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Review Article

Physiotherapy Section

Prediction of the One Repetition Maximum to Design Strength Training Protocol

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ABSTRACT

Accurate measurement of muscle strength is essential to design proper strength training protocol and to find out the efficacy of prescribed strength training protocol on muscle performance. One Repetition Maximum (1RM) is a reliable mean for the measurement of muscle strength. Primary goal of this review article was to explore the methods used in various articles of research databases that investigate the accurate way of estimation of 1RM before the design of strength training protocol. Wide range databases were searched to address articles on prediction of 1RM mentioned in Scopus, Pubmed, MEDLINE, Web of science, Google scholar databases, Wiley online library. Accurate determination of 1RM is based on various variables like gender, age, familiarisation of exercises, selection of predicted load, parts of body assessed (upper or lower limbs), rest interval given between exercise attempt and number of repetitions with percentage of predicted load. Prediction of 1RM varies significantly across different research studies. Based on the articles reviewed, it can be concluded that accurate prediction of 1RM is important to quantify current muscle strength level before one begins with strength training protocol. Many research articles mentioned that calculation of 1RM consists of trial and error, and it can also result into delayed onset of muscle soreness of particular tested muscles. Accurate Prediction of 1RM is important to design strength training protocol and it is also used to find out the efficacy of strength training protocol on muscle performance.

Keywords: Determination, Estimation, Resistance training

INTRODUCTION

Strengthening exercise program is required to promote healthy lifestyle which helps to prevent early aging in adults and prevention of age related musculoskeletal conditions due to deterioration of muscle strength [1-3]. Good muscle power is required to perform functional activities with ease and improve physical functioning. It also results into better achievement in physical activities and reduces risk of injuries, trauma to joint or risk of fall in geriatric. Strength training is recommended for improving muscular strength and slowing deterioration of age-dependent muscle strength and for rehabilitating the patients with musculoskeletal conditions [4]. It is performed either using isometric, isotonic or isokinetic muscle contractions. Accurate analysis of muscle power is essential to find out the efficacy of prescribed strength training protocol on muscle performance. Frequency, intensity and sets of prescribed strength training exercises based on calculated values of percentage of maximum strength which further focus on the need of accurate prediction of baseline outcome measure of muscle strength [5-7].

Reliable method of assessing muscle strength is essential for standard procedure of strength training protocol to safeguard sport and rehabilitation. Isokinetic dynamometer is used to assess muscle strength in clinical laboratory, but the disadvantage is that it is a costly equipment and single joint-based test of strength [3]. Standard outcome measure for resistance or load is 1RM.

The 1RM is a reliable mean for the measurement of muscle strength and is termed as the value of load against which prescribed movement is achieved only once in complete full range of motion with free weights with correct lifting technique [8,9]. Advantage of using 1RM test is that it is an inexpensive non-laboratory equipment and easy to perform [10]. Eccentric actions counter balanced by concentric action produce dynamic muscle actions which are commonly used in functional day to day activities and in strength training. 1RM also assess muscle strength in muscles that connect multiple joints. The 1RM is safe to perform in children, geriatric and athletics. Thus, 1RM is also called as a gold standard" test [3]. The 1RM is used as a benchmark to find the maximal dynamic strength and is safe when performed accurately. Repetition maximum is a baseline outcome measure used to find out the efficacy of strength training program and calculate exercise load for strength training. This term was first reported by DeLorme during his research for progressive resistive exercise [5].

The goals for determination of 1RM are documentation of baseline outcome measure which is used to find out effect of exercise induced improvement in strength against a specific load and comparison of the same. Another goal of 1RM is to recognise amount of exercise load that should be used to design frequency, intensity and sets of strength training exercises. Prediction of 1RM is an assessment method to identify a load which can be lifted once through complete motion [5]. The 1RM is the maximum load limit. Number of repetitions can be maximised by using small friction of 1RM. Percentage of 1RM load depicts maximum number of repetitions that can be performed with same estimated load (example: 60% 1RM load indicate maximum 6 repetitions can be achieved). Amount of 1RM load varies from person to person [4]. A 50% 1RM load improves muscle power, whereas 80% 1RM load improves bone density [11].

