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The Reliability and Validity of Shoulder Strength Measurements Using a Force Gauge and Strain Gauge in Diabetic Frozen Shoulder Patients

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ABSTRACT

Purpose/Aim: This study investigated the reliability and validity of shoulder strength measurements using a digital force gauge and strain gauge in diabetic frozen shoulder patients.

Materials/Methods: Digital force gauge and strain gauge to measure shoulder flexion, abduction, internal and external rotation in diabetic frozen shoulder patients.

Results: Excellent intrarater reliability was present with Intraclass Correlation Coefficients (ICC- 3,k) for Force Gauge ≥ 0.95. The concurrent validity Force Gauge was good with ICC (3,k) values of ≥ 0.85. The 95% limits of agreement suggest that the Force Gauge measurement instruments can be expected to strength from 2° to 20°. Digital force gauge flexion, abduction, external rotation and internal rotation measurements had a greater mean and standard deviation than strain gauge flexion, abduction, external rotation and internal rotation measurements.

Conclusions: This investigation is the first of its kind to evaluate the reliability and concurrent validity of strain gauge and force gauge measurements of muscles strength of shoulder flexion, abduction, external and internal rotation. When used with the measurement procedures outlined in this investigation, both techniques are reliable, as evidenced by reliability coefficients that exceed 0.90 (the threshold recommended for making clinical decisions). Good concurrent validity statistics were produced; however, one should recognize the potential ranges of disagreement between the two measurement instruments used in this study. When monitoring or comparing static shoulder strength measurements both researchers and clinicians should consider using similar instruments.

Keywords: Diabetic Frozen Shoulder Patients; Lutron Force Gauge; Reliability; Shoulder Validity.

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INTRODUCTION

The term "frozen shoulder" was first introduced by Codman in 1934. He described a painful shoulder condition of insidious onset that was associated with stiffness and difficulty sleeping on the affected side. Codman also identified the marked reduction in forward elevation and external rotation that are the hallmarks of the disease. Long before Codman, in 1872, the same condition had already been labelled "periarthritis" by Duplay. In 1945, Naviesar coined the term "adhesive capsulitis."[1]

Frozen shoulder (FS), is painful and debilitating characterized by pain on sudden movement, and a passiverestriction to range of movement, particularly of externalrotation of the shoulder, it is often misdiagnosed. FS, particularly in diabetics, is difficult to treat. There is currently no consensus in the management of diabetic FS,

The incidence of FS is between 3 and 5% and is considerably higher in diabetic patients, up to 30%, with a tendency to more severe symptoms and resistance to treatment. It most commonly affects patients in middle age and affects women slightly more than men. Frozen shoulder can be secondary to trauma and is associated with Dupuytren's contracture, Peyronie's disease and other connective tissue disorders. Post-operative FS has been reported in up to 11% of patients undergoing arthroscopy, with diabetes being a predictor for this post- operative complication.

In order to account for the higher rates of FS associated with diabetes mellitus, it has been suggested that higher systemic glucose concentrations result in faster glycosylation, resulting in increased rates of FS and other soft tissue disorders, such as Dupuytren's disease. Higher HBA1C is associated with development of FS indiabetic patients.

Arthroscopic biopsies of synovium in diabetic patients demonstrate greater endothelial growth factors compared with non-diabetic FS and reduced inflammatory growth factors, including ADAMTS-4, MMO-1 and particularly M-CSF. The latter mayaccount for slowing of the inflammatory response, therefore prolonging and increasing the severity of the disease. Some studies, however, have shown little difference in inflammatory markers compared to non-diabetic patients. It should be noted that studies using arthroscopic biopsies are only sampling more severe and intractable cases of FS, which require surgery.[2]

Frozen shoulder has been associated with a number ofsystemic conditions, including diabetes mellitus; indeed, the incidence of frozen shoulder amongst diabetic individuals is 10% to 36%, which is significantly greater thanthe 2% to 5% rate in the general population. Management options for frozen shoulder include simple analgesia, physiotherapy, local anesthetic and corticosteroid injection, hydrodilatation, manipulation under general anaesthesia (MUA), arthroscopic release, and even opensurgical release.[4] Advocates of each approach have published supporting results in the general population; however, it is uncertain which strategy is best in diabeticpatients, where the natural history of the condition is protracted and patients tend to respond less well to conservative or interventional treatment.[3]

A force gauge is a measuring instrument used to measure forces. There are two kinds of force gauges today: mechanical and digital force gauges. Force Gauges usually measure pressure in stress increments and other dependent human factors. A common mechanical force scale, known as the spring scale, features a hook and a spring that attach to an object and measure the amount of force exerted on the spring in order to extend it.[5]

