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Research Article

The Effectiveness of Five-Rung and Rapid Exchange Grip Tests in Detecting Sincerity of Effort Using the Jamar Dynamometer: A Systematic Review

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Abstract

Objective: The five –rung and rapid exchange grip (REG) tests are common methods used by clinicians to detect sincerity of effort. The purpose of this systematic review was to examine the effectiveness of fine-rung and rapid exchange grip tests.

Methods: Electronic database searches were carried out using Medline/Pubmed, CINHAL, Proquest and EMBASE from 1983to 2011. A total of sixteen met the inclusion criteria, eight studies on five-rung and eight on rapid exchange.

Results: A review of studies that utilizes five-rung and rapid exchange test reveals that shape of the curve is not related to the effort but rather strength dependent, because men had significantly greater standard deviation than women, and uninjured hand had significantly greater standard deviation than injured hand. In regards to rapid exchange test the studies reported variation in the administration and interpretation of test. The rapid exchange test the results suggested significant inconsistencies in the administration procedures and interpretation of test. There were significant variation in test methods in hand switch rate, handle setting, cueing, number of grip, rest breaks and comparative testing used to interpret the test. We found that lack of standardization of rapid exchange test may influence the outcome of test and may falsely label a patient as insincere.

Conclusion: The findings of the present study did not find that either five rung and rapid exchange test were effective in detecting sincerity of effort.

Keywords: Five-Rung; Rapid Exchange; Sincerity of Effort; Grip Strength; Jamar Dynamometer

Introduction

Grip strength is common assessment tool used by clinicians to measure a patient hand strength or weakness [19]. In clinical settings, many therapists utilize the Jamar dynamometer as a preferred tool to document and assess grip strength in patients with hand weakness [16]. The Jamar dynamometer is endorsed by the American Society of Hand Therapists as a gold standard for documenting grip strength [19], as there is available evidence on the validity of the tool [15]. Similarly, Jamar dynamometer is a portable device that has five handles or positions to accommodate different hand sizes, and a dial that reads force in kilograms and pounds [8]. In addition, to measuring grip strength, the Jamar dynamometer is also used to document improvement or deterioration in a patient's clinical course [11], to offer insight on voluntary effort [6] and to determine sincerity of grip effort [17].

Moreover, sincerity of effort refers to the patient's conscious motivation to perform optimally during an evaluation [14]. Sin-

cerity of effort is the basic tenet of grip strength measurement because only when the patient exerts maximal voluntary effort, is grip strength measurement objective and valid [22]. The phenomenon of 'sincerity of effort' is illusive and difficult to measure [14], as it explicitly implies a measure of motivation (by the patient), to exert his or her maximum voluntary effort [23]. However determining whether or not a patient is sincere or insincere effort during an evaluation is a difficult problem.

Some patients may choose to embellish their function during evaluation, since loss of grip strength is used to determine the degree of disability, as well as the extent of disability compensation [4]. Likewise some patients tend to fake or perform sub-maximal during grip strength testing for psychological or economic reasons [9]. When a patient exaggerates his or her reactions or responses during evaluation, the condition is known as malingering [29]. Malingering is often commonly reported among patients with work-related hand injuries, during grip strength testing [4]. Thus determining whether or not a patient is actually exerting maximal or sincere effort remains a difficult problem [29] and therefore, it is critical to develop sensitive and specific testing to detect sincerity of effort.

In response to need of understanding sincerity of effort or the patient's level of cooperation in grip strength testing, several methods have been established to evaluate sincerity of effort including rapid exchange grip test (REG), five-rung test or bell shaped curve, and coefficient variation test. However for this study, we will only be examining the five-rung and the rapid exchange grip tests, because they are the most commonly used methods by therapist in clinical settings.

Five-rung grip test as a method of detecting sincerity of effort

The Five-rung grip strength test or bell shaped curve is used by clinicians to detect sincerity of grip effort in patients recovering from injuries and diseases. It was first developed by Stokes [26] to detect insincere effort during grip strength evaluation. Stokes postulates that using the five- rung test as a method of detecting sincerity of effort can provide quantitative information to physicians on sincere or feign grip strength during evaluation.

The five-rung test method uses the Jamar dynamometer to evaluate grip strength. The individual is instructed to grip each of the five handles of the dynamometer, followed by collecting the measurements from all five handles, then plotting these measurements on a graph (contraction on the y-axis against the handle position on the x-axis). A skewed bell-shaped curve is produced in a sincere or maximal effort when the arm and hand are fully innervated, whereas a flat curve is produced on the graph with feign or insincere effort when the arm-hand are fully innervated [26].

Information to physicians on sincere or feign grip strength during evaluation.

The five-rung testing method involves gripping the Jamar dynamometer on the five positions. First, second and forth positions use superficialis and profundus muscules, forthposition uses mostly the profundus muscles, and the third position uses interosseous muscles besides superficialis and profundus [26]. Thus, in terms of neural innervation, that means the first and second rungs call for the dominant use of the median innervated musculature, while fourth and fifth rungs call for the dominant use of ulnar nerve. The third or middle rung requires use of both median and ulnar nerves, and all three peripheral nerves provide sufficient innervation for contraction at the wrist level to support the instrument in the hand.

