

Research article

## Reliability of the one-repetition maximum test based on muscle group and gender

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### Abstract

The purpose of the present study was to examine the influence of muscle group location and gender on the reliability of assessing the one-repetition maximum (1RM) test. Thirty healthy males ( $n = 15$ ) and females ( $n = 15$ ) who experienced at least 3 months of continuous resistance training during the last 2 years aged 18-35 years volunteered to participate in the study. The 1RM for the biceps curl, lat pull down, bench press, leg curl, hip flexion, triceps extension, shoulder press, low row, leg extension, hip extension, leg press and squat were measured twice by a trained professional using a standard published protocol. Biceps curl, lat pull down, bench press, leg curl, hip flexion, and squat 1RM's were measured on the first visit, then 48 hours later, subjects returned for their second visit. During their second visit, 1RM of triceps extension, shoulder press, low row, leg extension, hip extension, and leg press were measured. One week from the second visit, participants completed the 1 RM testing as previously done during the first and second visits. The third and fourth visits were separated by 48 hours as well. All four visits to the laboratory were at the same time of day. A high intraclass correlation coefficient ( $ICC > 0.91$ ) was found for all exercises, independent of gender and muscle group size or location, however there was a significant interaction for muscle group location (upper body vs. lower body) in females ( $p < 0.027$ ). In conclusion, a standardized 1RM testing protocol with a short warm-up and familiarization period is a reliable measurement to assess muscle strength changes regardless of muscle group location or gender.

**Key words:** Reliability, 1RM, resistance exercise.

### Introduction

The one repetition maximum (1RM) test is considered the gold standard for assessing muscle strength in non-laboratory situations (Levinger et al., 2009). It is defined as the maximal weight that can be lifted once with correct lifting technique, is comparatively simple and requires relatively inexpensive non-laboratory equipment (Kraemer et al., 2006). The 1RM testing is useful used by athletic trainers, health and fitness professionals and rehabilitation specialists to quantify the level of strength, assess strength imbalances, and to evaluate training programs (Braith et al., 1993).

Previous studies have suggested that the 1RM testing to assess muscle strength is safe for participants (Featherstone et al., 1993; Ghilarducci et al., 1989;

Gordon et al., 1995; Shaw et al., 1995). Due to the wide use of 1RM testing, it is important for the 1 RM to be a reliable measurement. Major exercises such as the bench press and squat have been shown to be reliable measurements for 1RM testing (Flansbjerg and Lexell, 2010; Levinger et al., 2009; McCurdy et al., 2004; Nevill and Atkinson, 1997; Tagesson and Kvist, 2007), but it is unclear if acceptable test-retest reliability exists for other less used muscle groups. Possible factors that may affect reliability are gender and/or muscle group location, therefore, the main purpose of this study was to determine the reliability of the 1RM strength test in healthy men and women for the influence of muscle group location and gender.

We hypothesized that the reliability of 1RM testing would not be different between large muscles and small muscles, upper body muscles and lower body muscles and also would not be different between men and women in healthy subjects. Therefore the purpose of this study was to examine the influence of muscle group location and gender on the reliability of assessing the 1RM test.

### Methods

#### Subjects

The institutional review board of the university approved the design of this study. Thirty healthy males and females aged 18-35 years ( $26.8 \pm 1.3$  years old of men and  $23.3 \pm 0.8$  years old of women), who experienced at least 3 months of resistance training during the last 2 years volunteered to participate in the study. Written informed consent was obtained from each participant before the start of the study. Potential participants were screened with a health history questionnaire prior to participation in this study. Their body weights were  $82.9 \pm 3.7$ kg in men and  $63.4 \pm 2.8$ kg in women. Based on the 2 X 2 repeated measures design and an anticipated statistical power of 0.80 with an effect size 0.8, it was determined that a total sample of 30 subjects would be necessary (G-power program 3.12, Germany).

