were shown to be consistently more reliable than measures of power, with PT demonstration the greatest reliability (S: R=.98-.99; D: R=.94-.97). Coefficients of variation were also found to be lower at 60 deg/sec across groups. Variables of torque also exhibited less variance than power variables in both groups, and sincere subjects exhibited lower coefficients of variance across all parameters than did deceptive subjects. Fisher concluded that subjects simulating an injury demonstrated lower reliability and greater variation in the isokinetic knee extension test than did subjects exerting true maximal force. She speculated that this may have been due in part to the subjects' lack of access to a reference point in terms of pain.

The most recent investigation using SCA was in 1991, Bogner attempted to determine if, by using coefficients of variation derived from data collected by Fisher (1989), it would be possible to develop prediction equations to discriminate between sincere and deceptive isokinetic knee extension tests, whether these equations could be applied to a new sample, and whether prediction accuracy is dependent on test speed. Fisher (1989) trained 76 college-age males subjects to either give a true maximal response of fake an injury during isokinetic knee extension/flexion test at 60, 180, and 300 degrees/second. Data were transmitted to a computer running Segmental Curve Analysis program (Eagles-Price, 1988 and Snider, 1989), which computed six variables for each torque curve: peak torque (PT), torque at five degrees prior to and post-PT (T-5, T+5), area to five degrees prior to PT (A-5), area beyond five degrees post-PT (A+5), and area between five degrees pre and post-PT (A55). Coefficients of variation were computed for each variable, which were used to develop prediction equations for each speed, and for all speeds combined. The prediction equations accurately predicted condition assignments when applied to Fisher's (1988) data. Prediction accuracy ranged from .57 to .79. A second sample was solicited, trained, and tested in a manner similar to Fisher (1988), and the same prediction equations were applied (Bogner 1991). There was no significant difference ($p < 0.05$) in the prediction accuracy of these equations between their application to Fisher's (1988) data or to data collected in the current study. Furthermore, there appeared to be no significant effect of test speed on prediction accuracy. These data suggest that coefficients of variation could be used to discriminate between sincere and deceptive isokinetic performances.

Summary

Isometric grip strength measurements are widely used to assess a person's degree of injury or as a measurement of improvement. To be able to assess measurements across norms very explicit, simple, standard instructions should be established. It is also necessary to use the same standardized equipment when comparing one test measurement to another (Caldwell et al, 1974, Fuitko, 1987, Bohannon, 1991, Balogun, 1991, and Mathowiowetz, 1984). There have also been studies suggesting higher reliability when subjects are tested during the same testing session instead of testing sessions on different dates (McGarvey et al, 1984, Stratford et al, 1989).

Malingering involves the fictitious representation of a physical or psychological ailment. Attempts have been made to use isometric measurements of hand grip strength to identify malingering behavior with mixed results (Gilbert and Knowlton, 1983; Niebuhr and Marion, 1987). The role of variability in individual performance has been examined as an indicator of maximal or submaximal isometric effort (Kroemer and Marras, 1980).

Segmental Curve Analysis has been incorporated in several studies to investigate the between trial variability of force curves when subjects were instructed to perform isokinetic muscular responses under various conditions (Earles-Price, 1988; Snider, 1989; Fisher, 1989; and Bogner, 1991). The SCA program was designed to provide a more extensive interpretation, evaluation and analysis of isokinetic torque curves than can be obtained from the standard Cybex equipment. The studies revealed that measurements taken were highly reliable in both the injured and uninjured subjects (Earles-Price, 1988; Snider, 1989).

CHAPTER III

JOURNAL MANUSCRIPT

Discrimination Between Sincere and Deceptive Isometric Hand Grip Responses

by

Molly Stout

ABSTRACT

This investigation was conducted to explore the between trial variability of the measures of the isometric peak force, time to peak force, area to peak force, area under the curve, slope (20%-80%), and average slope of subjects assigned to perform a series of four isometric grip strength contractions and to develop a discriminant function equation that would predict group membership. Forty-nine college students were instructed to perform either a series of four maximal voluntary contractions (sincere) or a series of four submaximal (deceptive) contractions. The subjects were retested 24-48 hours after the initial test session. Data from both test sessions were recorded, displayed, and analyzed using segmental curve analysis. The coefficients of variation were computed for each test variable. The grand mean coefficient of variation for the sincere condition was .31 $\pm$ .02 compared to the grand mean coefficient of varition for the deceptive condition which was .77 $\pm$ .11, ($p < .01$). Coefficients of variation for each variable were used to predict group membership. The prediction equation accurately classified 92% of the sincere condition and 64% of the deceptive condition.

Introduction

The measurement of grip strength is frequently used in an assessment to measure physical work capacity. Strength assessment can also give information about the degree of an individual's rehabilitation progress. There is however, a question of an individual's cooperation and motivation with regard to a measurement of maximal effort (Gilbert and Knowlton, 1983).

Deception is defined by the American Psychiatric Association as a voluntary production or gross exaggeration of symptoms with an obvious recognizable goal (Travin and Protter, 1984). This type of deception is used to encompass all forms of fraud related to health matters. For years deceptive responses have been used by workers to relieve them from specific tasks and work. Many insurance companies have been providing compensation for workers unnecessarily.

Detection of a deceptional behavior is a difficult task. At present suspected deceptions are a subjective measurement detected through clinicians intuitions rather than objective criteria. When using isometric grip strength as a physical work capacity assessment device several variables have been instrumental in detecting a true versus a deceptive isometric grip contraction.

In 1980, Kroemer and Marras reported that one method for detecting a deceptive effort was using the slope of the curve created by the exercise. They suggested the steeper the slope the higher the probability that the subject was performing a sincere maximal voluntary contraction and a submaximal or deceptive effort would have a longer build up period. Similarly, Gilbert and Knowlton (1983) using individual force curve, generated by each subject reported that slope would be greater for the sincere group than for the deceptive group and that the ratio of average force to peak force would be greater for the sincere group than for the deceptive group as well as the ratio of peak force to body weight when separated by gender.

A software program called segmental curve analysis, was written by the Mechanical Engineering department at Virginia Polytechnic Institute and State University (Bogner, 1991) and has been incorporated in several studies to investigate the between the trial variability of force curves when subjects were instructed to perform isokinetic muscular responses under various conditions (Earles-Price, 1988, Fisher, 1989, Snider,1989, and Bogner,1991). The Fisher (1989) and Bogner (1991) investigations reported the ability to predict group membership using coefficients of variation for the different segments of the isokinetic response curves.

This investigation attempted to explore the between trial variability of the isometric peak force (PF), time to peak force (TP), area to peak force (AP), area under the curve

(AC), slope (20%-80%) (SL), and average slope (AS) measurements of subjects assigned to perform a series of four isometric grip strength contractions and to develop a discriminant function equation that would accurately predict group membership (sincere or deceptive) of these subjects.

Methodology

Forty-nine (19 males, 30 females) college students volunteered to participate in this investigation. A trained laboratory technician oriented the subjects to the experimental task, determined hand preference, and trained them to give both maximal and deceptive isometric grip responses. The grip strength device used was a modified Jamar Hand Dynamometer. Attached to the dynamometer was a Genesco AWU force transducer. The data was collected by an IBM compatible 286 based micro computer. The digitized signals were stored on magnetic disc for off line analysis. Digitized signals were first filtered by a Butterworth low-pass filter, 40 Hz, then the actual measurements were quantified using a software program, Segmental Curve Analysis.

The subjects were seated in front of the device and instructed to adjust the grip to their preferred grip size. The grip measurements were then recorded for subsequent experimental trials. Using a strip chart recorder, the technician trained the subjects to give four maximal voluntary contractions (MVC) and four submaximal contractions of at least 25% of the MVC. The training force curves were recorded and displayed on a Kipp and Zonen strip chart recorder.

After the training session, the subjects were randomly assigned by the technician to one of the two experimental conditions (sincere, S and deceptive, D). They were given a brief written scenario outlining their task. The subjects assigned to the sincere condition were instructed to perform a series four maximal hand grip contractions exerting maximal force. The subjects assigned to the deceptive condition were instructed to perform the series in a manner appropriate for an injured person who was instructed to perform a maximal effort but attempting to deceive the test administrator.

