HORIZONTAL STRENGTH CHANGES: AN ERGOMETRIC MEASURE FOR DETERMINING VALIDITY OF EFFORT IN IMPAIRMENT EVALUATIONS A PRELIMINARY REPORT

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ABSTRACT

This study examines horizontal strength changes as a measure of determining maximum effort when using a standardized isometric strength protocol. A non-injured working sample was used to establish a cutoff for horizontal lift changes, that would be deemed as either appropriate or inappropriate. These cutoff scores were then applied to disability claimants involved in medico-legal proceedings. The results demonstrate that "inappropriate" horizontal strength changes may be used to indicate submaximal effort on the part of a patient during strength testing.

KEY WORDS: ISOMETRIC STRENGTH, INAPPROPRIATE HORIZONTAL STRENGTH CHANGE, MAXIMUM EFFORT, SYSTEM MAGNIFICATION SYNDROME, DISEVALUATION

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INTRODUCTION

The continuing disability claim crisis in this country has resulted in the adoption of state-mandated guidelines for determining impairment. Still, the presenting symptoms - limited motion, weakness, and pain - remain subjective in nature, placing the disability evaluating clinician at risk for making determinations that have little or no objective support. Some strides have been made to remedy this situation, including the incorporation of a validity factor during inclinometer measurements and a discussion of reliability of grip strength testing in the American Medical Association revised *Guides to the Evaluation of Permanent Impairment.*[1] While the AMA guides provide for establishment of impairment due to loss of strength, it remains difficult to determine if the impairment represents a true loss or if the patient's lack of effort obscures the clinical picture. Excessive performance variability has been used to indicate that an examinee is not using organic nociceptive input to determine the point of maximum exertion as described by Kroemer, Khalil, et al,[11,12] or force until discomfort as described by Harber and Soohoo.[10] Biomechanical ergometric technology was pioneered by Chaffin and others.[2-6] Subsequently, numerous studies have suggested strength norms and normative coefficients of variation for both normal and injured populations using static strength-testing units, the Jamar hand dynamometer, and several tools of the BTE.[4,7-10] Multiple choices are available to the physician for evaluating strength as well as the validity of the patient's effort during strength testing. No singular method is accepted at this time, although upper-extremity strength testing utilizing the Jamar hand dynamometer is a widely accepted strength testing device.

An ideal measure of maximum effort should be based on biomechanics that are stable across populations and obviate comparison of non-equivalent populations. Such a mechanism was suggested by Harber and SooHoo in their discussion of static ergonomic strength testing.[10] The premise is that, given a constant vertical height, an increase in horizontal distances from the load lifting capacity should diminish. Computerized biomechanical models that allow calculation of compression forces on various spinal levels suggest that this is indeed true. According to the *Work Practices Guide for Manual Lifting,* there is a "simple inverse linear relation between the maximum weight lifted and the horizontal location of the load."[7]

SUBJECTS

This study includes two separate sets of subjects. The first subject sample consisted of 49 individuals who had been referred by their employers for post-hiring strength and range of motion testing. The members of this sample had no previous neck or back injuries, and their future employment did not depend on the test results. These individuals were employed in jobs designated as medium or above in the *Dictionary of Occupational Titles.*

The second subject sample was not matched to the initial subject sample because the evaluations were based on biomechanical changes that should be stable across populations. These subjects were selected over a 6-month period from disability claimants evaluated at the Willis-Knighton Centers for Occupational Medicine. All patients in the injured group were at least 6 months post-injury. None were currently employed, and all showed a medicolegal involvement.

MATERIALS AND METHODS

Both groups were tested using isometric strength testing devices that used strain gauge technology as described by Chaffin.[2] These instruments collect data via a strain gauge attached to a load cell.

The protocol for both groups involved the use of the first, second, and seventh positions from the standardized protocol adapted from Keyserling's work[4] (Table 1). These three positions involved lifting from a fixed vertical height. The first, second and seventh positions were then altered by ±10 in to a constant vertical height with changes in the horizontal distance. The first and seventh position were moved 10 in closer to the lifting individual, and the second position was moved 10 in away from the individual. Each task was demonstrated to the subject before the performance of the task. The subjects were instructed to lift using maximum effort without experiencing "undue discomfort" or placing themselves at risk for injury. Instructions were given without encouragement, and no encouragement was given once the subject began to perform the task. The subjects performed three trials of each task with a minimum of 2 minute rest periods between exertions. The subjects were allowed to rest longer than 2 minutes but not more than 5 minutes. After a subject had performed the three trials at the established vertical height, the horizontal distance was changed and the subject then performed a single lift at the altered horizontal position. The subjects were allowed a 2-to-5 minute rest period between all exertions. Each trial lasted 5 seconds; the exertion during the last 3 seconds of the lift was averaged to arrive at the measurement for that lift. Performance information was not shared with the subjects during the test period.

Mean exertions for all tasks were calculated using the means of the three trials. The mean exertions for tasks 1, 2, and 7 were compared to the single horizontal change exertion to determine whether the change in strength could be classified as appropriate based on biomechanical modeling.