#### Materials

Instrumentation included Cybex machines for biceps curl, triceps extension, lat pull down, military press, bench press, low row, leg curl, leg extension, hip flexion, hip

extension, leg press, and squat (Lumex, Ronkonkoma, NY, USA).

### Procedures

On the initial visit, participants signed the informed consent form, and completed a physical activity questionnaire. Following an individual warm-up of stationary cycling and a brief familiarization with the equipment, 1RM for the biceps curl, lat pull down, bench press, leg curl, hip flexion, and squat were measured by a trained professional. Forty-eight hours after the first visit, subjects returned for their second visit. During their second visit, their 1RM of triceps extension, shoulder press, low row, leg extension, hip extension, and leg press were measured. One week from the second visit, participants completed the 1 RM testing as previously done during the first and second visit. The third and fourth visits were separated by 48 hours as well. All four visits to the laboratory were at the same time of day.

### 1RM strength testing

Participants warmed up prior to testing by cycling for 5 minutes on a stationary bicycle. After a 1 minute rest period, participants were familiarized with each of the resistance machines (Lumex, Ronkonkoma, NY, USA) by performing 8-10 repetitions of a light load (~50% of predicted 1RM). After a 1 minute of rest, participants performed a load (~80% of estimated 1RM) through the full range of motion. After each successful performance, the weight increased until a failed attempt occurred. One minute rests were given between each attempt and the 1-RM was attained within 5 attempts and 5 minutes rest separated each test. In order to facilitate the recovery and reduce the effect of fatigue, exercises were alternated between the upper and lower body. The order of the exercises during the first visit was as follows: biceps curl, leg curl, lat pull down, hip flexion, chest press, and squat. The order of the exercises during the second visit was as follows: triceps extension, leg extension, shoulder press, hip extension, low row, and leg press. All 1RM measurements were reported in kilograms for subsequent data analysis. We also defined large and small muscle groups by 1RM weight that is to say 1RM of Lat pull down, Bench press, Low row, Leg extension, Leg press, Squat were heavier than others.

### Statistical analysis

The data were analyzed using SPSS 17.0 software (SPSS, INC., Chicago, IL, USA) for windows. In this study, the reliability was performed according to the recommendation of two published papers (Atkinson and Nevill, 1998; Hopkins, 2000). The coefficient of variation (CV) was defined as the ratio of the standard deviation to the mean. Also intraclass correlation coefficient (ICC) was used as they are a common measurement of reliability that enables comparisons with other study (Atkinson and Nevill, 1998). ICC method was based on a repeat measurement of maximal strength and in which the same investigator conducted each test (Portney and Watkins, 2000). Differences between men and women were analyzed by means of repeated-measures ANOVA. Paired sample t-test was performed for examining difference between test and retest. Descriptive data are presented as means and standard error of the means. A p value of  $p < 0.05$  was accepted as the level of statistical significance for all variables.

### Results

Raw data of test and retest for all twelve exercises of 30 subjects are showed in Table 1. Also the interaction of gender X time for muscle strength is presented in Table 1. We found that there were no differences between males and females on reliability of the 1RM tests. Table 2 shows the reliability of test retest in males, females, and for the combined sample. A high intraclass correlation coefficient ( $ICC > 0.91$ ) was found for all exercises. Table 3 shows the interaction of muscle groups (upper body vs. lower body, large muscles vs. small muscles) X time for muscle strength test. There was a significant interaction effect on muscle group location (upper body vs. lower body) in females ( $p < 0.027$ ).

### Discussion

In the current study, our main findings showed that the 1RM test, using Cybex exercise equipment, is a reliable and simple method for assessing maximum strength for both men and women and for a wide range of large and small muscle groups. However, there was a significant interaction for the upper body muscle groups versus lower body muscle groups in females ( $p < 0.027$ ).

