Reliability of a 5-Repetition Maximum Strength Test in Recreational Athletes

Reliabilität eines 5-RM Krafttests für den Gesundheits- und Fitnesssport

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Multiple repetition maximum strength tests are proper alternatives to the 1-RM strength test, particularly in the context of recreational sports. In contrast to the 1-RM strength test, limited research has been conducted into the reliability of multiple repetition maximum strength tests. Consequently, there is a shortage of standardized and evaluated test protocols for multiple repetition maximum strength tests in the practice and science of sports. Therefore, the aim of this study was to evaluate the reliability of a 5-repetition maximum strength test in recreational athletes. After a short preparation session 25 healthy recreational athletes (16 men, 9 women; 31.5 ± 12.5 years, 177.3 ± 9.1 cm, 73.2 ± 13.4 kg; 17 strength training experienced, 8 strength training inexperienced) performed a 5-repetition maximum strength test for the lower body (leg press and leg curl) twice within 7 days on the same weekday and at the same time of day. There were no significant differences between test and retest (p > 0.05), so that learning and habituation effects could be excluded. A very high intraclass correlation coefficient (ICC = 0.99; p < 0.001) was found for the total sample as well as all sub-samples (men, women, strength training experienced, strength training inexperienced). Moreover, the coefficients of variation were very low and ranged between 2.2 and 4.7%. In conclusion, the 5-repetition maximum strength test is a reliable measurement method in recreational sports.

Key Words: leg curl, leg press, maximum strength, strength diagnostics, strength training, training load

INTRODUCTION

The 1-repetition maximum (1-RM) strength test is well known as the gold standard method for assessing muscle strength in non-laboratory settings (8, 9). The 1-RM is defined as the maximal weight which an athlete can lift once with the correct lifting technique (2, 4, 17). Previous 1-RM studies have demonstrated the high reliability of this method for muscle strength testing among different target groups (1, 8, 9, 19). The 1-RM strength test is in widespread use because it is a relatively simple and cost-effective method (8, 17). The main purposes are quantifying the level of muscle strength, assessing muscle strength imbalances, evaluating strength training programs and determining loads for strength training.

However, conducting a 1-RM strength test is somewhat critical, especially for the typical athlete in recreational sports (16). The 1-RM strength test is associated with high stress for muscles, connective tissue and joints (2). Moreover, determining the 1-RM involves a high risk for injuries (4, 8). In addition, studies show that the 1-RM is inappropriate for specifying load for strength training (10-20). For example, the frequently propagated linear 1-RM-repetition relationship is curvilinear and be strongly influenced by confounding factors like strength training experience and type of exercise (2). Therefore, the classical approach to derive loads for strength training as a certain percentage of the 1-RM often leads to an overestimated or insufficient load.
In the context of recreational sports, are multiple repetition max-
vals (CI) and coefficients of variation (CV) of 5-RM for test and retest. 

Intraclass correlation coefficients (ICC) with 95% confidence inter-
Table 2: 

|                | Test     | Retest    | Z      | p       |
|----------------|----------|-----------|--------|---------|
| Total          | Leg press| 130.0 ± 35.9 | 131.2 ± 34.1 | -0.832 | 0.405   |
| (n=25)         | Leg curl | 55.8 ± 18.9  | 55.2 ± 19.2  | -0.832 | 0.405   |
| Men            | Leg press| 151.3 ± 21.9 | 151.3 ± 18.9 | 0.000  | 1.000   |
| (n=16)         | Leg curl | 65.6 ± 14.6  | 64.4 ± 16.0  | -1.265 | 0.206   |
| Women          | Leg press| 92.2 ± 21.7  | 95.6 ± 24.0  | -1.342 | 0.180   |
| (n=9)          | Leg curl | 38.3 ± 11.5  | 38.9 ± 12.4  | -0.577 | 0.564   |
| Experienced    | Leg press| 143.5 ± 26.7 | 144.1 ± 24.0 | -0.333 | 0.739   |
| (n=17)         | Leg curl | 62.9 ± 16.5  | 62.1 ± 17.3  | -1.000 | 0.317   |
| Inexperienced  | Leg press| 101.3 ± 37.6 | 103.8 ± 37.4 | -1.000 | 0.317   |
| (n=8)          | Leg curl | 40.6 ± 14.5  | 40.6 ± 14.7  | 0.000  | 1.000   |

Table 2: Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) and coefficients of variation (CV) of 5-RM for test and retest.

Proper alternatives to the 1-RM strength test, particularly 
in the context of recreational sports, are multiple repetition ma-
maximum (M-RM) strength tests (2,8). The M-RM is defined as 
the maximal weight which an athlete can lift over a specified number of 
repetitions with the correct lifting technique (2). For instance, 
the 5-repetition maximum (5-RM) is the maximal weight which an 
athlete can lift five times with the correct lifting technique. 
The M-RM strength test can be used for the same purposes as the 1-RM 
strength test. Furthermore, the M-RM strength test is qualified for 
prescribing the intensity for strength training (23). Beyond this, 
the M-RM can be used as a predictor of the 1-RM. In particular the 
5-RM allows a very valid estimation of the 1-RM (2,4,16).

In contrast to the 1-RM strength test, limited research of the re-
iliability of M-RM strength tests has been conducted. Consequently, 
there is a shortage of standardized and evaluated test protocols for 
M-RM strength tests in practice and science of sports. This is particu-
larly regrettable as the M-RM strength test is a cornerstone of the 
motivation on a four-point scale. All tests were instructed and su-
ervised by the same researcher. The warm-up program consisted 
of 5 min moderate cycling (1 W per kilogram body weight at 60-
80 rpm) and one set of the test exercises (ten repetitions at 50% 
of the estimated 10-RM based on the individual assessment of the 
respective participant). Because of the negative effects on strength 
performance (3,6,13) and the lack of evidence for injury prevention 
(11), stretching was not included. All participants started with leg 
press followed by leg curl. The take-off weight was based on the 
individual assessment of the respective participant. The same was 
true for the extent of increase (successful test trial which means 
that the participant could manage to lift the weight five times) or 
decrease (unsuccessful test trial which means that the participant 
could not manage to lift the weight five times) after each test trial. 
The break duration was 2 min. Each participant was tested separa-
tely and requested to achieve maximal performance.

