

Reliability of 1-Repetition Maximum Estimation for Upper and Lower Body Muscular Strength Measurement in Untrained Middle Aged Type 2 Diabetic Patients

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Abstract

Purpose: The 1-repetition maximum (1-RM) test is the gold standard test for evaluating maximal dynamic strength of groups of muscles. However, safety of actual 1-RM testing is questionable in clinical situations such as type 2 diabetes (T2D), where an estimated 1-RM test is preferred. It is unclear if acceptable test retest reliability exists for the estimated 1-RM test in middle aged T2D patients. This study examined the reliability of the estimated 1-RM strength test in untrained middle aged T2D subjects.

Methods: Twenty five untrained diabetic males (n=19) and females (n=6) aged 40.7±0.4 years participated in the study. Participants undertook the first estimated 1-RM test for five exercises namely supine bench press, leg press, lateral pull, leg extension and seated biceps curls. A familiarisation session was provided three to five days before the first test. 1-RM was estimated for all participants by Brzycki 1-RM prediction equation. Another identical 1-RM estimation procedure occurred one week after first test. Intraclass correlation coefficients (ICC), paired *t*-test, standard error of measurement (SEM), Bland-Altman plots, and estimation of 95% CI were used to assess reliability.

Results: Test-retest reliability was excellent (ICC_{2,1}=0.98-0.99) for all measurements with the highest for leg extension (ICC_{2,1}=0.99). The SEM was lowest for lateral pull and leg extension exercises. Paired *t*-tests showed non-significant differences between the means of 2 sessions across three of five exercises.

Conclusions: The study findings suggest that estimation of 1-RM is reliable for upper and lower body muscular strength measurement in untrained middle aged T2D patients.

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INTRODUCTION

Strength training (ST) has been shown to be of great value in preventing and managing diseases and promoting health [1]. Since ST increases muscle force production resulting in an increase in muscle strength, assessing changes in muscular strength in response to an intervention in people with health conditions is clinically important. An actual determination of muscle strength in the laboratory situations includes the use of an isometric dynamometer and isokinetic dynamometers which require sophisticated equipment and trained personnel. A comparatively simple

alternative method, the one repetition maximum (1-RM) determination, has gained acceptance as the gold standard for assessing muscle strength [2]. The 1-RM method, requires relatively inexpensive non-laboratory equipment [3].

Though actual 1-RM testing is the most reliable test for evaluating the maximal dynamic strength of a muscle or group of muscles [4], untrained subjects are not always able to reach their 1-RM. Braith et al [5] suggested that actual 1-RM muscle strength testing may be contraindicated in individuals who have no previous lifting experience. Thus in clinical situations of muscle strength testing in low fitness profile

subjects, estimation of the 1-RM method is preferred to actual 1-RM testing. The procedures for 1-RM estimation have been described in the literature [6]. Validity of this estimation method has been established in measuring muscle strength in exercises such as the bench press, squat, dead lift, triceps press, bicep curl, leg press, hip flexion, hip extension, hip abduction, hip adduction, plantar flexion, and dorsiflexion [7]. The Brzycki 1-RM prediction equation [8] has been commonly used in estimating 1-RM, from a maximal repetition test (or 5-8 RM test). This formula has been shown to be the most valid equation in the prediction of a 1-RM for the bench press exercise ($r=0.98$) if the maximum number of repetitions does not exceed 10 during testing [9].

The test-retest reliability of the actual 1-RM test demonstrates high intraclass correlation coefficients (ICC) [4], however, it is unclear whether this test-retest reliability is applicable to estimated 1-RM measurement using Brzycki formula in untrained individuals with T2D. Reliability studies of maximal strength in middle-aged and older populations have used laboratory based equipments such as isokinetic dynamometers [10] and not non laboratory based equipments such as gym machines. Furthermore, studies on validity and reliability of 1-RM estimation methods in persons with health disorders such as type 2 diabetes are lacking. Recent evidence shows that skeletal muscle strength, especially in the lower extremity, is generally lower in adults with diabetes than in non diabetic subjects [11]. As reliability is said to be population specific, it is important to establish measurement properties of this method of muscular strength determination in people with health conditions such as T2D. Hence the current study was carried out with the purpose of examining the test-retest reliability of the estimation of 1-RM strength in determining upper body and lower body muscular strength of untrained middle aged individuals with T2D.