**Table 1.** Interaction of gender X time for muscle strength. Data are means ( $\pm$  SEM, kg).

	Male		Female		F	p
	Test	Retest	Test	Retest		
<b>Biceps curl</b>	56.2 (4.7)	56.2 (4.7)	18.0 (2.1)	18.2 (2.1)	.104	.749
<b>Triceps extension</b>	49.0 (3.7)	49.0 (3.7)	19.3 (1.9)	19.5 (1.9)	1.000	.326
<b>Shoulder press</b>	74.5 (3.3)	78.7 (5.4)	36.1 (2.8)	36.3 (2.8)	1.099	.304
<b>Lat pull down</b>	88.3 (4.5)	87.0 (4.8)	40.9 (3.3)	41.0 (3.4)	2.422	.131
<b>Low row</b>	95.5 (5.0)	98.9 (6.7)	42.0 (2.8)	42.0 (2.8)	1.000	.326
<b>Bench press</b>	98.6 (7.5)	98.0 (7.2)	39.3 (2.9)	39.3 (2.9)	.944	.340
<b>Hip flexion</b>	81.3 (3.5)	82.7 (3.6)	54.5 (4.7)	55.2 (4.8)	.341	.564
<b>Hip extension</b>	111.2 (1.3)	111.2 (1.3)	80.8 (4.1)	80.6 (4.1)	1.000	.326
<b>Leg curl</b>	102.2 (3.3)	102.3 (3.2)	59.0 (4.5)	59.8 (4.5)	1.068	.310
<b>Leg extension</b>	102.0 (4.1)	102.5 (4.0)	60.9 (3.6)	61.3 (3.6)	.152	.699
<b>Leg press</b>	159.2 (9.7)	159.2 (9.6)	103.5 (5.6)	104.1 (5.6)	.483	.493
<b>Squat</b>	116.8 (10.6)	116.2 (10.3)	52.1 (5.2)	54.0 (5.5)	2.033	.165

Tested by two-way mixed factorial repeated measures ANOVA for gender x time

**Table 3. Interaction of muscle group (upper body vs. lower body; large muscles vs. small muscles) x time for muscle strength. Data are means (± SEM, kg).**

	Male		Female	
	Test	Retest	Test	Retest
Upper body	77.0 (2.8)	78.0 (3.0)	32.6 (1.5)	32.7 (1.5)
Lower body	112.2 (3.6)	112.4 (3.5)	68.5 (2.7)	69.2 (2.7)
F	.570		4.959	
p	.451		.027*	
Large muscle	110.1 (3.8)	110.3 (3.9)	56.4 (2.9)	57.0 (2.9)
Small muscle	79.1 (2.7)	80.0 (2.8)	44.6 (2.8)	44.9 (2.8)
F	.574		.610	
p	.450		.436	

Upper body muscle groups: Biceps curl, Triceps extension, Shoulder press, Lat pull down, Low row, Bench press; Lower body muscle groups: Hip flexion, Hip extension, Leg curl, Leg extension, Leg press, Squat; Large muscle groups: Lat pull down, Bench press, Low row, Leg extension, Leg press, Squat; Small muscle groups: Biceps curl, Triceps extension, Shoulder press, Hip flexion, Hip extension, Leg curl. \* p < 0.05.  
Tested by two-way mixed factorial repeated measures ANOVA for muscle group x time.

**Table 2. The reliability of test and retest in male, female, and total.**

Test		Male (n=15)	Female (n=15)	Total (n=30)
Biceps curl	CV	.325	.64	
	ICC	.993**	.996**	.998**
Triceps extension	CV	.30	.55	
	ICC	1.000**	.995**	1.000**
Shoulder press	CV	.22	.44	
	ICC	.644**	.998**	.913**
Lat pull down	CV	.205	.44	
	ICC	.979**	.998**	.995**
Low row	CV	.23	.48	
	ICC	.836**	1.000**	.961**
Bench press	CV	.29	.535	
	ICC	.997**	1.000**	.999**
Hip flexion	CV	.17	.31	
	ICC	.969**	.996**	.992**
Hip extension	CV	.05	.20	
	ICC	1.000**	.999**	1.000**
Leg curl	CV	.12	.325	
	ICC	.998**	.994**	.998**
Leg extension	CV	.155	.31	
	ICC	.997**	.994**	.999**
Leg press	CV	.235	.315	
	ICC	.997**	.997**	.998**
Squat	CV	.345	.53	
	ICC	.992**	.973**	.994**