When the technician determined that the subject was properly trained to give maximal voluntary contractions or submaximal contractions (the submaximal contractions were at least 25% of the maximal contractions), the investigator, unaware of the group assignment, instructed the subject to provide four maximal grip contractions. The subjects provided a series of either sincere grip responses or a series of deceptive grip responses, depending upon their assigned condition. After the experimental testing session, the investigator scheduled the subject for a second testing session (retest) 24-48 hours after the initial experimental period.

The second testing session was also conducted by the principle investigator, who remained unaware of the subject's condition assignment. The subjects were requested to perform their originally assigned experimental task scenario.

The experimental data from both testing sessions were recorded, displayed, and analyzed using Segmental Curve Analysis. The experimental variables recorded were: Peak force (PF), the greatest amount of force exerted during the isometric contractions; time to peak force (TP), the amount of elapsed time to reach peak force; area to peak force (AP), the area under the curve measured from the lowest point prior to the curve up slope to the peak force; the area under the curve (AC), the measurement of the area under the curve from the lowest point prior to the up slope to the lowest point following the down slope; the slope (SL), the measurement of the upward curve between 20%-80% of the peak force; average slope (AS), the average of all slopes from the start to the peak force point.

Results and Discussion

The statistical program Number Cruncher Statistical System (NCSS) was employed by the investigator to provide all statistical analysis.

Pearson Product Moment Correlations were calculated for each subject to estimate the reliability of the test variables across the two testing sessions. The stability reliability estimates for the sincere condition ranged from r=.58 to .84. The reliability estimates for the deceptive condition ranged from r= -.09 to .64. Other studies (Mathiowetz et al., 1984; Stratford et al., 1989) reported higher reliability estimates but used only the measure of peak force. Stratford et al. (1984) reported r = .96 with normal subjects and r = .98 with injured subjects. Mathiowetz et al. (1984) reported reliability estimates of 27 females r =.88 for the right hand and r = .92 for the left hand.

All subsequent statistical analysis were conducted on the data set recorded during the second testing session (retest). Coefficients of variation were computed for each subject and for each test variable. The deceptive condition displayed the greatest amount of variation across the six experimental variables. See Figure 1. The grand mean (all variables included) coefficient of variation for the sincere condition was .31 $\pm$ .02 compared to the grand mean coefficient of variation for the deceptive condition was .77 $\pm$ .11, (x $\pm$ SE, $p < .01$).

The between group differences in the between trial variance of peak force were not consistent with the findings reported in the 1980 study by Kroemer and Marras, which stated that there was no significant variation between the sincere and deceptive conditions for the variable of peak force.

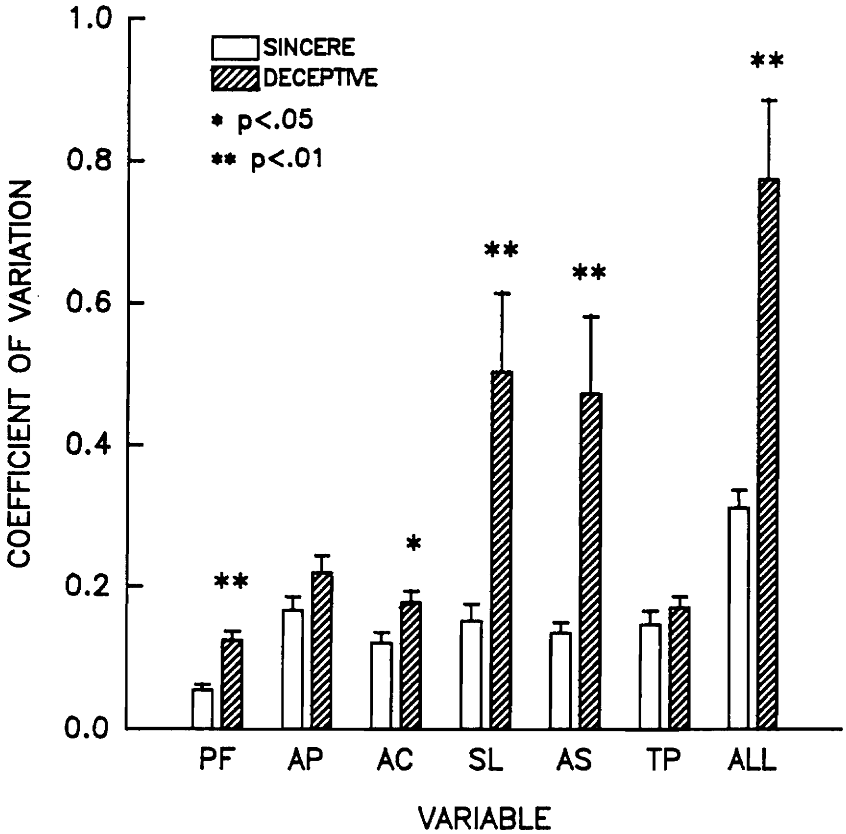

Figure 1: Coefficients of Variation for the Experimental Data Set

Conscious attempts at a deceptive behavior may require higher levels of processing than performances regulated by sensory inputs of pain, discomfort, and fatigue (Welford, 1978). Consider that when an individual has reduced sensory feedbacks while performing a task the individual may have to rely on higher-order mental capabilities. The higher order skills require capability to instantaneously interpret events, memory retention and verbal communication as well as the ability to apply knowledge acquired from one situation to another (Welford, 1980). A subject performing a deceptive contraction would have greater difficulty intterpreting feedback when using an isometric grip dynamometer, therefore they would have to use other skills to interpret the amount of force to apply to the handle. This would make one suspect that a deceptive response would have a longer build up phase, ie. lesser slope, greater time to peak. A response curve of a subject performing a sincere maximal contraction would have a steeper slope (Kroemer and Marras, 1980), less time to peak, less area to peak and of course a greater peak force.

The way a subject responds to pain will influence their behavior pattern. Sensory neurons provide information to the central nervous system (CNS) about the external environment or internal events that may influence activity; motor neurons transmit information from the CNS to the muscle to stimulate activity. In a simple two-stage system this is all that is required, the behavior is simply a response to internal or external stimuli. However, higher order activities require higher levels of processing resulting in a more complex behavior pattern (Darley et al., 1981). Kroemer and Marras (1980) theorized and demonstrated that submaximal efforts would require a longer build up phase than a maximal effort because of the amount of mental processing required for a submaximal effort. Therefore one would conclude that since a deceptive effort has been illustrated as a submaximal effort, a deceptive effort would require more processing than a true maximal effort whether limited by pain or not. This would indicate that there would be a more varied response to the task, therefore, a greater coefficient of variation for the deceptive condition than the sincere condition. This theory was supported by this investigation, cv = .50 $\pm$ .11 for slope (20%-80%) and cv = .47 $\pm$ .11 for average slope for the deceptive condition. The coefficients of variation for the sincere condition were slope (20% - 80%) cv = .15 $\pm$ .02 and average slope cv = .13 $\pm$ .01.

The major objective for this investigation was to develop and test a discriminant function prediction equation. Independent coefficients of variation for each variable were computed for each subject and substituted into the discriminant function equation to predict group membership. The next step was to determine which equation most accurately predicted group membership. The best single variable equation used the coefficients of variation of peak force. Using the single predictor, peak force, 88% of the sincere group and 60% of the deceptive group (73% overall) were correctly predicted. The inclusion of average slope inproved the percent of prediction significantly. The equation using the two variables peak force and average slope, predicted a higher percentage (77%) of the all subjects, (92% of the sincere group and 64% of the deceptive group). The results appear in Table 1. However the inclusion of an additional variable (AC) did not significantly improve the ability to predict group membership.

The following prediction equation was computed using NCSS:

$$\hat{y} = (\%PF)\ (24.05846) + (\%AS)\ (1.83693)$$

cut off score = 2.73.

where:

%PF = coefficient of variation for peak force;

%AS = coefficient of variation for the average slope.

Values greater than the cut off score were assigned to the sincere group (> 2.73) and values less than the cut off score were assigned to the deceptive group (< 2.73). These

Table 1

Correct classifications of the subjects into the sincere or deceptive conditions

	Experimental conditions		
Variables	Sincere N = 24 % correct	Deceptive N = 25 % correct	Overall % correct
PF	.88	.60	.73
TP*	.67	.48	.57
AP*	.71	.48	.59
AC*	.75	.64	.69
SL*	.88	.32	.59
AS	1.00	.32	.65
All variables	.88	.68	.78

* F ratio indicating the significance of this variable was not significant

predictions were then compared to actual condition assignments. The equation was significant at $F(6,42) = 9.94$, $p < .01$.