METHODS AND SUBJECTS

Participants:

Twenty five untrained type 2 diabetic males ($n=19$) and females ($n=6$) aged 40.7 ± 0.4 years were recruited

among employees at the local university and their relatives. Before inclusion, all subjects were examined by a physician, according to the recommendations in the American Heart Association scientific statement [12], and were medically cleared for strength testing. Subjects were included if they were previously inactive, defined as no strength training and <150 min of brisk walking/moderate exercise per week and <60 min of vigorous exercise per week in the preceding 6 months.

Exclusion criteria included individuals with heart disease, current insulin therapy, uncontrolled hypertension (blood pressure greater than 160/95 mm Hg), orthopedic problems during 6 months prior to study, nervous system disorders, proliferative retinopathy; myopathy, neurologic insult that resulted in mobility impairment and rheumatological disease that affected mobility. All participants received a complete explanation regarding the purpose and procedures of the study and regarding possible risks, before testing. They were also requested to sign an informed consent document. The study was approved by the human institutional ethics committee at the Department of Biosciences, Faculty of Natural Sciences of Jamia Millia Islamia (A Central University), New Delhi. All subjects were tested on two occasions using identical protocols.

Muscular Strength Testing Procedure:

A series of five exercises in the order of: supine bench press, leg press, lateral pull, leg extension and seated biceps curls were used to estimate 1-RM of upper and lower body musculature. Prior to muscular strength testing, each subject was instructed on proper technique of all the exercises. Details of the techniques and execution instructions of each exercise are outlined in table 1. All the exercises were performed on weight machines (Isoinertial based gym machines).

Two to three days before 1-RM estimation testing, each participant underwent a familiarization session using each piece of exercise equipment, according to the recommendations by Balady et al [13]. A weight was selected that the subject perceived as being of very low intensity with which correct lifting and breathing technique were taught and practiced. The practice was continued until the subject demonstrated to the researcher proper performance of the movement for a total of 10 repetitions for all the exercises using sub

Table 1: Details of exercises used for I-Repetition Maximum estimation

Exercise	Muscles Worked	Equipment	Technique Execution Instructions*
Supine bench press	Pectorals, Anterior deltoids, Triceps	Bench press machine	With your back flat on the bench without arching your back, lift the selected weight by extending the handles straight up in a slow, controlled motion until the arms are fully extended. Slowly return to the starting position
Leg press	quadriceps, hamstrings, gluteals	Leg Press machine	Extend knees and hips by pushing the foot plate of the machine and hold for a moment. Slowly return your legs back to the start position.
Lateral Pull	Latissimus dorsi, pectoralis major, biceps	Machine	Face the machine while seated and draw the bar down to the front of the chest in a slow, controlled manner. Pull the elbows in toward the body. The midpoint is reached when the bar almost makes contact with the chest. While remaining seated, slowly return the bar to the overhead position.
Leg extension	quadriceps	Leg Extension machine	Extend the knees in a slow, controlled motion until the knees are fully extended. Slowly return to the starting position
Seated biceps curls	Biceps	Biceps Curl Machine	Flex the arms in a slow, controlled manner, curling the handles of the machine up to the shoulders until the arms are fully flexed. Slowly return the handles to the starting position.

* For all exercises patients were instructed not to let the resistance rest on the weight stack of the machine between repetitions

maximal loads. Thereafter, the next appointment at the fitness centre for the first 1-RM estimation test was provided to each participant. In the familiarization and subsequent testing sessions, multi joint exercises were performed first followed by single joint exercises.

During the first testing session, each subject was instructed to perform a general warm up for 3 minutes by walking at self selected speeds on a treadmill, followed by whole body static stretching exercises. Thereafter using the amount of resistance used for the familiarization session, subjects were asked to complete 10 repetitions of each exercise. Afterward, the resistance was progressively increased until the subjects could perform only 9 or fewer repetitions of each exercise. The goal of the increase in resistance was to reach the desired repetitions in 3–6 attempts. The test was accepted only if the repetitions completed were 9 or less. 2 minutes of rest period was allowed between each attempt, and 3 minutes of rest was allowed between each specific exercise. Brzycki 1-RM prediction equation [8] was then used to estimate the 1-RM based on the resistance and repetitions recorded. The equation is mathematically expressed as $1RM = W / [102.78 - 2.78(R)] / 100$, where W is the weight used and R is the maximal number of repetitions performed. The second session occurred after 1 week, consisted of familiarization and 1-RM estimation procedures for the same 5 exercises, as in the first session.

Statistical analysis:

Sample size calculation: A power calculation using an F-test with a significance level of 0.05 revealed that a sample size of 19 subjects achieves 82% power to detect an R1 of 0.9 against a true R0 of 0.7. This was based on the literature on estimates for sample size requirements for reliability studies using interclass correlation coefficients (ICC) [14]. Assuming possible dropouts, twenty five subjects were recruited to adequately determine test retest reliability.