Rapid exchange grip strength as a method of detecting sincerity of effort

Rapid exchange grip strength test (REG) is also another grip testing procedural method used by clinicians to determine sincerity of effort Rapid exchange grip strength test was first developed by Lister [2] to detect submaximal from maximal effort in patients with grip strength deficits. The basic principle of rapid exchange grip strength is based on the fact that grip strength is difficult to consciously control when rapidly alternating grip efforts between both hands [12].

The rapid exchange grip strength test method has two procedural components: a static and a dynamic component. In the static component there are two static grip tests, the five-rung test and the maximal static grip test (MSGT). The dynamic component is known as the rapid exchange grip maneuver (rapidly alternation of both hands). The test method begins with the static test followed by the dynamic test. The five-rung test (static component) involves performing one repetition (trial) with the handle of the Jamar dynamometer on each of the five settings [12,21,25]. The examiner determines which handle has the highest score, followed by the ex-

aminer instructing the patient to alternate between hands as rapidly as possible for about five to ten grips [9,27]. Even though there is no standard amount of hand alternations, many studies reports using five to fifteen repetition [21].

Likewise, when the maximal static grip strength (MSGT) is used as the static measure in the test, the examiner will pre-set the handle of the Jamar dynamomter to either the second or third handle, (because they yield the maximum grip strength) followed by rapid exchange maneuver (rapidly alternating grips between both hands) [12]. The main difference between the static grip test and the rapid exchange maneuver is the duration of muscular contraction, that is static grip test has a longer muscular contraction than rapid exchange maneuver. Thus when the rapid exchange measurement is greater than the static measurement, then the test is said to be positive, indicating insincere effort; whereas when the static grip measurement is greater than the rapid exchange measurement then the test is negative test, indicating sincere effort. Lister and Czitrom [2] proposed that 'normal' rapid exchange grip strength will decrease, but increases significantly in patients who malinger or perform submaximal on the test. In synopsis, rapid exchange grip strength test (REG) involves administering both a static and a REG maneuver (rapid alternating grips between both hands) and comparing the scores obtained on both test procedures.

However there are several discrepancies among researchers about the rapid exchange and five-rung grip strength tests in detecting sincerity of effort [21]. The aim of this study is to perform a systematic review on what is known in terms of the use of rapid exchange and five-rung grip strength tests in detecting sincerity of effort. By performing this study we intend to provide clinicians with some guidelines to follow in choosing an appropriate assessment to evaluate sincerity of effort in patients recovering from injuries or diseases.

Method

Search Strategy

The literature was identified by means of systematic computerized search of the following databases: Medline/PubMed, Cumulative Index to Nursing and Allied health Literature (CINHAL), ProQuest and EMBASE from 1983 to 2011 for abstracts and full texts that include one or more of the following keywords or terms: sincerity of effort, voluntary effort, maximal effort, sub-maximal effort, malingering, feign weakness/fake weakness, five-rung test, five-handle position grip test, bell shaped curve, rapid exchange grip strength test and hand strength, rapid repeated grip test and the Jamar dynamometer. The use of synonyms "AND" and "OR" were also used to connect keywords together. In addition, the reference lists of relevant studies were also searched manually for supplementary articles, which met our inclusion criteria.

Selection

Inclusion criteria were defined and used to acquire all relevant literature. In order to be eligible for inclusion in this study, the article had to meet the following criteria: Peer reviewed articles with titles of five-rung and rapid exchange grip strength keywords were included. Likewise articles were also included if they were published in English language and conducted on adult (males and females); "healthy and unhealthy" subjects, injured or uninjured participants; participants that were instructed to feign weakness or exert maximal voluntary effort; and also participants who were instructed to use the dominant or non-dominant hands. Similarly, studies were included if they were performed in clinics or laboratories. In addition, articles were also included if they describe both test methods, but did not assess sincerity of effort. Moreover articles that used another tool besides the Jamar dynamometer were excluded from this study. Studies on all other methods that detect sincerity of effort were excluded.

Study selection

First the two authors reviewed the titles of studies that were obtained from the basis of the keyword searches for relevant articles that met our inclusion criteria. Secondly, abstracts were acquired of relevant studies, read and the inclusion criteria applied. If the abstracts met our inclusion criteria, full-text of each study were selected and read in their entirety. If the abstracts were not clear, according to the reviewers, the articles full-texts were also obtained and read for clarification. In addition, studies were also acquired if they used rapid exchange alone, or a combination of both rapid exchange and five handle position grip test. Furthermore all selected studies reference lists were also screened manually and the inclusion criteria were also applied. If they were disagreement between the reviewers in selecting appropriate studies, both reviewers came to a consensus.

Data extraction

A data collection table which was established by American Occupational Therapy Association (AOTA) Evidence-based Practice project [30] was used to extract data from the selected studies for this systematic review. Because the table evaluates evidence base studies, the table was modified to include the following items: the author and year, the design/participant (injured or uninjured hand, dominant or non-dominant), intervention and procedure; as these criteria influences the results and conclusions of this study. The level of evidence was excluded since most of the studies were not investigating evidence based treatment, but rather experimental studies, investigating the effectiveness of two methods. Even though the AOTA Evidence-based Practice Project table is used in most evidence based studies of treatment studies, modifying the table to suit our purposes is useful in critically appraising the two assessment methods (Five-rung and rapid exchange).