Design

Participants

Ten diabetic frozen shoulder patients'adult participants, 7 males and 3 females, were recruited from a Shri Mahant Indiresh Hospital, Department of Physiotherapy, Patel Nagar, Dehradun (Uttarakhand) setting. Participants who met study requirements were provided with an informed consent document approved by the Synopsis Approval Committee (SAC) of SGRR University and Institutional Ethics Committee of Shri Guru Ram Rai Institute of Medical & Health Sciences, Patel Nagar, Dehradun and all questions were answered to their satisfaction prior to commencing data collection.. Exclusion criteria consisted of reported cervical spine or upper extremity pain at the time of data collection or recent shoulder surgery on the dominant arm for which the subject was still receiving care.

INSTRUMENTATIONS

Lutron Force Gauge is an Electronic Force Gauge Included Components Force Gauge (20 Kg) Made in Taiwan. It's having Tension & Compression Capability. LutronForce Gauge has 3 Kind Display Unit, Kg/lb/Newton and Peak Hold (Max. Load) Measurement. Its Model Number FG-20 KG and Power Source Type is Battery Powered. The item weight 300 grams and manufacturer series number M:7980752747. Measurement Accuracy +/-0.5%. Specification Met ISO 9001:2015, CE, IEC 6010. Digital force gauges are the most popular form of measurement used to calculate force. Measured in Newtons, it's best to use a gauge at 20-80% of its capacity.

Procedures

Measurement of Muscle Strength

Muscle strength, defined as the maximal voluntary force that subjects were able to exert under specified testing conditions, was measured using Lutron

Force Gauge, which is made in Taiwan. Subjects were tested in standing for flexion, abduction and in sitting for external and internal rotation. Lutron Force Gaugeis attached to a stationary device stabilized at the edge of a portable examination table.

Proper Care is taken not to allow subjects to use other part of the body for thedesired movement. Patients were given total verbal encouragement during measurement. Maximum effort is used to perform the test, in which a subject exerted a maximal isometric force against the Lutron Force Gaugefor two to four seconds. We, therefore, calculated muscle strength deficits by a force gauge. This calculation, when multiplied by 0.05 N, is a percentage of muscle strength deficit value.

4:11:3:1 Flexor Strength: The patient were standing position and Lutron Force Gaugeattached with edge of examination table. The patient was positioned standing straight with back facing towards the Lutron Force Gaugethen, ask the subject to pull the chain forward away from the body. The test was performed in against gravity plain (Fig. 1)

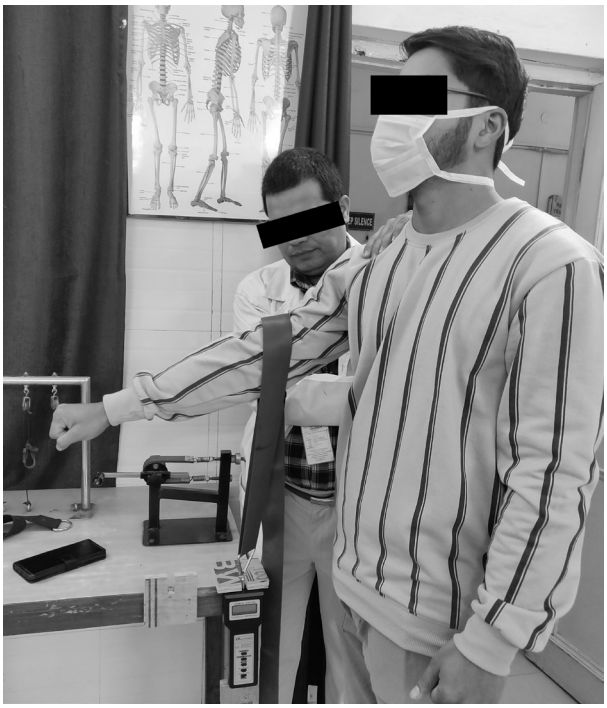

Fig. 1: Isometric Shoulder Flexion Strength Measurement by Lutron Force Gauge.

4:11:3:2 Abductor Strength: Position of the patients were standing andLutronForce Gauge fixed with treatment table. One end of the strap attached with Lutron Force Gauge and other with distal arm. And then pressed the button zero, told the patient to pull the strap away from the body.