All statistical analyses were carried out using the statistical 
software IBM® SPSS® Statistics version 22 (IBM® Corp., Armonk, 
NY, USA). Results are shown as mean±standard deviation. The 
normal distribution of the variables was tested by a Shapiro Wilk 
test. In accordance with the recommendations of Hopkins (7) three 
parameters were raised. Wilcoxon signed-rank tests were carried 
out to analyze whether significant differences existed between test 
and retest. Intraclass correlation coefficients (ICC) (21,24) were 
calculated to determine test-retest correlation. For this, the ICC 
1,2 (one-way random, average measure) was used because test and

**MATERIALS AND METHODS**

Twenty-five healthy recreational athletes (16 men, 9 women) wit-
hout exercise contraindications participated voluntarily in this stu-
dy and gave their written informed consent. The participants had 
an age, body height and body weight of 31.5±12.5 years, 173.3±9.1 
cm and 73.2±13.4 kg, respectively. Seventeen participants had at 
least 3 months strength training experience, whereas eight partic-
ients were inexperienced. All the procedures undertaken in this 
study were approved by the local ethics board of the University of 
Augsburg and are in compliance with the Declaration of Helsinki.

At first, all participants completed a preparation session to 
become familiar with the test devices (Trac Inc., Irvine, CA, 
USA) and the correct exercise techniques. After a few days break, 
the participants passed the 5-RM strength test with the both lo-
er body exercises leg press and leg curl twice within 7 days at the 
same weekday. To avoid negative impacts of circadian rhythm on 
the test results (5,18), test and retest were performed at approxi-
mately the same time of day. To identify potential differences in 
fatigue and motivation between test and retest, the physical and 
mental conditioning was documented by a self-administered ques-
tionnaire, where participants had to note their level of fatigue and 
motivation on a four-point scale. All tests were instructed and su-
ervised by the same researcher. The warm-up program consisted 
of 5 min moderate cycling (1 W per kilogram body weight at 60-
80 rpm) and one set of the test exercises (ten repetitions at 50% 
of the estimated 10-RM based on the individual assessment of the 
respective participant). Because of the negative effects on strength 
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(11), stretching was not included. All participants started with leg 
press followed by leg curl. The take-off weight was based on the 
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out to analyze whether significant differences existed between test 
and retest. Intraclass correlation coefficients (ICC) (21,24) were 
calculated to determine test-retest correlation. For this, the ICC 
1,2 (one-way random, average measure) was used because test and
retest were guided by the same researcher (14). The typical error was estimated by the coefficient of variation (CV). For this purpose, the CV was firstly calculated for each single participant, and then the mean CV was determined for the complete sample (12, 15). An alpha of 5% was accepted as statistically significant.

RESULTS

The mean values and standard deviations as well as Wilcoxon signed-rank tests for leg press and leg curl are presented in Table 1. There were no significant differences between test and retest (p > 0.05). Table 2 shows ICCs with 95% confidence intervals (CI) and CVs for both exercises. A very high ICC was found for total sample as well as all sub-samples (ICC > 0.90; p < 0.001). The CV’s ranged between 2.2 and 4.7%.

DISCUSSION

The aim of the current study was to assess the reliability of a 5-RM strength test in recreational athletes. For this purpose, a test-retest research design was used. After a short preparation session, twenty-five healthy men and women with different strength training experiences passed the 5-RM strength test for the both lower body exercises leg press and leg curl twice within 7 days at the same weekday and at the same time of day.

Systematic changes between test and retest in repeated muscle strength measurements during short time intervals can result from fatigue or motivational effects as well as learning and habituation effects (7). Fatigue and motivation were highly standardized due to the research design and monitored by a self-administered questionnaire. As a result of our study, learning and habituation effects can be excluded because the mean differences between test and retest were not significant. A short singular preparation session has proved to be sufficient to prepare participants for determining a baseline 5-RM in recreational sports when applying the described approach based on participant’s perceived exertion.

The very high retest correlations (ICC) and very low typical errors of measurement (CV) documented the excellent reliability of the 5-RM strength test in healthy men and women independent of their strength training experience. These results are in line with the reliability studies for the established 1-RM strength test which usually leads to a very high ICC of greater than 0.90 (1, 8, 9, 19). Furthermore, the present results were comparable to the results of Taylor and Fletcher (23). They investigated the reliability of an 8-RM strength test for different upper body exercises (chest press, pull-down, overhead press, and seated row) and found also very high ICCs of greater than 0.90 and low to very low CV’s between 3.4 and 10.4%.

In conclusion, the data confirmed the reliability of the 5-RM strength test in recreational sports for lower body exercises. The 5-RM strength test is a reliable and simple measurement method in healthy men and women and can be used by athletic coaches, health and fitness professionals as well as rehabilitation specialist to quantify the level of muscle strength, to assess muscle strength imbalances, to evaluate strength training programs and to prescribe load for strength training. Compared to the 1-RM strength test, the advantage of the 5-RM test is a potentially lower risk of muscle injury in the test phase and there is no need for a laborious preparation of the participants.

Similar studies in future research should include upper body exercises. Another research prospect is to determine the reliability of the 5-RM strength test in special target groups like older adults and people with impaired health.

Conflict of interest: The authors have no conflict of interest.
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