Data synthesis

Twenty seven articles met the search criteria. After a review and application of the inclusion criteria, only a total of sixteen studies that the two methods (five-rung and rapid exchange grip strength tests) were identified in detecting or determining sincerity of effort. Eight articles on five-rung test and seven studies on rapid exchange grip strength test were identified. Table 3 and 4 illustrates a summary of the selected studies and the criteria used to assess these studies.

Result

Sixteen studies were identified by the authors as relevant studies that examine these methods of interest (five-rung and rapid exchange grip strength) in detecting sincerity of effort. A review of the various studies revealed several controversies in both test methods in detecting sincerity of grip effort**.**

There was controversy concerning the ability of the five-rung test to distinguish between the sincere and insincere grips [7]. In regards to the rapid exchange grip test, various studies have reported a lack of homogeneity in the administration and interpretation of the test [21,22].

Five-rung test

Three studies [7,23,27] recruited only patients with "true injuries as participants but Stokes [26] did not report how many patients were in the study. Two studies [6,27] used both healthy participants and patients with true injuries, and the other three studies [17,18,29] had only healthy participants. In all studies, participants were instructed to feign grips, for example, 50% of the maximal strength. In addition, Stokes., *et al*. [27] employed two groups of patients, one group was patients who had workers' compensation with severe injuries (suspected to be sincere). The other group was patient who had compensation for trivial injuries (suspected to be faking). Both groups were instructed to exert maximal effort and those patients with severe injuries were suspected to be sincere, while those with trivial injuries were suspected to be faking.

Sincere grips produce skewed bell shaped curves

Six studies had consensus that the uninjured and injured hands produce a skewed bell shaped curves when the patient is exerting maximal effort [6,17,18,26,27,29]. However, two other articles [7,23] inferred the cause of skewed bell shaped curve to the strength, not to the effort dependent. This means greater strength generates more skewed curve, which indicates that people with weak hands do not make skewed curve when they exert maximal effort which is discussed next.

Differences between sincere and insincere hand grips

There were 6 studies addressing the most controversial finding concerning the five rung test [7,17,18,23,27,29], which is the effectiveness of the test to detect sincerity of effort of grip strength, that is, is there a difference between the curves produced by sincere and insincere grips. The original article by Stokes [26] is the only study that supports the fact that faking grip on the five positions of the dynamometer produces a straight line on a graph as mentioned earlier. Other studies, however, discovered that the faking grip strength produces a less skewed bell curve, not a straight line, than the sincere grip [17,18,27]. Later studies by Stokes., *et al*. [27] did not rely on visual analysis as earlier studies by Stokes [26], but they introduced a quantitative method to evaluate the shape of the curve by calculating the standard deviation of the five strength measurements. They found that the greater standard deviation, the more sincere the subject was, since skewed curve had more variability between the scores than the flatter curve. Thus they established a cutoff value for the standard deviation which was 7.5 pounds, indicating that standard deviation above 7.5 pounds indicated sincere grip, while less than 7.5 pounds indicated feigned grip.

Conversely, three studies [7,23,29] found no difference between the curves produced by sincere grip and feigned. This was due to the fact that the shape of the curve is strength dependent. For instance, Shechtman., *et al*. [23] found that there was no significant difference of the shape of the curve between the injured hand exerting maximal effort and the uninjured hand exerting submaximal effort.

Rapid exchange Grip Test (REG)

A general review of the literature reveals a total of eight studies on rapid exchange grip test. Six out of the eight studies were conducted from 2000 to 2011 [21,22,25,28,29,31]. Four out of six current studies suggest diversity in the methodological administration of the test [21,22,25,28]. For example there was incongruence in the various studies in hand switch rate, handle setting, cue, number of grips, rest breaks and comparative testing. In studies by Hildreth., *et al*. [9] they reported a vague protocol of the administration of test including the hand switch rate, number of grip and rest breaks. Likewise studies by Joughin [12] and Stokes [27] also reported variation in test methods including the handle setting, switch rates (80, 100, 45 repetition per minute), number of grips, cues, and rest breaks. Three other studies also documented inconsistencies in the test protocol including handle setting, switch rate and number of grips [28,29,31], lending to the many inconsistencies or validity of the test in detecting sincere or insincere effort.

Moreover, findings from this review reveals that Hildreth., *et al*. [9] and Stokes., *et al*. [27] documented some similarities in few portions of the test, for example, using the same handle setting that renders the highest reading from the five rung grip test, but differs in hand switch rates. Table 1 summarizes several studies with their administration protocol and shows the many incongruities in the administration of the test.