4:11:3:3 Internal Rotator Strength: The patients weresittingpositionedonthechairwith their arm beside their trunk, their shoulder in neutral rotation, their elbow at 90 degrees of flexion, their forearm in neutral supination, and their arm and shoulder stabilized as required. LutronForce Gauge fixed with treatment table and one end of strap attached with LutronForce Gauge and other with distal forearm that must be perpendicular to the floor. And then pressed the button zero, told the patient to apply force towards the trunk. (Fig. 2)

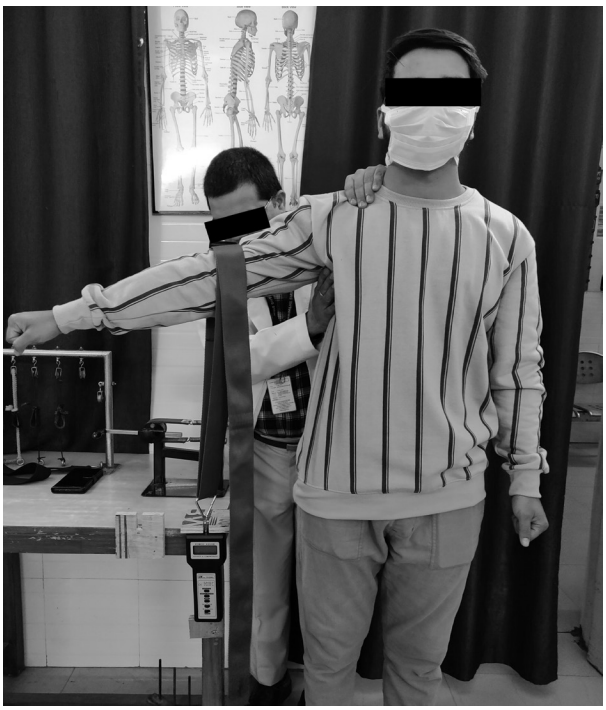

Fig. 2: Isometric Shoulder Abduction Strength Measure -ment by Lutron Force Gauge.

4:11:3:4 External rotator strength: The patients were sitting positioned on the chair with their arm beside their trunk, their shoulder in neutral rotation, their elbow at 90 degrees of flexion, their forearm in neutral supination, and their arm and shoulder stabilized as required. LutronForce Gauge fixed with treatment table and one end of strap attached with LutronForce Gauge and other with distal forearm, that must be perpendicular to the floor. And then pressed the button zero, told the patient to apply force away from the trunk.[89 & 90](Fig. 3)