Physiotherapist should estimate the baseline 1RM on the basis of number of repetitions that can be performed with specific selected load through the entire range, without sign of fatigue. Calculation of 1RM consists of trial and error [4], but 1RM is most common assessment method used for design of strength training protocol in healthy adults, athletic, geriatric population and musculoskeletal rehabilitation [5]. Accurate assessment of 1RM is time-consuming and can result into delayed onset muscle soreness of particular tested muscles [4]. Prediction of 1RM varies significantly across different research studies. Therefore, purpose of this review article was to investigate the accurate way of prediction of 1RM reported in individual studies and summarises their findings.

Literature Search Strategy

A range of English-language research databases of Scopus, Pubmed, MEDLINE, Web of science, Google scholar databases, Wiley online library were searched to find articles on prediction of 1RM to design a strength training protocol using the following research syntax (prediction, determination, estimation of 1RM). All the research articles that investigated the prediction of 1RM test were reviewed.

DISCUSSION

The authors found studies where 1RM was estimated on healthy population, on both gender especially in women [5,12], Spinal Cord Injury (SCI) [13], Down's syndrome [14], athletic and geriatric population and in population with pathological conditions [15,16]. Chandler J et al., reported that prediction of 1RM is very complex from physiological or kinesiologic aspect. Speed of motion and types of muscle contraction changes the force produced by muscle action. Estimation of 1RM was carried out over series of trials where the volume of load to be lifted is increased gradually until the participant fails to achieve a complete range of motion. Multiple repetitions are required in this method; fatigue may alter the results [17].

LeSuer Dale A et al., reported that prediction of 1RM can be a concern as it is time-consuming and there is risk of injuries while lifting heavy loads. The main purpose of this study was to find out the accuracy of seven predicted equations to estimate 1RM from number of repetitions to fatigue for squat, bench press and deadlift. A total of 67 untrained college students (40 males, 27 females) were enrolled in strength training protocol and they were trained for 45 minutes with proper correct lifting technique with maximum weight to predict 1RM. Subjects choose a load by themselves to test 1RM and a weight that would fatigue them in few repetitions. Before testing 1RM, subjects performed light warm up exercises. To test 1RM, weight was added gradually till subjects failed to lift the further weight. It was achieved in 3-6 attempts with 3 to 5 minutes interval between each attempt. Subjects were randomly assigned into two groups. Group 1 was initially tested for 1RM test with prescribed weight followed by 10 minute rest and repetitions to fatigue testing. Group 2 was initially tested for repetitions to fatigue followed by 10 minute rest and 1RM test. The 1RM was estimated with minimum of 48 hours rest interval between each three lifts. All correlation coefficients were significant (r=0.95) for predicted and achieved 1RM. It was concluded that all equations were efficient to predict 1RM. Formula of deadlift significantly underestimate accuracy of 1RM despite high correlation [18].

Brown LE and Weir JP reported in their study that 1RM is standard for the prediction of isotonic strength. Subject performed warm up exercises followed by eight repetitions of 50% estimated 1RM load. Again three repetition of 70% estimated 1RM load with rest interval between the trials was 1-5 minutes. Load was increased gradually for single repetition until 1RM was achieved for particular subject until failure. In this study, it was mentioned that 1RM testing can be confounded by fatigue due to multiple trials. Number of factors need to considered while predicting 1RM like selection of starting load, criteria for increments of load between attempt, rest interval between trials and feedback from subject regarding predicted weight they can lift [19].