	Czitrom., *et al*. (1988)	**Hildreth., *et al.* (1989)**	**Joughin., *et al.* (1993)**	**Stokes., *et al.* (1995)**	**Taylor and Shechtman (2000)**	**Tredgett and Davis (2000)**	**Westbrook., *et al*. (2002)**
Handle setting	"The optimal span grasp position"	Handle setting rendering highest reading on 5R	Third Handle	Handle setting rendering highest reading on 5R	Second handle	Second handle	The handle that renders maximal grip (2 or 3 handle) on 5R
Switch Rate	____	____	80 and 100 repetition per minute (rpm)	45 rpm	45 and 60 rpm	_____	_____
Cueing	Not specified	___	Auditory cues: metronome	Auditory cues: computer	Auditory cues: metronome	_____	____
Number of grips	Not addressed	5-10 grips	10-15 grips both hands	A total of 16 both hands	5 repetitions for each hand	Ten repetition	Ten grips both hands until fatigue
Rest breaks	Not addressed	_____ _____	Some 2 minutes	No rest allowed	2 minutes rest breaks	2 seconds	____

Table 1: Summary of Studies with Differences in the Administration of Rapid Exchange grip test using the Jamar Dynamometer.

Note: 5R (five rung) and MSGT (maximal static grip) are static test; SG denotes static grip; REG, rapid exchange test; (-) not mentioned or specified.

Similarly, findings from this review also reveal inconsistencies in the interpretation of the rapid exchange grip strength test. Three studies [9,21,22] reported findings of ambiguity in determining a "positive or negative test." Two out of eight studies support the premise of "positive REG score" [9,31] and another two studies supported a "negative REG" [9,21]. However three studies dispute the concepts of a "positive" or "negative" REG score [12,27,31]. From this systematic review, all seven studies used a different static grip test to interpret REG test.

Four studies [9,27-29] compared REG scores with peak five-rung test scores, whereas the others compared REG scores with maximal static grip test scores [12,21,31]. In Taylor and Shechtman [21] study they utilized two static tests and report that during sincere effort; peak maximal static scores were significantly higher than five-rung scores; but that with submaximal effort, peak five-rung and maximal static grip test score did not differ. Results obtained from comparing REG scores with peak five-rung or maximal grip static grip scores can result in different outcomes. Table 2 provides a summary of the variation in the administration and interpretation of REG scores on the eight included studies.

	Czitrom., *et al.* (1988)	**Hildreth., *et al.* (1989)**	**Joughin et al. (1993)**	**Stokes., *et al.* (1995**	**Shechtman and Taylor (2000)**	**Tredgett and Davis (2000)**	**Westbrook., *et al.* (2002)**
Comparative (Static grip Test)	Not mentioned	Five rung test (5R)	Maximal static grip strength test (MSGT)	5R	5R	MSGT	5 R
Peak or mean scores	Not mentioned	vague	Mean REG scores	Peak REG scores	Peak REG scores	___	___
Positivity of test	REG >SG	REG> SG or REG-SG>0	[(SG-REG)/ SG]100>25% That is a 25% or more increase in percentage change of peak REG scores compared with MSGT scores	REG-SG>12 pounds (peak REG scores exceed peak 5R scores by 12pounds	REG >SG (only when peak REG compared to 5R scores	Sensitivity used to detect fake hand weakness and specificity	Sensitivity used to detect fake hand weakness and specificity

Table 2: Summary of the Differences in the Administration and Interpretation of rapid exchange grip strength test using the Jamar Dynamometer.

Note: 5R (five rung) and MSGT (maximal static grip) are static test; SG denotes static grip; REG, (rapid exchange test).

Author/ Year	**Study Objectives**	**Design/Subjects**	**Intervention and Procedure**	**Results**	**Study Limitations**
Stokes, 1983	To provide an objective method of documenting real, as opposed to fictitious, loss of grip	The number of subjects are not mentioned, but they are real patients	Five-rung test using Jamar	Sincere patients produced bell shaped curve. Insincere patients produced straight line (all grips at five positions of Jamar were equal)	

Niebuhr and Marion, 1987	To determine if results similar to those of Stokes (1983) can be obtained from normal uninjured subjects who have been instructed to voluntarily demonstrate weakness of grip	Quasi-experimental. 25 healthy subjects: 9 M, 16 F	Five-rung test using Jamar. Both hands were tested. Patients were asked to do sincere effort and to fake weak grips. Then comparison was made between sincere and fake grips.	Sincere and fake grips produced curves. Fake curve was not straight but was significantly less skewed than sincere curve. Sincere grip force were greater than fake grip force	Results may not generalizable to real patients.
Niebuhr and Marion, 1990	To investigate the degree of control normal subjects have over submaximal effort and their ability to feign weakened.	Experiment 1. To determine if subjects instructed to exert a specific amount of effort will produce feigned effort consistent with Stokes' hypothesis. 30 subjects: 13 M, 17 F Experiment 2. To examine the ability of subjects to produce varying amounts of submaximal effort on demand. 20 subjects: 5 M, 15 F Experiment 3. To determine whether healthy people could by exerting different effort at the various handle positions when instructed emulate the grip of an injured person.	Experiment 1: Using only positions 1, 3, 5 of the Jamar. Testing only the Dominant hand to exert sincere effort and 50% (feigned effort) of maximal effort. Experiment 2: Both hands exerted 30, 50, 70, 90, and 100% of maximal effort. Experiment 3: Sincere (all positions) Feigned (using positions 1,2,3,4,5 with these effort 30,70,70,50, and 40 respectively). Only dominant hand.	Experiment 1: Sincere and fake grips produced curves. Fake curve was not straight but was significantly less skewed than sincere curve. Sincere grip force were greater than fake grip force Subjects were able to produce 50% of maximal effort. Experiment 2: Using the most comfortable position on Jamar for subjects. Subjects can control grip force on demand to a reasonably accurate degree. The curves of grip force as a function of handle position would be parallel for the sincere and feigned condition.	The subjects were healthy, not patients. The subjects had many trials practicing the dynamometer. The data were averaged for many subjects.