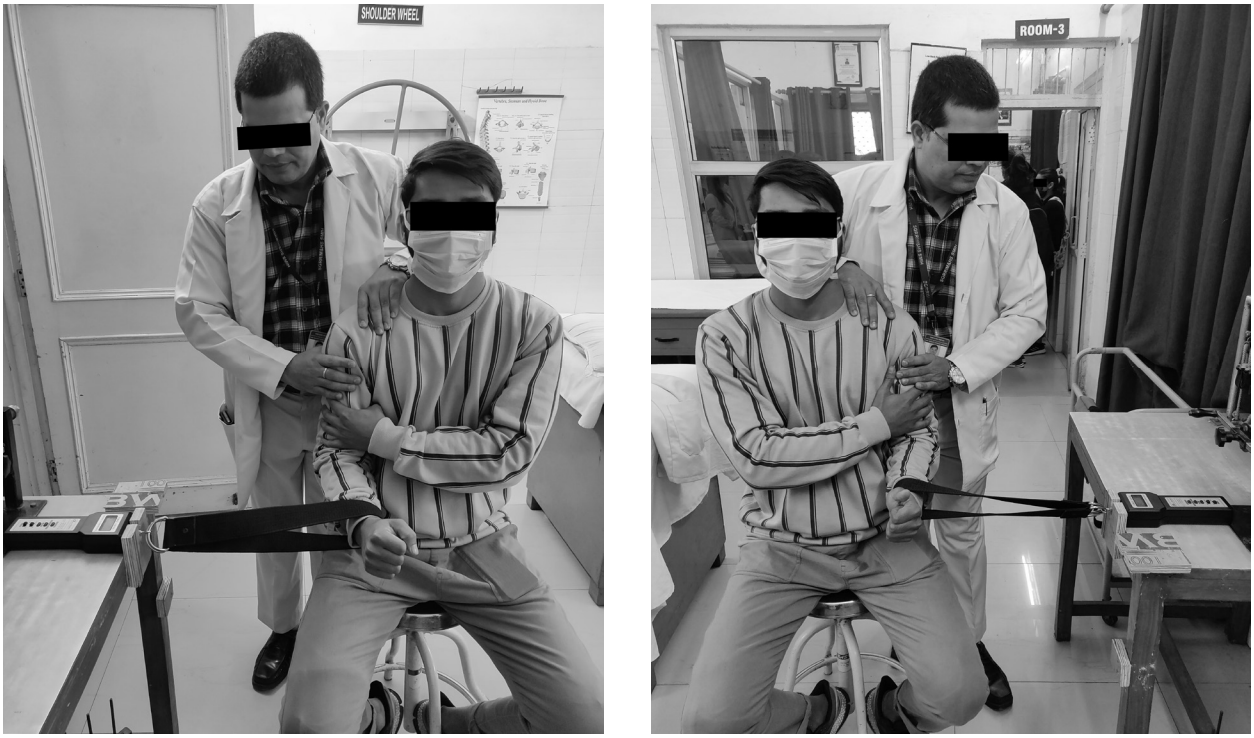

Fig. 3: Isometric Shoulder Flexion Strength Measurement by Lutron Force Gauge.

Table 1: Subject Position, Placement of Force Gauge, Provided for Each Tested Muscle Action.

Muscle Action	Limb/Joint Positions	Subject position	Force Gauge Placement
Flexion	Flexion at 0° abduction	Standing	Distal Humerus/ Lateral Epicondyle of Humerus
Abduction	Abduction at 0° abduction	Standing	Distal Humerus/ Lateral Epicondyle of Humerus
External Rotation	Shoulder 90° abduction + Elbow 90° Flexion	Sitting	Distal Forearm/ Above wrist
Internal Rotation	Shoulder 90° abduction + Elbow 90° Flexion	Sitting	Distal Forearm/ Above wrist

STATISTICAL METHODS

Data analysis was performed with SPSS version 15.0 for Windows. Descriptive data including mean measurement angles with standard deviations (SD) were calculated for each session. The intrarater reliability was determined by the ICC Model 3, k. The mean value from each testing session was used for the analysis. Model 3, k was used for the intrarater analysis because the specific rater was the only tester of interest.[10,11] Interpretation of ICC values was based on guidelines offered by Portney and Watkins, 10 where a value above 0.75 was classified as good reliability. ICC values may be influenced by inter subject variability of scores, because a large ICC may be reported despite poor trial-to-trial consistency if the intersubject variability is too high.[10,12] The standard error of measurement (SEM) is not affected by intersubject variability.[12] Therefore, SEM was reported in conjunction with the ICC's using the formula: SEM = SD 1− r. 10 An ICC Model 3, k was used in the concurrent reliability analysis to determine if both methods of measurement analysis produced comparable results. ICC value interpretations were based on the aforementioned guidelines established by Portney and Watkins.[10] The 95% limits of agreement (LOA) were calculated using the formula: 95% limits of agreement = mean difference +/- 2SD.10

RESULTS

Descriptive data, including the mean and SD for each of the four measurements are presented in Table 1. Intrarater analysis suggested excellent reliability for all measurements with both instruments ranging from, ICC (3, k) = 0.94-0.98. There was a trend for higher reliability with the inclinometric measurements when compared to goniometry. Measurement data from the intrarater reliability analysis including the ICC, 95% CI and SEM are presented in Table 2**.**

Table 2: Descriptive Measurement Data

	Flexion Mean °(SD)	Abduction Mean °(SD)	External Rotation Mean °(SD)	Internal Rotation Mean °(SD)
Strain Gauge	156 (9)	161 (11)	92 (10)	48 (10)
Force Gauge	164 (9)	162 (11)	100 (11)	49 (11)

SD= Standard Deviation;

The concurrent validity between goniometry and digital inclinometry measurements are presented in Table 3.

Table 3: Descriptive Measurement Data. Intrarater Reliability of Strain Gauge and Digital Force Gauge.

	Flexion	Abduction	External Rotation	Internal Rotation
Strain Gauge ICC (95% C1) SEM	0.95(0.89-0.98)2	0.97(0.94-0.99)2	0.94(0.87-0.97)3	0.95(0.89-0.98)2
Force Gauge ICC (95% C1) SEM	0.95(0.90-0.98)2	0.97(0.94-0.98)2	0.98(0.96-0.99)2	0.97(0.93-0.98)2

ICC=Intraclass coefficient; SEM=Standard error of measurement rounded to nearest degree; CI= Confidence interval ;

When comparing the mean end-range angles for the instruments a trend existed for lower goniometric values of flexion, abduction and external rotation compared to inclinometry. The mean goniometric value of internal rotation, however, was greater than the mean inclinometric value. In regards to agreement the 95% LOA suggests that goniometry may range from being 20° less than to 5° greater than inclinometry when measuring flexion. The 95% LOA suggests that goniometric abduction may range from 17° less than to 14° greater than inclinometry. Goniometric external rotation may range from 2-16° less than inclinometry, whereas internal rotation measurements ranged from 3- 15° greater than inclinometry.