Data Analysis: Statistical analyses were carried out using SPSS version 16.0 for Microsoft Windows. Means and Standard Deviations for age, anthropometric data, fasting blood sugar and glycosylated haemoglobin were calculated for all subjects. The systematic error (the mean of difference scores of retest and test) was checked by a paired t-test with the significance level set at 0.05.

Test-retest reliability of estimated 1-RM was assessed using intra-class correlation coefficient (ICC) at an alpha level of 0.05. We wished to generalize the findings of this study to equally trained clinicians using estimated 1-RM measurements, hence ICC model 2,1 was used. Portney and Watkins stated that correlation value, $R > 0.75$ indicates good-excellent reliability [15]. Standard error of measurement (SEM), as an indicator of absolute reliability was calculated for each estimated 1-RM. SEM explores the precision of measurement i.e.

Table 2: Characteristics of untrained type 2 diabetic patients before study

Characteristic		Frequency or Mean (SD)	Range(Min-Max)
No. of Subjects(n)	Males	19	-
	Females	06	-
	Total	25	-
Anthropometric Data	Age (years)	40.7 (4.0)	29-41
	Body mass index (kg/m ²)	27.2 (3.2)	19-31
	Waist Circumference	91.2 (9.4)	78-107
	Waist Hip Ratio	1.2 (0.2)	1.0-1.9
Metabolic Variables	FBG levels (mg/dl)	169.0 (27.4)	125-215
	HbA1c levels (%)	7.8 (0.5)	6.9-8.7

FBG: Fasting blood glucose, HbA1c: Glycosylated Haemoglobin

typical error associated with the measurement. SEM was calculated as $SEM = SD_{\text{baseline}} \cdot \sqrt{(1 - r_{\text{test-retest}})}$ [16].

Bland-Altman plots were used to visually compare measurements of estimated 1-RM between the initial test and re-test. Bland-Altman plots were obtained for each exercise test by plotting the difference between retest and initial test values versus the mean of the retest and initial test scores [17].

RESULTS

Twenty five subjects (19 males and 6 females, mean age 40.7 ± 0.4 years) completed the study. Summary statistics of baseline characteristics are provided in Table 2. No adverse events occurred during the study period. Mild muscle soreness as a result of strength testing occurred, but this was not considered as an adverse event as it is common during 1-RM testing procedures.

The retest reliabilities ($ICC_{2,1}$) results together with the 95% CI and SEM results for all the exercises are

presented in Table 3. ICC results of all exercises ranged from 0.98 to 0.99, indicating excellent reliability in predicted 1-RM strength for all exercises. The leg extension exercise showed the highest retest reliability ($ICC_{2,1} = 0.99$), followed by the leg press, seated biceps curl, lateral pull and supine bench press ($ICC_{2,1} = 0.98$). The test-retest reliabilities of all 5 exercises exceeded 0.98. The paired *t*-tests showed non-significant differences between the means of the 2 sessions across all exercises except supine bench press and leg extension. There was a significant but small difference in leg extension ($0.76, P < 0.05$) and supine bench press ($0.88, P < 0.05$) predicted 1-RM with retest being slightly higher than test.

The SEM was lowest for seated biceps curl; leg extension and lateral pull exercises, suggesting that these measures also demonstrated high absolute reliability. The Bland-Altman plot provided for upper body exercises in Fig. 1 and lower body exercises in Fig. 2, illustrated that all data points were within the 95% limits of agreement (LOA) for leg press lateral pull and seated biceps curls, and only one out of 25 data points of supine bench press and leg extension lie outside. Paired *t*-test indicated no significant difference of the physical activity levels between test and retest

Table 3: Estimated 1-RM muscle strength* for 25 individuals with type 2 Diabetes Mellitus

Exercise	Initial Test	Retest	P value ‡	ICC (2,1)	95% CI for ICC	SEM
Supine bench press	50.5 (9.8)	51.4 (8.7)	<0.05	0.98	0.94-0.99	1.38
Leg Press	140.4 (25.2)	139.9 (24.3)	0.6	0.98	0.97-0.99	3.56
Lat Pull	51.1 (8.8)	51.7 (8.6)	0.08	0.98	0.95-0.99	1.24
Leg extension	64.0 (12.4)	64.8 (12.83)	<0.05	0.99	0.97-0.99	1.24
Seated biceps curls	17.46 (4.8)	17.56 (4.8)	0.5	0.98	0.97-0.99	0.67

* Estimated 1-RM was calculated using Brzycki 1RM prediction equation; ‡ T Test Results

ICC 2,1 = intra-class correlation coefficient; CI = confidence interval; SEM = standard error of measurement, Calculated as: $SEM = SD_{\text{baseline}} \cdot \sqrt{(1 - r_{\text{test-retest}})}$

occasions ($t = -0.225, P = 0.8$).