Goldman, Thomas, and An, 1991	To test the hypothesis that the results from the 5 rung tests of an injured hand will produce a curve that is similar to a healthy hand, although the force generated by the injured hand may be less.	26 healthy subjects: 16 F, 10 M, 22—39 years old. 21 injured patients: 11 F, 10 M, 23-84 years old.	Patients and volunteers were tests on both hands using Five rung methods.	The curve is noted in the curves of the healthy subjects as well as the patient's uninvolved and involved hands, but the curve on the injured hand is reduced in force output.	
Stokes, Landrieu, and Kunen, 1995	The effective of Five rung test in detecting low-effort patients (insincere).	Group 1: 40 normal mean ages: 38. Group 2: 30 normal mean ages 24. Group 3: 32 Sincere patients who had workers' compensation, mean age 37. Group 4: 27 Patients with trivial injuries, mean age: 37.	Group 1: Five rung test on both hands (only maximal effort) Group 2: Five rung test: one hand is sincere and the other hand to fake grips. Group 3 and 4: Five rung test using only the injured hand. Modified Jamar dynamometer in conjunction with the EVAL system was used.	The performance curves of the groups differed significantly. Group 2 and 4 have much less variability in their performance curves. Using an SD score of 7.5 or less among grips indicates low effort (insincere).	EVAL system's reliability and validity has not been established yet.
Tredgett and Davis, 1999	To evaluate the effectiveness of the five rung test in distinguishing between the normal pattern of grip strength and feigned hand weakness.	27 healthy subjects: 5 M, 22 F, mean age: 37	Using the Jamar, on day 1 &2 each subject performed five rung tests with maximum effort in both hands. On day 4 each subject was instructed to fake 50% weakness in one hand whilst performing maximally with the other hand.	Maximum effort always produced skewed bell shaped curve. When feigning weakness, 33% of participants showed normal pattern of grip strength. Five rung test reliably detected feigned hand weakness in only 15% of subjects.	

Gutierrez and Shechtman, 2003	To investigate whether the shape of the curve generated by the five rung test is affected by the amount of strength exerted by the gripping hand.	30 patients, 18 M, 12 F, mean age is 39.	Session 1: Subjects exerted maximum effort with both hands. Session 2: Subjects were instructed to exert submaximal effort with the injured hands, and maximal with the other hands. Session 3: Subjects were instructed to exert maximal effort with the injured hands, and submaximal with the other hands.	The strength and standard deviation were greater for men than for women, for maximal effort than for submaximal effort, and for the injured hand in comparison with the healthy hand. However, women had no significant differences in standard deviation among any of the condition, which means that five rung test is strength dependent not effort dependent.	
Shechtman, Gutierrez, and Kokendofer, 2005	To analyze four methods commonly used to evaluate the shape of the curve generated by maximal versus submaximal efforts.	30 patients, 18M, 12F. Mean age 39.	Session 1: Subjects exerted maximum effort with both hands. Session 2: Subjects were instructed to exert submaximal effort with the injured hands, and maximal with the other hands. Session 3: Subjects were instructed to exert maximal effort with the injured hands, and submaximal with the other hands.	Visual analysis and SD: No differences were observed between the injured hand exerting maximal effort and uninjured hand exerting submaximal effort Analysis of variance: The curves generated by maximal and submaximal effort exerted by the injured hand were parallel and that when gripping with the injured hand, submaximal effort did not generate a flatter curve than maximal effort. Normalization of data: No significant interaction between effort and position, indicating no differences in the shape of the normalized curve generated by maxima and submaximal effort in both the injured and uninjured hands.	Fatigue because of 30 trials. Subjects were instructed to fake 50% weakness, not fake a general weakness. Uncertainty of being compliant.

Table 3: Summary of the studies on five-rung test.