Rontu JP et al., compared traditionally used 1RM to new 1RM bench press by using sub maximal load. The aim of this study was to find the accuracy accelerometer-based method to estimate 1RM of bench press. Twenty two floorball players were recruited. They performed strength training exercises for three days a week. Subjects performed warm up exercises, two bench press series with 50% estimated load for 10 lifts followed by four repetitions of one series with 60% of estimated load and then finally four repetitions of one series with 80% load. In traditional 1RM test, subjects were instructed to select load on the basis of previous efforts. Aim was to achieve 90% load of estimated 1RM initially and then gradually loads were increased in next attempt. A 3 kg load was increased at every attempt till subject failed to lift the sub maximal load. Maximum load lifted once through entire motion was considered as 1RM bench press test. Once 1RM test was done, five single bench press lifts were performed. Rest duration between trials was 5 minutes. Acceleration signal was taken from equipments installed at wrist level and bar during lifts. Calculated means of 1RM were 69.85-69.97 kg. Correlation between traditionally measured and estimated 1RM was very high (0.89-0.97, p-0.001), difference between them was very small to be documented (0.11-0.01 kg). In this study, it was reported that new method had very small dynamic area for prediction of 1RM. One Repetition Maximum cannot be achieved by just performing single repetition but need several repetitions based on percentage of loads. The problem with new method was that estimation equation was different for different load. This study concluded that lifting sub maximal load only once through the entire motion provides estimation of 1RM immediately [20].

Maythew JL et al., performed a study to find accuracy of current prediction equations for determination of 1RM bench press before and after 12 weeks resistance training in women and also whether strength training can change prediction of 1RM. Repetition to fatigue could be a good predictor of 1RM in men if load is less than 1RM but there is insufficient information about it in females. A total of 103 young college women were recruited in resistance training program. Every participant's participated in progressive strength training exercises for three days per week for 12 weeks. Exercises included in strength training were latissimus dorsi pull-downs, bench press, bicep curl and calf raises. A total of 1RM was tested by using free loads to measure strength of upper body musculature. Participants were instructed for proper lifting technique. Initially warm up exercises were performed for 6-10 repetitions using lighter load. Participants performed single repetition against 90% of their maximum weight ability. 1RM was achieved by either addition or deduction of weight. Five minutes rest interval was given after every attempt. The 1RM was achieved in 3-5 attempts. Greatest weight lifted once throughout the range with proper lifting technique was considered as participants 1RM. Reliability of this was >0.98. 1RM bench press significantly improved after 12 weeks of resistance training (28±21%) but average improvement in repetition to fatigue. Predicted 1RM values were highly significant than actual 1RM. This study concluded that resistance training improve muscle strength without comprising accuracy of 1RM [12].

Ploutz-Snyder LL and Giamis EL stated maximum research studies suggested the geriatric population had wider range for increase in muscle strength following resistance training. The aim of this study was to find out number of repetitions required to predict accurate 1RM muscle strength in older and young women. Baseline outcome measure was 1RM which was increased by not more than 1 kg at every attempt. Untrained healthy young and older women participated in the study. Participants had two familiarisation sessions for resistance training protocol consisting of isotonic exercises on knee extension dynamometer in sitting position. Warm up exercises were performed with lighter load for 10 repetitions, followed by five repetitions of medium weights. Concentric bilateral 1RM was tested by identifying greatest load lifted once throughout the range. It required 3-5 trails depending on participants. Two minutes rest interval was given after every two trails. Participants were screened for 1RM over course of several days. A 48 hours of rest interval were given between every trial of 1RM measurements. Analysis of result showed a significant difference (p<0.0001) in 1RM in both groups; 8-9 sessions were required in old women, whereas young women required 3-4 sessions. It was concluded that older population had wide range of improvement in muscle strength and required familiarisation sessions compared to young population and 1RM is a reliable measure of calculating muscle strength [15].