These findings were similar to the theory deveolped by previous studies (Gilbert & Knowlton, 1983; Kroemer & Marras, 1980) suggesting that slope is a strong indicator of group membership. However this investigation did not suggest that slope was the best indicator of group membership. A possible reason for this could have been the instructions given to the subject. It was possible that the instructions given to the subjects assigned to the deceptive condition were not specific enough regarding the length of time to hold the contraction and allowed the subjects to produce extremely short term contractions.

In summary this investigation did show a greater between trial variation with a deceptive hand grip response than with a sincere maximal contraction. With the coefficients of variation, a discriminant function equation was developed that was able to discriminate between a sincere maximal isometric grip strength contracrion and deceptive isometric grip strength contraction.

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CHAPTER IV

SUMMARY OF THE STUDY

This investigation was conducted to explore the between trial variability of the measures of the isometric peak force, time to peak force, area to peak force, area under the curve, slope (20%-80%), and average slope of subjects assigned to perform a series of four isometric grip strength responses. The subjects were instructed to provide either a series of maximal voluntary contractions (sincere) or a series of submaximal (deceptive) contractions. A discriminant function equation designed to predict group membership (sincere or deceptive) was also evaluated. Forty-nine subjects between 18 and 24 years of age were asked to participate in this study. All subjects were screened for injury to the wrist or hand and signed an informed consent form prior to the testing. All subjects completed a series of four grip strength trials across two testing sessions. The orientation session served to train the subjects to give either a maximal hand grip contraction or to fake an injury by giving a deceptive hand grip response. After the orientation procedures each subject was assigned to either the sincere (S) or the deceptive (D) experimental condition by a trained laboratory technician. The investigator unaware of the group assignment, collected the initial testing data.

The second testing session (retest) was also conducted by the principle investigator, who remained unaware of the subjects condition assignment. Each subject was tested using their preferred hand. Data were displayed and recorded on a IBM 286 computer. Analysis of the response curves was completed using the segmental curve analysis program (SCA) to derive the values for each of the six variables: Peak force, time to peak force, area to peak force, area under the curve, slope (20%-80%), and average slope. Coefficients of variation were computed for each of the experimental variables using data recorded during the second testing session. These values were then used to develop a discriminant function equation (NCSS) to predict group membership. Prediction accuracy was expressed as the number of correct predictions of group membership (sincere or deceptive).

Results and Discussion

Pearson Product Moment Correlations were calculated to estimate the reliability of the test variables across the two testing sessions. The reliability estimates ranged from r = .58 to .84 for the sincere condition and from r = -.09 to .64 for the deceptive condition. Other studies (Mathiowetz et al., 1984; Stratford et al., 1989) reported higher reliability estimates but used only the measure of peak force. Stratford et al. (1984) reported r=.96 with normal subjects and r=.98

with injured subjects. Mathiowetz et al, (1984) reported reliability estimates of 27 females r=.88 for the right hand and r=.92 for the left hand. Compared to this study in which r=.66 for the sincere condition and r=.48 for the deceptive condition.

All subsequent statistical analysis were conducted on the data set recorded during the second testing session (retest). The coefficients of variation were computed for each test variable. The deceptive condition displayed the greatest amount of variation across the six variables. The grand mean (all variables included) coefficient of variation for the sincere condition was .31 ± .02 compared to the grand mean coefficient variation for the deceptive condition which was .77 ± .11 ($p < .01$). The coefficients of variation for peak force were .05 ± .01 for the sincere condition and .12 ± .01 for the deceptive condition, which were significant at $p < .01$. The coefficients of variation for the other five variables were higher for the deceptive condition as well: TP cv = .15 ± .02 (S) and .17 ± .02 (D); AP cv = ..17 ± .02 (S) and .22 ± .02 (D); AC cv = .12 ± .01 (S) and .18 ± .02 (D) ($p < .05$); SL cv = .15 ± .02 (S) and .50 ± .11 (D) ($p <.01$); AS cv = .13 ± .01 (S) and .47 ± .11 (D) ($p < .01$).

The between group differences in the between trial variation of peak force was not consistent with the findings represented in the 1980 study reported by Kroemer and Marras, which stated that no significant variation between the sincere and deceptive conditions for the variable of peak force.

Conscious attempts at a deceptive behavior may require higher levels of processing than performances regulated by sensory inputs of pain, discomfort, and fatigue (Welford, 1978). Consider that when an individual has reduced sensory feedback while performing a task the individual may have to rely on higher-order mental capabilities. The higher order skills require capability to instantaneously interpret events, memory retention and verbal communication as well as the ability to apply knowledge acquired from one situation to another (Welford, 1980). A subject performing a deceptive contraction would have greater difficulty interpreting feedback when using an isometric grip dynamometer, therefore they would have to use other skills to interpret the amount of force to apply to the handle. This would make one suspect that a deceptive response would have a longer build up phase ie. lesser slope and greater time to peak. A response curve of a subject performing a sincere maximal contraction would have a steeper slope (Kroemer and Marras, 1980), less time to peak and of course a greater peak force.

The way a subject responds to pain will influence their behavior pattern. Sensory neurons provide information to the central nervous system (CNS) about the external environment or internal events that may influence activity; motor neurons transmit information from the CNS to the muscle to stimulate activity. In a simple two-stage system this is all that is required, the behavior is simply a response to internal or external stimuli. However, higher order activities require higher levels of processing resulting in a more complex behavior pattern (Darley et al., 1981). Kroemer and Marras (1980) theorized and demonstrated that submaximal efforts would require a longer build up phase than a maximal effort because of the amount of mental processing required for a submaximal effort. Therefore one would conclude that since a deceptive effort has been illustrated as a submaximal effort, a deceptive effort would require more processing than a true maximal effort whether limited by pain or not. This would indicate that there would be a more varied response to the task. Therefore, a greater coefficient of variation for the deceptive condition than the sincere condition. This theory was supported by this investigation, cv = .50 $\pm$ .11 for slope (20%-80%) and cv = .47 $\pm$ .11 for average slope for the deceptive condition. Compared to the coefficients of variation for the sincere condition slope (20% - 80%) cv = .15 $\pm$ .02 and average slope cv = .13 $\pm$ .01.

The major objective for this investigation was to develop and test a discriminant function prediction equation. Independent coefficients of variation for each variable were computed for each subject and substituted into the discriminant function equation to predict group membership.

The next step was to determine which equation most accurately predicted group membership. The best single variable equation used the coefficient of variation of peak force. Using the single predictor, peak force, 88% of the sincere group and 60% of the deceptive group (73% overall) were correctly predicted. The inclusion of avarage slope improved the percent of prediction. The equation using peak force and average slope predicted a higher percentage (78%) of the all subjects, (92% of the sincere group and 64% of the deceptive group). However the inclusion of an additonal variable (AC) did not significantly improve the ability to predict group membership.

These findings were similar to the theory developed by previous studies (Gilbert & Knowlton, 1983; Kroemer & Marras, 1980) suggesting that slope is a strong indicator of sincere or deceptive group membership. However in this investigation slope was not the best indicator. A possible reason for this could be the instructions given to the subjects. The instructions given to the subjects assigned to the deceptive condition were not specific enough regarding the length of time to hold the contraction and allowed the subjects to produce extremely short term contractions.

Further Research

The following recommendations for further research in this area were made by the investigator: 1) To cross-validate the discriminate function equation by using this equation with another sample of subjects. 2) To investigate the between trial variability of grip strength using the same experimental variables on subjects that have an injury to their hand. 2) To develop a standard isometric grip strength maximum voluntary contraction (MVC) model using the existing data measuring the between trial variability of peak force, time to peak, area to peak, area under the curve, slope (20% - 80%) and average slope.

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APPENDIX A

METHODOLOGY

METHODOLOGY

Selection of subjects

Forty nine (19 males, 30 females) college students volunteered to participate in this investigation. A trained laboratory technician gave the subjects a brief overview of the investigation prior to requesting that each subject complete a screening form (appendix B) and a informed consent (appendix C).