ICC, intraclass correlation coefficient; CV, coefficient of variation; \* p < 0.05, \*\* p < 0.01

This study is the first to examine the reliability of 1RM testing for a wide range of resistance exercises (twelve exercises), compared to many previous studies that only used major muscle groups (Frontera et al., 1993; Levinger et al., 2009; McCurdy et al., 2004; Ploutz-Snyder and Giamis, 2001; Tagesson and Kvist, 2007). Flansbjerg and Lexell (2010) reported the reliability of 1RM testing on leg extension and leg curl, Levinger et al. (2009) reported the reliability of 1RM testing on chest press, leg press, lat pull down, triceps push down, knee extension, seated row, and, biceps curl. McCurdy et al. (2004) reported the reliability of 1RM testing on squat, Tagesson and Kvist (2007) reported the reliability of 1RM testing on squat and knee extension, with all studies reporting that each 1RM test was reliable. In the current study, we examined the reliability of 1RM testing on upper and lower body and large and small muscle groups

in both males and females. Our results suggest that coaches and clinicians can utilize the 1RM testing to reliably monitor the progress of muscle strength in healthy men and women.

An important part to ensure reliability in 1RM testing is the use of familiarization. Some previous studies reported that multiple familiarization sessions are needed before assessing maximal strength in order to avoid an improvement in muscle strength due to improved motor coordination or other neural adaptations (Kraemer et al., 2006; Ploutz-Snyder and Giamis, 2001). Also it has been suggested that a familiarization process prior to 1RM strength test is essential for ensuring reliable test results, and minimize learning effects or systematic bias (Frontera et al., 1993; Hopkins, 2000). Our participants were familiarized with each of the resistance machines by performing 8-10 repetitions of a light load (~50% of predicted 1 RM) before the 1RM testing. This short familiarization period may be adequate for assessing maximal strength, since our reliability of the 1RM tests were very good (ICC > 0.91, r > 0.92) for each muscle group and both genders.

Interestingly, we found a significant interaction between the upper body versus lower body reliability in the female group (p < 0.027) indicating a slight improvement between the different testing sessions for the lower body muscles compared to the upper body muscles. These results may indicate the need for more familiarization for larger muscle groups in order to ensure a more stable measure since they are more capable of exerting muscle greater forces than the upper body muscles.

**Practical applications**

This investigation sought to determine the reliability of a standardized 1RM testing protocol in healthy men and women and for a variety of muscle groups. The results of the current study suggests that the 1RM test is a reliable and simple method to evaluate maximal strength of resistance exercises in healthy men and women and that the 1RM test can be used by athletic trainers, health and fitness professionals and rehabilitation specialists to quantify the level of strength, to assess strength imbalances, and to evaluate training programs.

**Conclusion**

In conclusion, a standardized 1RM testing protocol with a short warm-up and familiarization period is a reliable measurement technique to assess muscle strength changes regardless of muscle group location or gender.

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### Key points

- The one repetition maximum (1RM) test is considered the gold standard for assessing muscle strength in non-laboratory situations.
- This study was done to examine the influence of muscle group location and gender on the reliability of assessing the 1RM test.
- The standardized 1RM testing protocol with a short warm-up and familiarization period is a reliable measurement technique to assess muscle strength changes regardless of muscle group location or gender.

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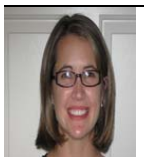
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