Author/Year	Study Objectives	Design/Subjects	Intervention and Procedure	Results	Study Limitations
Czitrom and Lister (1988)	To examine the effects of rapid exchange grip test (REG) as true indicator in detecting organic pathology in 'obscure' wrist pain	81 patients with chronic wrist pain from a hand clinic	REG test utilizing the Jamar dynamometer at an "optimal span grasp position", a Tc diphosphonate bone scan is also used to determine 'obscure' pain	Significant decrease of grip strength in patients with proven wrist pathology, compared to those with no known pathology. REG test is a grip specific indicator of wrist pathology	No statistical analysis of the test score was presented. The test did not mention the number of grips, hand switch rate, (REG at 45 or 60 repetition per minute), length of rest and handling in administering REG test; limits reproducibility Did not specify the handle used (whether handle2 or 3) only the optimal grasp, limits credibility of the test Vague administration of protocol Limited evidence to support its use in detecting sincere effort in patients with "obscure wrist pain"

Hildreth., *et al*. (1989)	To examine the effectiveness of REG test in detecting sincerity of effort among patients with decrease grip strength	205 participants from physical therapy program, private hand practice and normal patients	Use the handle setting rendering the highest reading on the 5 R test followed by REG Part 1: 100 normal participants took 5R and REG and performed maximally Part II: 45 patients with hand injury from a physical therapy program randomly chosen to take 5R test. Part III: A blinded control study of 15 normal subjects instructed to feign or fake injury, took both the 5R and REG test Part IV: Evaluation of data for all 45 patients from a private hand practice who were either on worker's compensation or not taken the 5R and REG test over 4 years.	In normal participants that exerting maximal effort, the REG scores were lower (15%) than the static test indicating a negative REG (sincere effort), however when the subjects were asked to feign grip strength the REG score was higher (67%) than static score, indicating a positive REG or insincere effort. More patients from workers compensation showed significant increase of REG scores indicating a positive REG compared to those that were not on workers compensation.	Limited information on administration of REG test, including hand switch rates i.e. REG- 45 or 60 repetition per minute, amount of rest breaks, grips trials, position of subjects, for easy replication and credibility of study
Joughin., *et al*. (1993)	To determine the effectiveness of rapid exchange grip test (REG) and the modification of this test (rapid simultaneous) grip test (RSG) in detecting submaximal or sincere grip efforts	Group I: 57 uninjured subjects – 30 participants grip dynamometer (at handle number 3) maximally alternating between the two hands. 27 were instructed to perform submaximal at same handle. Group II: clinical population as two subgroups: Subgroup 1: 30 patients with true hand weakness and Subgroup 2: 14 patients with complaint of hand weakness with no objective findings (workers compensation hand clinic). Both group grip the Jamar dynamometer at handle three.	Utilize the third handle setting REG given at 80 and 100 repetitions per minute on Jamar Dynamometer, RSG at 80 and 100 repetitions with two dynamometer simultaneously	Significant difference in grip strength was reported in both the dominant and non- dominant hand of the truly injured group, but in the no objective finding group there were significant increase in grip strength noted in the weak hand indicating a positive REG score	Small sample size of the truly injured group. No objective findings that the tests detect sincere effort or submaximal effort

Stokes., *et al.* (1995)	To further define five-rung grip test, explore the use of five rung grip test in conjunction with the rapid exchange grip test in detecting low effort patients, and to develop objective criteria for clinicians to use to accurately detect low effort patients	Group1: Consist of 40 normal volunteers participants instructed to exert maximal effort Group II: consist of 30 normal participants asked to feign a weak grip Group III: consist of 32 patients (from hand clinic) thought to be sincere Group IV: consist of 27 patients suspected of low effort	Administer 5R on all participants starting with the left hand then right, followed by the rapid exchange grip test (using the maximum force from the 5R) either at handles 2 or 3 of the Jamar dynamometer that was connected to a Greenleaf Medical computer evaluation system	The 5R test easily identifies low effort patients. No statistical difference between peak score on five rung and rapid exchange test in sincere normal and sincere patients	No predetermined handle of the dynamometer was established to use in rapid exchange, for easy replication of study. Small sample size. Participants were not instructed to feign hand weakness limits reliability and validity of study.
Taylor and Shechtman, (2000)	To investigate the effect of three factors (hand switch rate, number of grip and comparative test) on rapid exchange grip test	146 uninjured volunteers in two studies part1 and 2. The sample consist of 17 men and 129 women	Each participants completed a series of 4 randomly assigned grip tests including the 5R, maximal static grip test (MSGT), 2 REG maneuver (45 vs. 60 repetition per minute) with the Jamar Dynamometer. A series of tests performed on both hands with maximal effort and once with 1 hand performing submaximal (at 50%). Each subject performed five grips per hand for each test and a total of 40 grip repetition per hand.	There was no significant difference between the scores obtain from rapid exchange grip (REG) maneuver performed @ 45 and 60 repetition per minute when the subject exert maximum or submaximal effort, however there was significantly greater REG scores when REG was performed at five trials or three trials of both maximum or submaximal effort @ 45 and 60 repetition per minute. During maximal effort, peak maximal static grip test (MSGT)scores very significantly greater than five rung scores, but for sub maximal effort peak five-rung and MSGT did not differ significantly	A significant large percentage of the population was women, limiting generalizability. Normal control has no upper extremity injury. Participants ask to feign 50% of maximal effort. Using the second handle of the Jamar dynamometer for rapid exchange rather than the handle setting that yield the maximum score on the five-rung test