Experimental Organization

Subjects were seated in front of the hand grip dynamometer. Hand preference was determined by asking the subject which hand would they use to provide a maximal grip muscular contraction. Attached to a modified Jamar Hand Dynamometer was a Genesco AWU force transducer. Signals from the load cell were amplified by a Kube amplifier. This system was linear from 0-250 lbs (1111.1 N). Signals from amplifier were digitized and sampled at 1000 Hz by a MegaByte Das-16 A/D converter (12 bit resolution +/- 10 volts). The hand grip equipment was calibrated by hanging known weights from the load cell. The data was collected by an IBM compatible 286 based micro computer. The digitized signals were stored on magnetic disc for off line analysis. Digitized signals were first filtered by a Butterworth low-pass filter, 40 Hz, then the actual measurements were quantified using a program written in QuickBasic.

The subjects were instructed to adjust the grip to their preferred grip size. The grip measurements were then recorded for subsequent experimental trials. Using a strip chart recorder, the technician trained the subjects to give a maximal voluntary contraction (MVC) and a submaximal grip response of at least 25% of the MVC. The force curves were recorded and displayed on a Kipp and Zonen Strip Chart Recorder.

The subjects were randomly assigned by the technician to one of the two experimental conditions (sincere, S or deceptive, D). They were given a brief written scenario outlining their task. The subjects assigned to the sincere condition were instructed to perform four maximal hand grip responses exerting maximal force. The subjects assigned to the deceptive condition were instructed to perform in a manner appropriate for an injured person who was required to perform a maximal effort (appendix D).

Data collection test

When the technician determined that the subject was properly trained, the investigator entered the room and instructed the subject to provide four maximal grip contractions. The subjects provided a series of sincere grip responses or a series of deceptive grip responses, depending upon their assigned condition. The investigator was not aware of which condition the subjects had been assigned. After the experimental testing session, the investigator scheduled the subject for a second session (retest). The second session was scheduled 24-48 hours after the initial experimental period.

<u>Data collection retest</u>

During the second experimental session, the subjects were requested to perform their originally assigned experimental task scenario.

<u>Data analysis</u>

The experimental data from both testing sessions were recorded, displayed, and analyzed using a computer software program. The experimental variables recorded were: peak force, time to peak force, area to peak force, area under the curve, slope 20-80%, and average slope. Peak force was the greatest amount of force applied during the contraction. Time to peak force was the amount of elapsed time from the beginning of the curve to peak force. Area to peak force was the area under the curve measured from the lowest point prior to the curve up slope to the peak force. The area under the curve was the measurement of the area under the curve from lowest point prior to the up slope to the lowest point following the down slope. The slope was the measurement of the upward curve between 20% - 80% of the peak force. Average slope was the average of all slopes from the start to the peak force point. See Figure 2 (Appendix E) for descriptions of variables measured.

Reliability

The statistical program Number Cruncher (NCSS) was employed by the investigator to provide all statistical computations. Descriptive statistics are displayed in Table 2 (Appendix F). The mean peak force value for the sincere condition was 61.26 lbs (272.27 N) compared to the mean of the deceptive group 31.22 lbs (138.76 N). The mean for slope of the sincere condition was 1.59 lb/sec (7.1 N/sec) and the mean of the deceptive condition was 2.33 lb/sec (10.4 N/sec). T-test were computed to demonstrate the difference between condition data.

Stability (test-retest) reliability estimates were computed using Pearson Product Moment correlation. The greatest peak force, time to peak force, area to peak force, area under the curve, slope (20%-80%), and the average slope for each subject from the first testing session (test) was correlated with the data collected from the second testing session (retest). The stability reliability estimates for the sincere condition ranged from r=.58 to r=.84. The stability reliability estimates for the deceptive condition ranged from r=-.09 to r=.64. The reliability estimates appear in Table 3 (Appendix G).

All subsequent statistical analysis were conducted on the data set recorded during the second testing session (retest). Coefficients of variation for the retest data were computed for each test variable. The coefficients of variation appear in Table 4 (appendix H). Individual t-test were computed on the coefficient of variation to determine if the experimental conditions were significantly different. The average variation across all 6 variables for the sincere condition was cv = .31 $\pm$ .02. The average variation across all 6 variables for the deceptive condition was cv = .77 $\pm$ .11, t(DF=47) = 4.06, $p<.05$. The greatest variation within the sincere condition was cv = .17 $\pm$ .02 (the area to peak force). The least amount of variation recorded was peak force (cv = .05 $\pm$ .01). The deceptive condition displayed the greatest amount of variation across the six experimental variables. The average slope (cv = .50 $\pm$ .11) produced the greatest amount of variation. The least amount of variation was peak force (cv = .12 $\pm$ .01).

Using the data from the second testing session, coefficients of variation were computed for each subject for each variable. The coefficients of variation were substituted into the discriminant function equation and a prediction was made as to which condition each subject had been assigned. To determine which discriminant function equation to use a steqwise addition of variables were computed by the program. The stepwise equations appear in Table 5 and Table 6 (appendix I).

The prediction value (NCSS) for each subject was derived from the following prediction equation:

$$\hat{y} = (\%PF)\ (24.05846) + (AS)\ (1.83693)$$

the cut off score = 2.73.

<u>Where</u>:

%PF = coefficient of variation of peak force,

%AS = coefficient of variation for the average slope

The values greater than the cut off score were assigned to the sincere condition (> 2.73) and the values less than the cut off score were assigned to the deceptive condition (< 2.73). These predictions were then compared to actual condition assignments. The equation correctly classified 22 out of 24 (92%) in the sincere condition and 16 out 25 (64%) in the deceptive condition or 38 out of 49 (78%) overall, $F(6,42) = 9.94$, $p < .01$. The number of correct classifications for each variable and all variables combined appear in Table 1, page 44.

The raw data recorded during this investigation is located in appendix J.

APPENDIX B

SCREENING FORM

Screening Form

Name:______________________________ Date:__________

Local Address:______________________ Age:

Local Phone:________________________

1. Have you experienced any wrist pain in the last six months? YES or NO. If yes, please explain:

2. Have you ever sustained an injury or trauma or had any surgery to your wrist? YES or NO. If yes, please explain:

3. If you have an injury, surgery, or trauma to your wrist, do you feel that you have fully recovered from it? YES or NO. Do you feel that your involved limb has been fully rehabilitated? YES or NO. If no, please explain:

4. Do you feel in any way that you have any orthopaedic or medical problems that may hamper your performance in this isometric hand grip response? YES or NO. If yes, please explain:

Signature of Participant:______________________________

Date:__________________

Condition assigned to: GREEN RED

APPENDIX C

INFORMED CONSENT

Human Performance Laboratory

Division of Health, Physical Education and Recreation
Virginia Polytechnic Institute and State University

Informed Consent

I, ______________________________, do hereby voluntarily agree and consent to participate in a testing program conducted by the personnel of the Human Performance Laboratory of the Division of Health, Physical Education and Recreation of Virginia Polytechnic Institute and State University.

Title of Study: Discrimination Between Sincere and Deceptive Isometric Grip Response Using Segmental Curve Analysis

The purpose of this experiment is to develop a method to discriminate between normal and deceptive isometric hand grip response using segmental curve analysis.

I voluntarily agree to participate in this testing program. It is my understanding that my participation will include: completion of information pertaining to my medical condition as it relates to this study. Specifically, I will inform the investigator of any history of injury to the wrist which may predispose me injury as a result of my participation in this study. In addition, I will be involved in a short orientation and training session by a laboratory technician. I will participate in two approximately 15 minute isometric hand grip sessions conducted by trained personnel to familiarize me with the apparatus and the testing procedure, and to collect data for this study. If at any time I feel that I cannot proceed with the testing, I have the option to terminate the session. All medical information will be kept strictly confidential and will only be used for this research project.

The isometric hand grip response involves four maximal or submaximal contractions (depending on my group assignment) in 15 seconds using my preferred hand.

I understand that any data of a personal nature will be held confidential and will be used for research purposes only. I also understand the these data may be used only when not identifiable with me.

I understand that I may abstain from participation in any part of the experiment or withdraw from the experiment should I feel that the activities might be injurious to my health. The

experimenter may also terminate my participation should he feel the activities might be injurious to my health.

I understand that it is my personal responsibility to advise the researchers of any preexisting medical problems that may affect my participation or of any medical problems that might arise in the course of this experiment and that no medical treatment or compensation is available if injury is suffered as a result of this research.