Neto FR et al., studied the accuracy of 1RM predictive equations to assess the muscle strength in individual with Spinal Cord Injury (SCI). Aim of article was to test current 1RM and compare it with 4-12 RM test in men with SCI. Forty five male patients, diagnosed with SCI between C6 and L2 causing motor impairment, were included into three groups. The 1RM and 4-12 RM test by using bench press exercise was performed by same tester and at interval of 48-72 hours to avoid fatigue. Before the assessment of 1RM, patients were instructed to perform warm up exercises with the 50% of perceived maximum resistance for 5-10 repetitions. The 1RM interval was given and further progressed to 50% of perceived maximum resistance for 3-4 repetitions. After 2 minute rest interval, 1RM was calculated by either increasing or decreasing load. To assess 4-12 RM test, same 1RM warm up protocol was used. Initial resistance was 80-90% of greatest load. Participants were informed to perform atleast 4 to 12 repetitions. Five minute rest interval was given after every attempt. Intraclass Correlation Coefficient (ICC) was used to compare 1RM test with current predictive equations and was found satisfactory and rated as excellent. All current predictive equations were based on Cicchetti standards. Multiple regression analysis was used to predict 1RM load. There were no significant differences between current equation and 1RM test. This study concluded that 1RM predictive equations are the accurate method for the assessment of muscle strength in SCI at bench press exercise [13].

do Nascimento MA et al., studied that Brzycki equation can be used in assessment of 1RM for bench press. In young adults, O'Connor equation calculates correct 1RM. This study reported that all equations provide accurate estimation of 1RM in SCI. Limitation of study was, due to unavailability of load ranges the accuracy of load was not achieved, moreover the same testing person was used to assess 1RM and tester was not blind folded during assessment [13,21].

García-Ramos A et al., used three different methods for the estimation of 1RM during free weight prone bench pull exercises. A lifts-to-failure equation proposed by Lombardi was used to predict 1RM. Twenty six male (22 rowers and 4 weight lifters) participants were instructed not to do strenuous exercises before 24 hours of session. Warm up exercises included of 5 minute jogging, five repetitions of prescribed exercises with joint mobility exercises before beginning with the testing of 1RM. Weight was increased gradually till 1RM was achieved. In the beginning three repetitions performed with lighter load, two repetitions with moderate load followed by one repetition with heaviest load (MV <0.80 $m*s^{-1}$). Rest interval for intraset was 1 second and for interset was 5 minutes. A series of repetitions-to-failure with a weight ranged from 75%-90%, 1RM was performed for 10 minutes. ANOVA showed significant difference in 1RM values among different methods. Lifts-to-failure equations, General load-velocity relationship and Individual load-velocity relationship were able to estimate 1RM accurately. All methods had acceptable reliability for the prediction of 1RM [22].

Determination of 1RM is based on several factors which is based on selection of starting load, increments in loads, repetitions with selected loads, rest interval between each trials and lifting procedure of weights [23,24].

Many authors had reported difficulties in execution of 1RM testing, due to heavy load lifting specially in untrained individuals. It is time consuming because adequate rest duration is required between attempts [18,25]. Lifting of heavy loads increased chance of injuries and put stress on muscle, ligament and connective tissues. The 1RM prediction can be hampered by unavailability of information about acceleration, rate of force development and contraction momentum. The 1RM could not be predicted by performing just single repetition but requires number of repetitions depending of selected load. Many research articles suggested that repetitions to failure (10 or less repetitions) can predict 1RM accurately. Participants who are unknown to strength training or measurement of 1RM, for them attempting heavy weight can be intimidating task. The key aim of any strength training protocol is to track the improvement in muscle strength accurately resulting from training.

CONCLUSION(S)

Prediction of 1RM varies significantly across different research studies. Testing of 1RM is safe but can result into potential injuries while lifting heavy loads. 1RM consists of trial and error. Repetitions of prescribed strength training exercises are based on the calculated values of percentage of maximum strength lifted once, which further focus on need of accurate estimation of baseline outcome measure of muscle strength. Accurate prediction of 1RM is important to quantify current muscle strength level before beginning with strength training protocol. Based on the review of literature, it is concluded that accurate prediction of 1RM is important to design strength training protocol and it is also used to find out the efficacy of strength training protocol on muscle performance.

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