Shectman and Taylor (2000)	To investigate whether the REG test is a valid measure of sincerity of effort	146 uninjured volunteer participants. Sample size 129 women and 17 men	146 uninjured participants used the Jamar dynamometer with an electronic metronome to establish hand switch rate for REG maneuver at 45 and 60 beats per minute. Each participants completed four randomly assigned grip test 5R, MSGT (at the second handle position) and REG at 45 (45rpm) and REG at 60. The series of test was completed once with both hands exerting maximal effort and once with one hand exerting 50% submaximal effort. Each participants performed five grips per hand for each test and a total of 40 per hand	Findings support the concept of "negative REG". During maximal effort peak static scores were significantly greater than peak REG scores for both REG maneuvers (REG-45 and REG-60) and both the 5R and MSGT, however the concept of "positive REG" was supported only when peak REG scores were compared with peak 5R score. Findings reveal that REG test is not sensitive and specific enough to effectively detect sincerity of effort, since there is no standard guidelines	A large sample size of uninjured young women limits generalizability and makes it difficult to apply to patients with upper extremity injuries. Having participants fake or perform submaximal limits generalizability. Study need to be conducted on patients with 'true' hand weakness
Tredgett and Davis (2000)	To assess the use of rapid repeated exchange grip strength in detecting insincere hand weakness	A total of 105 participants in study. Group I: 41 healthy volunteer participants with no history of upper extremity injury performed rapid repeated test in both hands (33 women and 8 men) Group II: 25 of the 41 healthy volunteer repeated test on both hands one week later, while instructed to feign 50% Group III: 65 patients (44 women and 21 men) recovering from carpal tunnel decompression surgery post 6 weeks performed rapid repeated test. All of this group had 'genuine' hand weakness from surgery	Repeated rapid exchange grip strength test using the Jamar dynamometer set at the second handle setting Outcome Measure Sensitivity used to detect fake hand weakness and specificity	Grip strength fatigue by an average of 23% in the normal healthy participants and increase in grip strength in 2% of patients with carpal tunnel decompression. Significant increase in grip strength occurred in normal healthy patients (39%) after the first effort, 52% in participants faking hand weakness, and a 69% increase in carpal tunnel decompression	Using second handle of the dynamometer Having participants fake hand weakness limits generalizability and makes it difficult to include patients with true hand weakness A large sample size of uninjured women limits generalizability No established number of hand switch rate during REG testing, limits accurate replication of study No established rate of REG (REG -45 rpm or REG -60) limits replication

Westbrook., *et al*. (2002)	To examine the reliability and validity of REG test to detect submaximal grip effort among motivated participants and patients with genuine hand weakness secondary to pain	100 participants in study 50 normal volunteer participants and 50 patients recovering from carpal tunnel decompression	All participants utilize the Jamar dynamometer by first performing the 5 R test (for maximal grip), followed by REG Group 1: healthy participants performed REG on both hands with maximal effort Group II: The same healthy subjects post one week were asked to fake 50% weakness in dominant hand on the REG test Group III: 50 patients with unilateral carpal tunnel decompression surgery (37 women and 13 men) performed the REG test Outcome Measures Sensitivity and specificity of REG, positive and negative predictive values for grip strength; utilize eight criteria to measure dynamic or REG (85%, 90%, 95%, 100%, 101%, 105%, 110% and 115%)	In 28% of normal participants (maximal effort) the dynamic measure was greater than static measure with 72% specificity, whereas 58% of carpal tunnel decompression patients had a specificity of 42%, and participants giving submaximal effort had 74% sensitivity.	Having subjects fake hand weakness limits generalizability. Having a large sample size of women versus male limits generalizability. Having some of the patients performing at varying handles of the dynamometer (handles 2 or 3) makes it difficult for another researcher or replicate research

Table 4: Summary of studies on rapid exchange grip test.

Discussion

The present study examined the effectiveness of rapid exchange and five-rung test in detecting sincerity of effort. Our findings reveal: 1) that the skewedness of the bell shaped curve is force dependent not strength dependent [7,23], 2) there is a lack of uniformity in the administration of rapid exchange and [3] also a lack of consensus in the interpretation of rapid exchange test scores [21,29,31]. These findings lends to the questionable validity of these methods in detecting sincerity of effort. The findings from this review will be discussed in two sections. The five-rung method will be discussed first, followed by rapid exchange grip strength.

Five-rung test

The findings of the present study showed controversy in the literature surrounding the effectiveness of the five-rung grip test in detecting sincerity of effort due to poor quantitative results. In early studies [6,17,18,26], they relied on visual analysis and reported that insincere grip on the test formed flatter or less skewed curves than sincere grip. In clinical settings, using visual analysis is problematic because it is difficult to determine if the curve is skewed or less skewed. That is because what one thinks the curve is skewed another one may think it is less skewed. Stokes., *et al*. [27] introduced a quantitative methods using standard deviation. This finding was acceptable until two recent studies were conducted [7,23].

Two studies [7,23] concluded that the shape of the curve depends on strength of the person. That means the stronger the person, the more skewed the shape of the curve would be. Additionally, patients with hand injuries often experience weakness and exert smaller forces on the five-rung test, which make the curve seem less skewed. This explains why earlier studies found that submaximal effort produced less skewed curves. Participants, in

early studies, were instructed to exert, for example, 30, 50, or 70% of the maximal effort. Niebuhr and Marion, [18] found that participants were able to control grip force at each rung when instructed to a reasonably accurate degree. Those participants produced less skewed curves when exerting 50% of their effort. This indicates individuals who are 50% weaker than those of the study produce flatter curve even if they exert maximal effort.