I have read the above statement and have had the opportunity to ask questions. I understand that the researchers will, at any time, answer my inquiries concerning the procedures used in this experiment.

Scientific inquiry is indispensable to the advancement of knowledge. Your participation in this experiment provides the investigator the opportunity to conduct meaningful scientific observations designed to make significant educational contribution.

Signed_______________________________ Date______________

Witness_______________________________

APPENDIX D

EXPERIMENTAL CONDITION SCENARIOS

True Maximal Effort Scenario

During the isometric hand grip response test, you will perform four maximal isometric hand grip contractions within 15 seconds (squeeze to maximal grip and release). A maximal effort implies that you are exerting the greatest amount of force that you are physically capable of exerting.

Standardized Injury Scenario

You are a factory worker who has to lift large crates. Six months ago you injured your hand in an accident at the plant. Fully recovered now, you are attempting to fake your injury to collect workman's compensation. In order to collect you have to convince the examining physician that you are still injured. The investigator will instruct you to give four maximal contractions. You however, will give four contractions reflecting your injury.

APPENDIX E

DESCRIPTION OF VARIABLES

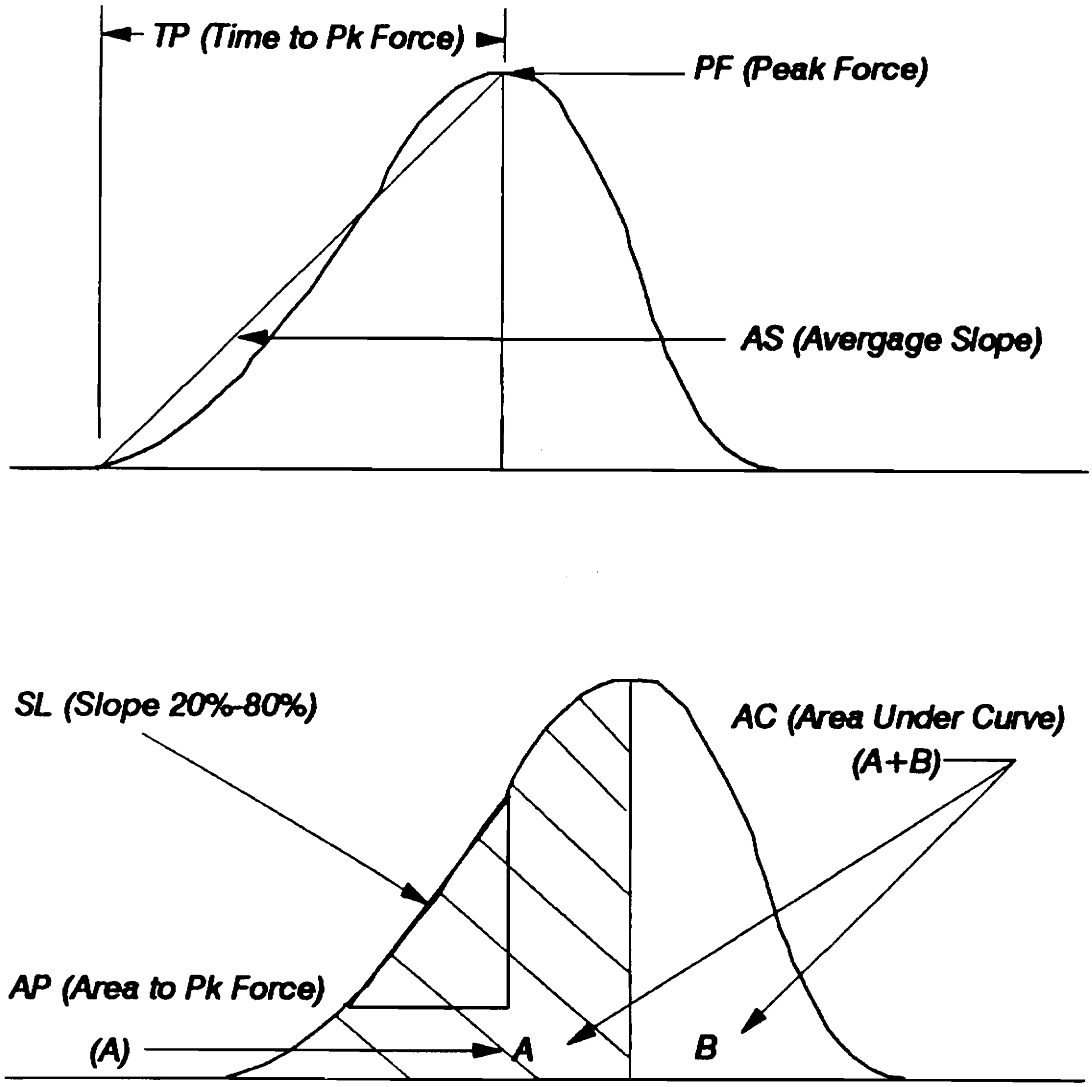

Figure 2: Measurements taken from the Response Curves

APPENDIX F

DESCRIPTIVE STATISTICS

Table 2

Descriptive statistics for the sincere (S) and the deceptive (D) conditions

Variable	Mean ± Std. Dev. Sincere	Deceptive
PF	61.2 ± 18.8	31.2 ± 11.1
TP	.9 ± .3	.9 ± .3
AP	46.3 ± 28.3	19.3 ± 9.7
AC	63.2 ± 41	28.3 ± 15.6
SL	1.6 ± .6	2.2 ± 3.2
AS	.7 ± .3	1.9 ± .2

PF = Peak Force
TP = Time to Peak Force
AP = Area to Peak Force
AC = Area Under the Curve
SL = Slope (20% - 80%)
AS = Average Slope

APPENDIX G

STABILITY RELIABILITY ESTIMATES

Table 3

Pearsons Product Moment correlation between the test- retest data set

Variable	Experimental conditions	
	Sincere	Deceptive
Peak force	r = .66	r = .48
Time to peak force	r = .58	r = .58
Area to peak force	r = .80	r = .62
Area under the curve	r = .84	r = .64
Slope (20%-80%)	r = .60	r = -.09
Average slope	r = .66	r = .03

APPENDIX H

COEFFICIENTS OF VARIATION

Table 4

Coefficients of variation for the experimental data set

	Experimental conditions	
	Sincere	Deceptive
Variable	$\bar{\bar{x}} = .31$	$\bar{\bar{x}} = .77$**
Peak force	.05	.12**
Time to peak force	.15	.17
Area to peak force	.17	.22
Area under the curve	.12	.18*
Slope (20%-80%)	.15	.50**
Average slope	.13	.47**

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

APPENDIX I

DEVELOPMENT OF THE DISCRIMINANT FUNCTION EQUATION

Table 5

Stepwise procedure for the development of the discriminant function equation

Model variables	F	P	Wilke's Δ
1. PF	21.7	< .05	.684
2. PF	15.6	< .05	.627
AS	4.2	< .05	
*3. PF	9.0	< .05	.615
AS	4.5	< .05	
AC	.9	NS	

* Stepwise procedure terminated after evaluation of the three variable equation

Table 6

Discriminant function equations and the percent of correct predictions

1.	PF	(%PF) (25.553)
	cut off score = 2.30	
	Correct predictions: 88% (S) 60% (D) 73% (overall)	
2.	PF, AS	(%PF)(24.058) + (%AS)(1.837)
	cut off score = 2.73	
	Correct predictions: 92% (S) 64% (D) 78% (overall)	

APPENDIX J

RAW DATA

RAW DATA: TEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
1	1	49.31	1.68	45.33	56.04	.33	.27
	2	63.57	3.02	56.61	102.91	.27	.21
	3	57.27	2.01	46.48	65.33	.71	.28
	4	47.00	1.18	26.38	63.41	.58	.40
2	1	73.69	1.07	35.42	48.80	2.47	.67
	2	70.55	1.16	38.74	50.96	2.23	.61
	3	68.09	1.54	42.29	52.92	2.06	.44
	4	67.40	1.34	45.41	57.65	2.20	.50
3	1	41.29	1.13	24.96	33.38	.52	.37
	2	32.42	1.26	21.01	28.43	.47	.25
	3	24.06	1.30	13.91	22.99	.27	.18
	4	34.04	1.08	18.25	35.55	.63	.31
4	1	54.71	1.22	33.45	46.93	.76	.43
	2	45.72	1.22	32.14	41.45	.63	.37
	3	45.72	1.11	33.49	41.12	.69	.40
	4	46.49	1.40	36.26	44.58	.61	.33
5	1	45.94	.87	23.52	32.45	1.53	.52
	2	44.02	.84	27.12	31.12	1.40	.52
	3	44.84	.74	19.90	32.33	1.88	.59
	4	44.16	1.08	32.99	36.55	1.35	.40
6	1	48.29	.74	18.24	26.57	1.15	.63
	2	18.36	1.08	10.17	17.22	.24	.17
	3	19.01	1.31	9.99	14.00	.36	.14
	4	27.87	1.18	10.28	20.92	.71	.23