Excellent intrarater reliability was present with Intraclass Correlation Coefficients (ICC 3,k) for LutronForce Gauge ≥ 0.95. The concurrent validity Lutron Force Gauge was good with ICC (3,k) values of ≥ 0.85. The 95% limits of agreement suggest that the Lutron Force Gauge measurement instruments can be expected to strength from 2° to 20°.

DISCUSSION

When adhering to the procedures outlined in this investigation, measurements taken using both the inclinometer and goniometer possessed good intrarater reliability. The reliability results are comparable to previous research which has reported the good to excellent intrarater reliability when utilizing similar measurement procedures.[8] In regards to concurrent validity, measurements with a digital inclinometer were found to be comparable to those taken with the standard 12 inch plastic goniometer with ICC values ≥ 0.85. Also, there was a trend for inclinometric measurements being greater than goniometry for flexion, abduction and external rotation. In contrast, goniometric internal rotation measurements had a greater mean measurement angle than inclinometry. The mean differences in measurements between the instruments were the greatest for external rotation and flexion and had the narrowest range for abduction. There was no identifiable systematic error in technique that could explain the differences. One might surmise that Rater A (who took all goniometric measurements) was biased toward lower angles, however, internal rotation was higher from Rater A which challenges that assumption. Furthermore, the landmarks for measurements are different which may produce different end-ranges and should be of concern to clinicians. Unfortunately, no studies have established the validity of these instruments concurrently with radiography to determine which one might offer a more valid estimate of mobility. Clinicians and researchers should recognize that the difference between these two measurement instruments can be expected to vary by 2°-20° with differences dependent upon the movement being measured. From a clinical perspective this cannot be overlooked as the upper range of disagreement at 20 degrees may lead to differences in both diagnosis and the plan or care particularly as related to interventions designed to improve mobility. Only two previous studies have investigated the concurrent validity of similar

instruments for measuring shoulder function. One study investigated the concurrent validity of scapular plane elevation using similar instruments to this investigation.[13] In the aforementioned study the concurrent validity was good with an ICC value of 0.94 and the 95% LOA suggesting that the difference between these two measurement instruments can be expected to vary by up to +/- 11°. Another study investigated the concurrent validity of goniometry and a construction grade digital level and reported ICC values of non-involved (asymptomatic) to involved (symptomatic) shoulder motions of flexion, ER and IR.14 In the aforementioned study the concurrent validity was reported to range from ICC = 0.71-0.98 for both non-involved and symptomatic shoulders. For shoulder flexion the ICC ranged from 0.91-0.95 for the involved shoulder compared to 0.81-0.86 for the uninvolved. ER ranged from 0.91-0.96 (involved) to 0.71- 0.94 (uninvolved) whereas IR ranged from 0.82-0.96 (involved) to 0.83-0.93 (uninvolved).[14] While the aforementioned study offers insight into the interchangeability, the construction grade digital level may not be comparable to traditional inclinometers such as the one used in this investigation. This study was the first to analyze the concurrent validity of goniometric and digital inclinometric measurements of shoulder mobility. Due to the lack of research in this area, a comparison between the current study and previous research cannot be made. However, this study does set the groundwork for further research in this area in order to evaluate the interchangeability of goniometric and digital inclinometric measurements.

Limitations and Future Research

When interpreting the reliability values in our investigation, one must recognize that the consistency of AROM in individuals with healthy shoulders may not correlate with those who have shoulder pathology. Triffitt et al.[15] assessed the reproducibility limits of inclinometric shoulder abduction and external rotation in both symptomatic and asymptomatic subjects. Asymptomatic subjects had a difference ranging from 24 to 33° for all measurements as compared to 24 to 41° in symptomatic subjects, suggesting a greater variance among those with a painful shoulder. While the authors of the current study cannot state with certainly that this would be the case with all testers and procedures it is an issue requiring consideration.

CONCLUSIONS

The results cautiously support the interchangeable use of Lutron Force Gauge for measuring shoulder strength measurements. Although reliable, clinicians should consider the 95% limits of agreement when using these instruments interchangeably as clinically significant differences are likely to be present.

Level of evidence: 2b

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