DISCUSSION

This study is one of the first investigations on the test retest reliability of upper and lower body muscular strength estimation in T2D subjects. The ICC value for estimated 1-RM strength across all the exercises studied ranged from .98 to .99. According to Portney and Watkins [15], ICC values above 0.75 are considered good to excellent. The ICC of 0.98 or greater for intra rater reliability achieved in this study indicates that excellent reliability was achieved for multiple exercises. Furthermore, excellent reliability in the measurements were demonstrated in the Bland Altman plots by showing good agreement between test and retest values. These results indicate that estimation of 1-RM method can be reliably used in assessing muscular strength of T2D patients.

Estimation of a 1-RM as a method of assessment of muscular strength performance has been shown to be valid [6,7]. But, no studies were discovered that described reliability of 1-RM estimation on a series of exercises in T2D subjects. The results of this study also indicate that Brzycki 1-RM prediction equation may be useful in the estimation of upper body and lower body muscular strength of T2D patients. These results are similar to findings of Mayhew et al [9], that Brzycki 1-

RM prediction equation is valid in predicting 1-RM for the bench press ($r = 0.98$). Mayhew et al study was conducted on healthy subjects whereas the present study is on T2D patients, and testing was done on a series of exercises in contrast to bench press exercises only in Mayhew et al study. Findings of both studies are only applicable if the maximum number of repetitions does not exceed 10 during testing.

The ICC values obtained in this study are also similar to previous studies [18,19] reporting test retest reliability of actual 1-RM measurement techniques. Levinger et al [18] examined the intrarater reliability of 1-RM testing of a range of different exercises and reported ICC values ranging from 0.97 to 0.99. Levinger et al investigated the test retest reliability of actual 1-RM; whereas the current study used estimated 1-RM. ICC ranging from 0.98 to 0.99 in our study is comparable to Levinger study, indicating both actual and estimated 1RM can be reliably used for muscle strength measurements. Reliability is considered to be a population specific characteristic, therefore we considered the importance of establishing reliability in a sample of T2D, where altered muscle function is most likely to occur. The results suggested a comparable reliability between healthy and T2D subjects in terms of muscle strength measurements. This study is particularly important in the light of recent evidence that skeletal muscle strength, especially in the lower extremity, is generally lower in adults with diabetes than in nondiabetic subjects [11].

The excellent retest reliability obtained in this study

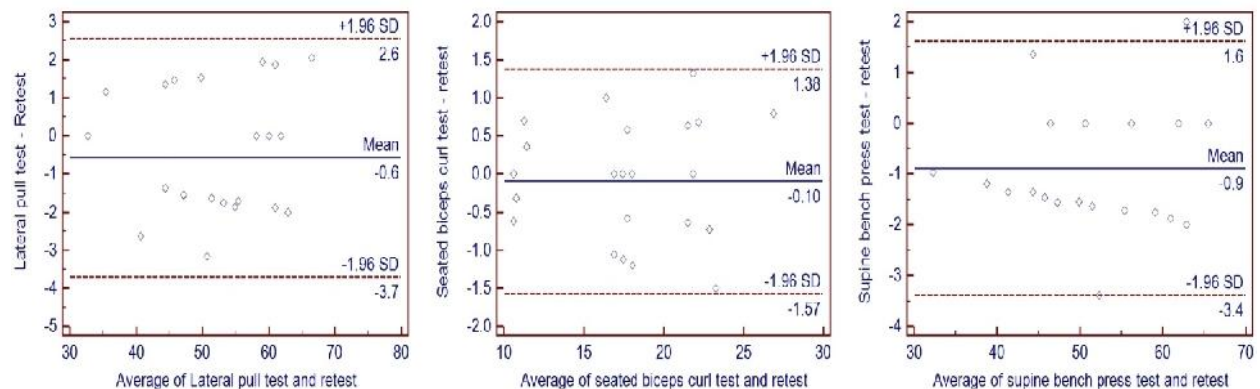


Fig 1: Limits of Agreement Plots for three upper body exercises. The differences between estimated 1-RM test scores on test and retest are plotted against each individual's average for the two tests. The dotted lines represent the 95% limits of agreement (+1.96 standard deviations). Values along X and Y axis are given in kilograms.