Table 1. — Standard Lifting Positions

	Horizontal	Vertical	Instruction
Task 1	10	6	Lift
Task 2	15	15	Lift
Task 3	13	62	Pull
Task 4	14	49	Push
Task 5	15	44	Push
Task 6	Determined by Height		Lift
Task 7	10	60	Lift

RESULTS

The non-injured group was evaluated to establish a cutoff score that would represent either a pass (be appropriate) or fail (inappropriate) based on their strength measurement. Because these post-hire non-injured individuals had no history of injury, their effort should represent an acceptable maximum effort. Because the horizontal strength changes would be based on ergometric modeling, it was not necessary to match the normal population to any subsequent injured population. Horizontal strength changes should remain constant for all populations without regard to sex, age, height or weight. The measurement is a change in isometric strength when the horizontal position is changed by 10 in and the vertical position remains the same during the three lifts. Initially, the action limit was calculated for these lifts as recorded in Table 2. The action limit represents the amount of isometric force at which the L5/S1 disc experiences a compression of 770 pounds. This also represents the force that 75% of the women and 99% of the men should be able to generate when performing an isometric lift.[7] Calculations were made using the University of Michigan 2D Biomechanical Model Software. The results of action limit calculations for constant vertical height at 2 horizontal distances are shown in Table 2. Moving 10 in away from the load for these particular tasks decreased the action limit by 50%. Moving 10 in closer to the load increased the action limit by 100%.

Table 2. — Action Limit Determinations

Horizontal	Vertical	Action Limit
10	6	41
20	6	20.5
15	15	30
5	15	60
10	60	38
20	60	19

Examination of the efforts obtained from the normal subject sample yielded the following information. The horizontal distance for the first position (squat lift) was moved 10 in farther from the subject and decreased a mean 60.337% (S = 8.97). The horizontal change for the second position (back lift), in which the load was moved 10 in closer to the subject, showed a mean increase of 116.738% (S = 44.53). Horizontal change for the seventh position (high near lift) was once again moved 10 in farther from the subject and decreased a mean 51.977% (S = 12.97). The mean decrease for the first and seventh positions corresponded very closely to the expected percent change based on action limit analysis. An increase for the second position was greater than expected using these calculations.

The data were analyzed to determine an appropriate percentage cutoff of either increased or decreased strength that would yield the least number of false positives in this normal population. Using a 50% change as the cutoff score, 10.2% failed in the first position, 6.12% failed in the second position, and 42.86% failed in the seventh position. These "failures" represent false positive errors because the normal subjects should not demonstrate inappropriate horizontal strength changes and therefore should not fail. The higher number of failures in the seventh position was felt to be due to the subjects' tendency to lean toward the load after it had been moved 10 in away, despite instructions not to do so. The cutoff percentage was then recalculated to reduce the false positive rate, establishing a lower cutoff rate of 33% change in the appropriate direction. With this as the cutoff, 0% failed in the first position, 2.04% failed in the second position, and 6.12% failed in the seventh position.

A cutoff score of 33% over the main lift for the second position and a decrease of 33% over the main lift for the first and seventh positions were therefore established. An inappropriate horizontal strength change (IHSC) occurs when an individual fails to demonstrate the increase or decrease in isometric strength within the parameters established above. For example, if the subject's mean squat lift was 60 lb, the horizontal change for the squat lift would be considered appropriate if it were ≤40 lb. If it were >40 lb, the subject would have failed the test, and this would be considered an IHSC. The number of IHSC among normal subjects was examined based on the cutoff of 33%. Of these 49 individuals, 8.16% had 1 IHSC and 0% had more than 1 IHSC. This provided further evidence of the minimal number of false positives when 33% change was the cutoff score.

Using a cutoff of 33% for the population of nonworking disability claimants revealed 1 or more IHSC in 59%. Of the total sample, 37% had 1 IHSC, 17% had 2 IHSC, and 5% showed 3 of 3 possible inappropriate changes. These disability claimants demonstrated a much higher incidence of IHSC than the normal population: 22% with >1 IHSC vs 0%, respectively.

DISCUSSION

Reviewing a normal population enabled us to establish a percentage cutoff to define "inappropriate" strength changes. Establishing a minimum of a 33% increase or decrease in isometric force with a respective 10 in decrease or increase in horizontal distance at a constant vertical height minimizes false positives. None of the normal subjects demonstrated 2 or more inappropriate changes or false positives, in clear contrast to the disability population. The overall incidence of inappropriate changes significantly increased from 8% to 59% of the individuals tested. The percentage of normal individuals with 2 or more changes was 0% and of the disabled population, 22%. Statistical analysis showed this ergometric measure for determining validity of effort to be significant. These inappropriate horizontal strength changes, as defined in this study, utilized a method based on biomechanical modeling to evaluate patient effort during isometric strength testing. A score of 2 or more IHSC seems to indicate submaximal effort on the part of the subject being tested.

Further study is underway to evaluate the false-positive and false-negative rates in various normal and injured populations. Additionally, we are investigating the correlation between inappropriate horizontal strength changes and other ergometric tests that have been used to identify symptom magnification syndrome. This investigation is being done since the percentage of disability claimants in group 2 that had ≥2 IHSC (22%) is similar to the recorded incidents of symptom magnification syndrome in other disability claimant populations.

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