Rapid exchange grip strength (REG)

Moreover, rapid exchange grip strength test (REG) was another method used frequently by many clinicians to detect sincerity of effort [28]. Findings from this review revealed that rapid exchange grip strength test is not effective in detecting sincerity of effort due to, variation in the administration and interpretation of the test among researcher and clinicians [14,22,31]. Study by Shechtman and Taylor [22] supported our findings that lack of uniformity or standardization of the rapid exchange grip test, results in discrepancies in the outcomes of REG test; and therefore may result in serious implications for therapists that utilize the test. When a test is not administered and interpreted consistently, it may diminish the possibility of the test to be reliable and valid in detecting sincerity of effort [22].

Similarly, findings from the review also supported the inconsistencies in the administration procedure of the test in all eight included studies on the hand switch rate, handle setting, cue, number of grips and rest breaks [2,9,21,27,29,31]. Using different handle settings on the Jamar dynamometer may influence grip strength results [21]. Studies by Shechtman and Taylor [22] found that maximal grip strength was obtained at the second handle, however some patients could obtain maximal grip at the third handle. Similarly the number of repetitions performed during REG test may also influence the results of the test. Two studies [9,22] used 5 to 10 grips, whereas others used 10 to 15 grips [12,29,31]. Having variation in number of repetitions may influence results. Likewise Therefore having variations in administration of rapid exchange test protocol is likely to add to inconclusiveness of the test results. When a test is not standardized, it reduces the potential for another researcher to repeat the study, thereby compromising validity of the test [21,28].

In regards to the interpretation of rapid exchange test, there was also reported variation in the literature regarding what constituted a "positive" or "negative score" [21,25]. Similarly the lack of standardized administration procedures also influences the interpretation of test scores. A contributing factor for the discrepancy in interpreting rapid exchange score is the variation of comparative tests (static test) used by researchers to interpret a rapid exchange grip (REG) score. When REG scores is compared with different static tests (peak five-rung or maximal static grip scores), the scores of the test may result in difference in the test outcome. Hence, utilizing different comparative testing may influence the "positivity" or "negativity" of the test, which may influence the outcome of the test, and thus falsely label a patient as insincere when the patient is truly sincere [25]. This could pose serious problem for the clinician and patients. For example, they may lose financial remuneration, misdiagnosing and inappropriate treatment and loss of job; [14,24]. In regards to the clinicians, they may violate the patient's rights.

The present study has some limitations that may possible influence the interpretation of the result. Firstly, one limitation is that previous review studies on these two methods are lacking in this area. This could pose some potential bias of the research. Another limitation to this study is that additional studies could have since been published and were not identified, since the study was limited to the period of 1988 to 2011. Similarly another limitation to study was that the search was restricted to only English language and other studies could have been published in other languages.

Implications for practice

Although there is significant evidence from the present study that five-rung grip test is not effective in detecting sincerity of effort, clinicians can still use it with caution, but only if the shape of the plotted measurements is other than a bell curve. For instance, straight line, reverse bell curve, and wave shape are indicators of faking. Similarly, rapid exchange grip test is also not effective in detecting sincerity of effort, due to the poor standardized administration and interpretation of the test. Therefore, if clinicians used this test, they should not base their decision solely on the test, since the test is not a reliable or valid tool; but rather consider other factors such as pain and psychological factors. In addition the clinician should also consider bio-behavioral factors such as patients disease conviction, perceived control, fear of pain, perception of work and family, and self –worth [20], before making a decision that the patient is sincere or insincere [14], because the results of their clinical judgment could have serious implications.

Conclusion

The findings of the present study showed that the five-rung test and rapid exchange grip strength test is not effective in detecting sincerity of effort. The five- rung grip strength test is not a good measure to detect sincerity of effort since the skewedness of the bell curve depends on strength and visual analysis rather than concrete scientific evidence. Having poor scientific evidence impacts the validity of test. Similarly, the rapid exchange test is not a good method to detect sincerity of effort due to lack of standardized administration and interpretation protocol of the test.

The findings of the present study supported the various inconsistencies in the literature on the rapid exchange grip strength test in detecting sincerity of effort. Variation of testing procedures in the nine studies supported the need for a standardized protocol of the test, in order for test to be effective in detecting sincerity of effort. Without uniformity in the administration and interpretation of the REG test, the outcome of test is difficult to reproduce, making the test unreliable and invalid in detecting sincerity of effort in patients with illness or injuries. Similarly basing clinical decision on a test that is questionable is unethical and in violation of patient's rights and could pose serious problem for clinicians. Falsely reporting sincere effort as insincere may result in serious problems for patients such as emotional, physical and financial problems, misdiagnosing and inappropriate treatment and possible loss of job.

Recommendations

Future studies on five-rung and rapid exchange grip strength methods in detecting sincerity of effort should be conducted, to assist in emphasizing the need for standardization of test methods. Standardization of test methods with scientific evidence may assist in finding a more effective method in detecting sincerity of effort in people with illness and injuries.

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