RAW DATA: TEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
7	1	37.95	.87	17.70	26.53	.42	.36
	2	40.05	1.12	22.02	29.30	.38	.30
	3	36.45	.77	17.26	24.10	.37	.37
	4	37.26	.78	21.52	28.89	.62	.38
8	1	77.97	.66	24.71	32.74	2.46	1.17
	2	81.31	.77	37.86	62.21	2.39	1.05
	3	77.71	.72	32.03	55.64	2.49	1.07
	4	73.94	.87	37.20	56.15	2.22	.84
9	1	55.23	1.21	35.38	49.69	.82	.45
	2	53.46	1.19	35.48	50.50	.75	.44
	3	54.28	1.02	30.72	46.43	1.26	.51
	4	53.73	1.12	33.11	44.26	.81	.47
10	1	19.00	.79	9.53	13.54	.27	.20
	2	23.93	.98	11.82	17.20	.25	.22
	3	21.74	.93	9.89	13.44	.17	.19
	4	25.17	.80	11.11	16.13	.40	.28
11	1	27.48	1.13	9.44	13.15	.47	.23
	2	30.22	1.12	9.53	13.18	.61	.27
	3	33.09	1.16	13.70	18.38	.62	.22
	4	27.62	2.10	18.89	22.54	.27	.13
12	1	50.08	.97	22.19	30.34	.88	.50
	2	63.05	1.01	19.88	41.74	1.82	.62
	3	53.04	.78	15.00	41.67	1.44	.68
	4	49.70	.72	19.25	45.14	1.39	.69

RAW DATA: TEST

SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
13	1	33.39	.45	5.06	7.73	1.75	.73
	2	22.86	.45	3.78	5.78	1.00	.50
	3	20.80	.46	3.18	4.90	.95	.45
	4	26.20	.53	4.44	6.41	1.05	.48
14	1	67.68	1.08	37.25	52.54	.94	.60
	2	77.95	.95	36.76	58.78	1.16	.82
	3	67.03	.86	27.02	50.06	1.15	.78
	4	65.11	1.02	33.66	54.17	.82	.63
15	1	19.69	2.08	12.78	15.33	.15	9.27
	2	17.09	1.15	14.08	17.43	.14	.11
	3	20.78	1.37	17.07	25.13	.28	.15
	4	19.82	1.91	21.47	23.82	.22	.10
16	1	85.40	1.27	41.38	60.89	1.63	.65
	2	96.44	1.13	65.17	97.24	1.60	.84
	3	100.42	1.77	98.19	139.03	1.38	.57
	4	86.55	2.05	118.96	174.91	1.37	.42
17	1	73.97	.63	32.74	42.92	2.78	1.16
	2	79.49	.61	30.35	43.04	2.56	1.30
	3	78.85	.73	35.07	47.18	2.73	1.07
	4	77.18	.45	23.07	47.77	3.06	1.72
18	1	13.81	2.00	15.49	18.56	.12	5.95
	2	13.26	1.02	9.63	14.94	.22	.11
	3	14.77	1.12	11.43	15.26	.20	.11
	4	16.27	1.16	13.52	18.32	.24	.13

RAW DATA: TEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
19	1	36.09	1.18	24.68	39.07	.35	.28
	2	44.02	1.21	30.41	47.65	.56	.36
	3	47.03	1.03	26.04	50.69	.66	.45
	4	41.15	1.22	30.52	50.92	.53	.33
20	1	42.12	.95	22.82	27.69	.56	.44
	2	41.48	.88	21.11	26.12	.57	.47
	3	37.37	.97	20.31	25.72	.51	.38
	4	40.45	1.16	26.04	31.37	.48	.35
21	1	119.04	.82	51.27	86.88	2.40	1.45
	2	120.58	.84	71.92	98.68	2.94	1.43
	3	118.53	.86	67.37	95.73	3.23	1.38
	4	115.71	1.02	79.76	108.13	3.07	1.13
22	1	51.68	1.48	46.47	69.18	1.02	.32
	2	51.95	1.27	30.88	59.14	.62	.39
	3	51.54	1.27	30.88	59.14	.62	.39
	4	53.59	1.43	34.78	56.02	1.28	.37
23	1	11.81	.77	4.15	5.23	.28	.15
	2	14.00	.75	5.20	7.17	.28	.18
	3	14.77	.72	5.74	7.67	.31	.20
	4	14.13	.79	6.32	8.04	.25	.18
24	1	121.23	1.25	110.30	167.20	2.29	.96
	2	107.23	1.04	67.19	135.94	2.26	1.03
	3	112.75	1.39	105.96	148.96	1.47	.81
	4	101.71	1.47	99.75	154.38	1.62	.69

RAW DATA: TEST

SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
25	1	45.08	.78	14.51	23.25	.83	.55
	2	46.36	.73	15.96	22.37	1.09	.63
	3	37.76	.61	11.36	16.02	1.00	.61
	4	55.86	.81	20.89	26.84	.96	69
26	1	48.54	1.15	28.28	35.70	.52	.41
	2	39.10	1.53	22.71	30.54	.52	.25
	3	34.73	1.61	27.65	38.64	.35	.21
	4	41.45	1.65	32.67	41.51	.48	.24
27	1	49.08	.64	15.83	23.50	1.53	.76
	2	47.44	.67	18.81	25.54	1.67	.70
	3	44.30	.56	13.74	20.38	1.50	.78
	4	44.43	.54	12.77	19.20	1.77	.81
28	1	22.01	1.39	17.68	24.66	.29	.14
	2	17.50	1.88	16.04	18.66	.15	8.94
	3	19.28	1.68	13.19	19.10	.13	.11
	4	14.77	1.61	11.77	15.75	.11	9.17
29	1	66.72	1.23	62.77	78.24	1.93	.54
	2	62.75	1.23	56.93	75.64	1.82	.51
	3	61.39	1.17	45.44	64.99	1.94	.52
	4	62.21	1.51	56.56	74.80	1.81	.41
30	1	84.62	1.27	38.48	80.98	2.69	.65
	2	80.96	.98	41.43	79.24	2.55	.82
	3	73.59	1.07	45.33	75.57	2.42	.68
	4	77.07	1.03	51.81	81.00	2.19	.73

RAW DATA: TEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
31	1	67.68	1.10	30.40	44.36	1.77	.61
	2	73.15	1.06	39.22	49.89	1.44	.69
	3	73.28	.99	33.64	47.40	1.57	.73
	4	73.42	.85	34.63	43.84	1.49	.84
32	1	30.63	.97	16.94	20.00	.67	.31
	2	31.99	1.02	19.12	24.94	.87	.31
	3	33.63	1.22	19.20	26.16	1.03	.27
	4	39.38	.81	25.12	29.30	1.41	.46
33	1	48.99	.92	26.57	34.44	.80	.49
	2	64.17	1.06	27.63	35.86	1.54	.59
	3	34.73	.88	18.03	24.17	.74	.39
	4	37.43	1.17	20.02	25.25	.44	.32
34	1	14.08	1.67	18.45	20.59	.20	7.12
	2	17.50	1.34	8.64	12.69	.26	.13
	3	18.05	1.45	13.96	17.05	.19	.12
	4	25.57	1.18	15.55	21.66	.32	.21
35	1	15.04	1.06	8.35	11.60	.14	.14
	2	20.65	1.17	12.22	17.04	.16	.17
	3	19.82	.96	9.14	17.91	.22	.20
	4	19.96	.98	10.64	15.33	.23	.20
36	1	20.42	1.03	9.39	16.26	.29	.20
	2	23.50	.98	14.29	18.36	.46	.24
	3	31.85	.99	17.63	25.54	.38	.32
	4	26.71	1.03	20.61	25.60	.44	.26