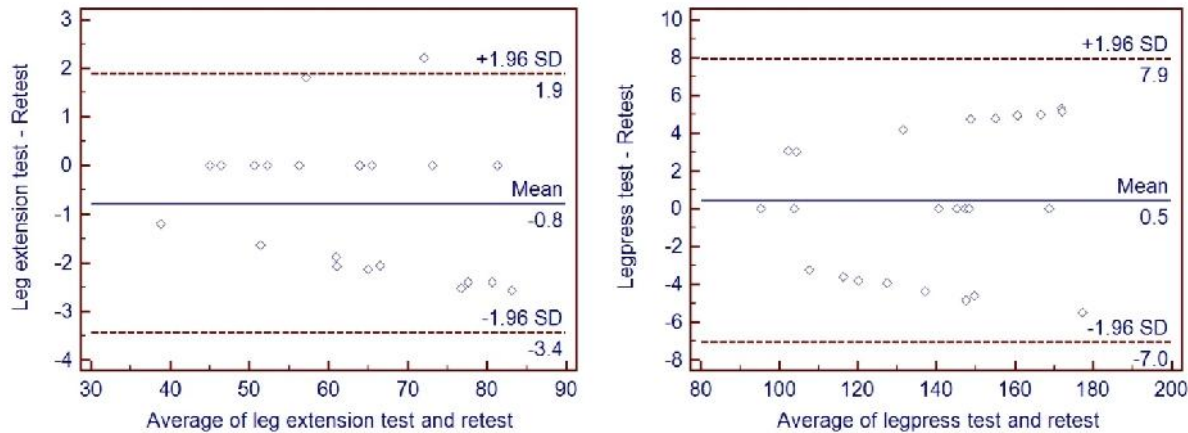


Fig 2: Limits of Agreement Plots for two lower body exercises. The differences between estimated 1-RM test scores on test and retest are plotted against each individual's average for the two tests.

might be explained by the use of familiarisation sessions before testing. Previous studies investigating reliability of 1-RM testing also used the familiarization session prior to testing [18,19]. Taylor et al [19] studied the reliability of 8-RM test in young men and women after familiarization, in which excellent reliability of 8-RM test was demonstrated. Furthermore, we used a relatively younger sample of T2D subjects, where no diabetes complications such as neuropathy or nephropathy were reported. Previous studies found that muscle weakness in T2D patients are related to presence and severity of peripheral neuropathy. Middle aged T2D patients in this study, without peripheral neuropathy may have responded to strength testing in a way comparable to healthy subjects.

Although a good amount of peer reviewed literature is available on the reliability of actual 1-RM testing in healthy populations, there is scarcity of data on its usefulness in clinical populations. Furthermore, actual 1-RM muscle strength testing may be contraindicated in individuals who have no previous lifting experience. Therefore, estimation of muscle strength provides a useful alternative for muscular strength testing in clinical populations, such as T2D. The data from the current study suggest that estimation of 1-RM method is a reliable and simple method to evaluate upper and lower body maximal strength in T2D patients.

The limitations of our study were an unequal number of men and women in the study sample and inclusion of very small range of age group. The subsample of women was too small in our study to

investigate the influence of gender on test retest reliability. Future studies should consider examining reliability of estimated 1-RM strength testing in diabetic men and women separately. Future reproducibility studies on muscle strength measurement should also be conducted on elderly diabetic subjects, where estimation of muscle strength may be more applicable, because of the deterioration of muscle function resulting from ageing and diabetes. Furthermore, this study used self report measure to designate participants as previously inactive. Self report measures probably have limited reliability and validity relative to laboratory measure of physical activity [20]. Therefore inclusion of physically inactive subsets of patients based on laboratory measures of physical activity in future studies may yield more generalizable results. More studies on a variety of age and ethnic groups intended to provide normative muscle strength data should also be conducted, which could be used for comparison of variability of the observed strength data.

CONCLUSION

Actual and predicted 1-RM determination has been recommended for determining muscular strength and prescribing resistance exercises. Measurement properties of actual 1-RM determination are well

established, but minimal research has been done on the reliability of prediction 1-RM on people with health disorders such as type 2 diabetes. Therefore, the investigation of reliability of this method of muscle strength determination is warranted. The findings of this study suggests that prediction of 1-RM muscle strength by Brzycki 1-RM prediction equation, can be used reliably to measure upper and lower body muscle strength in type 2 diabetic patients, where there is chance of altered muscle function.

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Conflict of interests: None

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