RAW DATA: TEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
37	1	36.64	1.37	38.80	48.51	.63	.23
	2	33.09	1.33	27.73	50.79	.42	.24
	3	38.69	1.21	30.46	42.52	.70	.30
	4	34.86	1.16	28.87	37.78	.65	.29
38	1	13.54	.90	8.09	10.35	.35	.15
	2	15.18	.61	5.08	11.65	.37	.25
	3	14.63	.68	6.48	10.46	.49	.21
	4	16.00	.81	8.56	12.30	.41	.20
39	1	21.74	.71	8.60	13.07	.43	.29
	2	20.37	.93	9.15	15.97	.35	.21
	3	24.20	1.30	13.83	18.88	.25	.19
	4	20.37	1.56	13.00	15.76	.17	.13
40	1	80.66	1.05	56.74	73.28	1.65	.74
	2	81.76	1.26	61.96	83.27	1.38	.63
	3	80.39	.89	44.28	70.24	1.66	.88
	4	79.02	.99	51.23	85.90	1.82	.78
41	1	41.53	1.62	37.42	48.52	.34	.24
	2	43.99	1.47	35.15	45.61	.50	.29
	3	49.00	1.22	39.12	51.49	.81	.40
	4	39.75	1.32	31.68	36.38	.38	.29
42	1	25.53	.82	12.29	19.54	.43	.27
	2	58.86	1.22	34.15	42.18	.60	.47
	3	63.73	1.24	37.32	47.02	.72	.51
	4	77.63	1.13	41.11	54.37	1.02	.68

RAW DATA: TEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
43	1	67.13	1.54	61.77	85.05	1.45	.44
	2	71.06	1.42	53.05	70.27	1.37	.49
	3	66.08	1.23	58.52	75.25	1.14	.48
	4	67.76	.99	49.92	66.19	1.50	.60
44	1	57.92	1.49	40.67	50.63	1.06	.39
	2	60.49	.69	20.71	41.64	2.05	.87
	3	54.83	.71	25.85	37.79	1.93	.77
	4	57.79	.72	22.40	42.40	1.34	.80
45	1	29.12	.64	11.43	15.32	.65	.45
	2	29.94	.56	10.96	17.53	.91	.53
	3	27.75	.72	13.94	18.95	.71	.38
	4	32.27	.82	18.94	25.02	.74	.39
46	1	29.14	2.08	31.97	37.39	.18	.13
	2	36.91	2.02	40.29	49.31	.26	.18
	3	42.89	1.72	43.20	54.43	.32	.25
	4	39.19	1.77	21.62	51.04	.34	.22
47	1	39.51	.77	12.96	18.69	.85	.51
	2	55.51	.69	17.06	23.33	1.44	.80
	3	45.80	.77	16.82	20.90	.75	.59
	4	41.84	.68	12.80	17.20	1.04	.61
48	1	58.93	.73	29.60	45.08	2.28	.79
	2	59.75	.96	34.29	47.33	1.69	.62
	3	55.23	1.01	34.79	51.14	1.51	.54
	4	51.00	.94	29.33	41.29	1.52	.54

RAW DATA: TEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
49	1	60.43	1.01	32.53	43.91	1.02	.55
	2	60.84	.67	25.96	42.23	1.97	.88
	3	66.17	.77	35.12	50.32	1.92	.84
	4	64.67	.88	32.36	58.49	1.84	.73

RAW DATA: RETEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
1	1	34.59	1.78	26.35	40.83	.24	.18
	2	34.86	1.58	23.08	42.95	.45	.22
	3	31.99	1.69	24.04	33.63	.29	.19
	4	32.81	1.31	21.28	31.87	.38	.25
2	1	66.45	1.21	36.45	50.41	1.90	.55
	2	63.16	1.03	28.76	42.53	1.80	.61
	3	62.62	.81	26.89	40.17	1.90	.77
	4	60.15	1.09	32.41	41.08	1.74	.55
3	1	27.48	.82	10.74	15.16	.61	.34
	2	33.50	1.17	17.69	23.48	.52	.29
	3	30.49	1.16	16.41	23.18	.54	.26
	4	33.50	1.26	15.34	29.59	.69	.26
4	1	34.42	1.31	20.49	34.65	.57	.25
	2	39.42	1.36	33.74	46.24	.61	.28
	3	38.14	1.38	33.74	41.76	.47	.27
	4	38.78	.87	16.80	42.14	.70	.44
5	1	47.03	1.00	29.26	35.78	1.16	.46
	2	43.89	.64	19.52	24.16	2.02	.68
	3	46.21	.63	18.12	25.87	1.80	.73
	4	47.58	.80	25.73	32.61	1.42	.59
6	1	16.00	.62	4.41	10.70	.44	.24
	2	19.69	1.05	12.40	15.19	.27	.16
	3	16.27	.42	3.87	8.65	.42	.34
	4	12.99	.40	2.98	5.40	.43	.29

RAW DATA: RETEST

SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
7	1	12.17	.52	4.43	9.05	.17	.15
	2	10.66	.67	5.15	8.41	8.20	7.96
	3	15.31	.73	6.92	11.10	.11	.12
	4	13.13	.59	5.23	11.93	.11	.12
8	1	63.16	.85	27.11	46.27	1.90	.72
	2	67.13	.84	40.29	56.31	2.04	.79
	3	65.35	.70	29.73	51.41	2.07	.93
	4	64.67	.75	35.14	49.83	2.27	.86
9	1	46.90	.84	13.98	27.20	1.09	.56
	2	52.50	1.11	29.69	44.40	.85	.46
	3	54.00	1.23	35.29	52.46	.83	.43
	4	53.32	1.23	37.42	49.76	.99	.42
10	1	13.81	.99	7.78	16.01	.13	.11
	2	14.22	1.21	10.96	17.55	9.23	8.36
	3	14.63	1.05	8.65	13.93	.10	.11
	4	16.82	.85	7.27	11.49	.21	.17
11	1	13.67	.83	5.89	8.10	.33	.16
	2	16.13	.52	4.58	8.34	.57	.31
	3	19.69	1.03	9.27	12.31	.24	.19
	4	19.41	.96	8.13	15.10	.39	.20
12	1	31.17	1.26	8.85	17.24	1.01	.25
	2	31.86	.88	16.93	21.06	.46	.35
	3	30.76	.90	20.69	25.76	1.01	.32
	4	35.41	.70	15.64	21.38	.65	.47

RAW DATA: RETEST

SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
13	1	29.41	.67	8.65	11.26	.72	.42
	2	43.28	.66	10.49	14.70	1.28	.65
	3	38.14	.45	6.94	10.21	1.37	.83
	4	38.52	.41	6.49	9.66	1.49	.92
14	1	34.29	.67	12.01	21.80	.54	.45
	2	40.07	.88	18.06	25.38	.80	.43
	3	32.10	.73	12.08	19.58	.61	.41
	4	42.89	.85	19.77	31.98	.82	.47
15	1	9.71	.79	3.59	6.05	.14	.12
	2	10.25	1.09	5.31	8.71	.15	9.28
	3	13.95	1.72	11.80	13.56	.13	.08
	4	11.35	1.13	5.84	10.00	.21	.10
16	1	55.10	1.34	50.10	70.85	.88	.40
	2	64.67	1.51	63.20	83.52	.77	.40
	3	73.56	1.86	105.89	144.82	.95	.34
	4	78.89	3.23	138.91	166.05	.32	.24
17	1	70.37	.52	19.28	31.45	3.35	1.32
	2	66.78	.57	23.04	31.08	2.59	1.14
	3	67.42	.61	27.48	35.29	2.75	1.09
	4	66.39	.83	38.65	47.46	2.42	.79
18	1	11.07	1.68	8.17	16.25	6.91	5.94
	2	13.26	1.08	8.75	13.68	.17	.11
	3	16.82	1.27	11.00	14.23	.15	.13
	4	13.81	1.29	11.26	14.30	.17	.10

RAW DATA: RETEST

SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
19	1	26.11	.92	12.33	21.55	.46	.28
	2	25.29	1.20	19.55	28.83	.41	.21
	3	34.04	1.16	20.65	36.63	.45	.29
	4	41.15	.76	15.73	31.65	.89	.54
20	1	70.00	1.49	63.01	72.87	.86	.46
	2	73.69	1.33	60.11	69.65	.93	.54
	3	72.05	1.36	58.52	72.05	.84	.52
	4	69.18	1.38	63.56	88.04	1.09	.49
21	1	65.75	1.49	59.19	68.44	.81	.44
	2	69.22	1.33	56.46	65.42	.88	.51
	3	67.68	1.36	54.97	67.68	.79	.48
	4	64.98	1.38	59.70	82.81	1.02	.46
22	1	50.18	1.32	40.72	81.15	1.03	.36
	2	51.27	1.01	26.31	76.40	.82	.50
	3	48.26	1.29	44.17	65.23	1.16	.37
	4	58.65	1.21	42.21	70.09	.98	.48
23	1	48.81	1.16	23.15	35.75	1.32	.42
	2	50.59	.91	30.28	43.22	1.30	.49
	3	50.72	1.01	32.46	46.63	1.09	.44
	4	50.45	.97	34.27	45.37	1.17	.44
24	1	99.27	.89	52.77	98.62	2.11	1.11
	2	115.32	1.21	85.13	114.02	1.97	.95
	3	123.41	1.35	99.83	151.44	1.79	.91
	4	110.95	1.28	79.16	187.67	1.87	.87

RAW DATA: RETEST

SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
25	1	59.06	.76	21.61	31.09	1.46	.72
	2	64.81	.65	24.57	41.97	2.13	.99
	3	68.77	.79	31.19	46.22	2.32	.84
	4	70.82	.88	35.98	50.59	2.20	.77
26	1	25.57	1.71	18.44	26.03	.19	.15
	2	22.56	2.09	27.74	31.22	.11	.11
	3	24.06	2.23	25.81	31.29	.15	.11
	4	20.65	1.70	17.76	19.94	.11	.12
27	1	49.22	.71	17.78	23.77	1.41	.69
	2	44.30	.64	15.42	22.80	1.35	.69
	3	43.07	.58	14.32	20.99	1.39	.74
	4	38.15	.51	10.25	19.26	1.38	.75
28	1	30.76	1.07	11.03	30.36	.89	.28
	2	21.74	1.22	15.96	21.58	.27	.17
	3	27.07	1.23	13.67	17.98	.30	.21
	4	17.91	.98	8.42	11.40	.19	.18
29	1	57.83	1.47	52.34	91.72	1.03	.38
	2	59.20	1.31	59.95	91.59	1.48	.45
	3	58.52	1.48	64.43	92.28	1.34	.39
	4	54.55	1.95	80.68	90.44	1.25	.28
30	1	56.88	.87	37.43	59.89	2.22	.59
	2	56.60	1.00	36.50	51.42	1.65	.53
	3	55.78	.79	29.27	58.51	1.61	.66
	4	51.13	1.23	40.62	65.14	1.21	.39

RAW DATA: RETEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
31	1	57.01	.56	17.25	26.43	1.64	1.00
	2	59.75	1.19	24.00	33.10	1.40	.50
	3	56.88	.84	19.05	26.62	1.47	.68
	4	57.83	.73	20.41	28.54	1.63	.79
32	1	35.41	.76	18.95	27.04	.93	.42
	2	36.50	1.03	26.84	33.78	.92	.31
	3	40.53	.91	24.18	29.05	.41	.39
	4	41.29	.77	25.37	30.87	1.51	.50
33	1	23.79	1.63	19.66	29.59	.21	.14
	2	18.59	1.53	12.38	21.28	.23	.12
	3	19.82	1.18	10.51	20.92	.35	.17
	4	21.88	1.36	11.06	17.52	.38	.15
34	1	12.31	1.12	8.48	10.61	.16	.10
	2	24.88	1.66	12.55	18.42	.30	.15
	3	25.29	1.41	13.72	18.54	.26	.18
	4	29.94	1.11	12.53	18.15	.37	.27
35	1	27.21	.90	13.78	18.87	.52	.30
	2	26.60	1.41	25.32	29.87	.31	.30
	3	24.75	1.58	20.20	26.45	.30	.16
	4	26.11	1.14	16.54	22.69	.33	.23
36	1	59.34	1.09	41.08	66.47	1.25	.48
	2	70.14	1.60	68.42	82.98	1.35	.43
	3	65.90	1.67	62.83	74.04	1.39	.37
	4	71.23	1.58	62.22	80.90	1.47	.42

RAW DATA: RETEST

SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
37	1	37.60	.91	20.24	31.85	.83	.39
	2	35.00	1.35	26.87	35.28	.54	.25
	3	29.40	1.26	23.52	37.11	.39	.23
	4	26.66	1.34	23.33	33.08	.28	.20
38	1	14.49	.89	8.05	10.07	.31	.16
	2	18.46	.67	6.73	13.41	.34	.27
	3	22.83	.62	9.38	16.91	.68	.37
	4	25.02	.67	9.30	13.19	.64	.37
39	1	18.59	1.03	8.50	11.35	.26	.18
	2	18.32	.93	6.86	9.78	.20	.19
	3	15.72	1.11	6.31	8.88	.23	.14
	4	16.13	.95	6.40	9.68	.25	.17
40	1	79.16	1.04	51.45	69.10	1.52	.73
	2	81.21	1.13	58.66	77.29	1.94	.71
	3	81.62	1.13	56.50	86.67	1.89	.71
	4	81.21	1.09	57.99	92.57	2.16	.74
41	1	20.10	1.72	19.33	23.14	9.83	.11
	2	25.43	1.01	14.60	20.83	.32	.25
	3	26.39	1.30	17.54	23.17	.35	.20
	4	24.75	1.28	15.72	21.15	.36	.19
42	1	17.09	1.46	11.41	17.15	7.36	.09
	2	20.51	1.11	9.82	13.95	.13	.15
	3	31.45	1.33	17.10	29.93	.22	.20
	4	28.44	.92	10.63	17.56	.48	.27

RAW DATA: RETEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
43	1	45.66	1.35	31.98	44.27	1.23	.33
	2	47.85	1.29	33.94	45.26	1.24	.35
	3	53.05	1.27	28.65	43.62	1.11	.42
	4	58.11	1.22	25.70	43.75	1.22	.47
44	1	57.92	1.49	40.67	50.63	1.06	.39
	2	60.49	.69	20.71	41.64	2.05	.87
	3	54.83	.71	25.85	37.79	1.93	.77
	4	57.79	.73	22.97	42.40	1.35	.79
45	1	27.21	.78	21.16	17.29	.51	.35
	2	31.17	.88	14.69	21.83	.61	.35
	3	33.09	.88	16.58	24.20	.48	.37
	4	27.21	.95	12.90	25.60	.54	.28
46	1	21.47	2.93	31.98	37.24	.14	7.09
	2	24.47	1.52	19.89	35.88	.17	.16
	3	20.78	2.24	27.40	34.98	.11	8.97
	4	16.82	1.31	12.86	27.25	.19	.12
47	1	36.78	1.14	16.02	20.40	.76	.32
	2	37.32	.82	16.92	20.61	1.07	.45
	3	50.45	.94	21.99	26.04	.81	.54
	4	48.81	.79	19.33	24.60	.94	.62
48	1	54.69	.94	27.04	40.24	1.76	.58
	2	45.66	1.13	24.07	32.72	1.26	.40
	3	48.54	1.02	28.70	36.87	1.24	.47
	4	44.98	.87	25.69	34.47	1.20	.52

RAW DATA: RETEST							
SJT	TRIAL #	PEAK FORCE	TIME TO PEAK	AREA TO PEAK	AREA UNDER CURVE	SLOPE	AVE. SLOPE
49	1	55.23	1.01	27.57	38.99	1.65	.55
	2	64.67	1.04	32.63	54.99	1.53	.62
	3	71.50	1.31	45.54	60.79	1.28	.54
	4	70.27	1.15	41.47	60.05	1.71	.61

VITA

Molly Stout was born in Wichita, KS, on June 11, 1964. She is the middle child of five children. When she was young she competed in gymnastics for 10 years. In addition to gymnastics, Molly was a diver on her high school swimming team. She graduated form the university of Kansas in May 1988, with a Bachelor of science in Exercise Science. After College, Molly moved to Kansas City, Missouri, where she began working for Trinity Lutheran Hospital in the Center for Wellness and Cardiac Rehabilitation department. After working for two years Molly decided to return to school for a Masters in Education in Exercise Science at Virginia Polytechnic Institute and State University.

Molly Stout