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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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SUMMARY

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 > 0.90; $p < 0.001$) 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

ZUSAMMENFASSUNG

Die Ermittlung eines Mehrwiederholungsmaximums gilt als adäquate Alternative zum klassischen 1-RM Krafttest speziell im Gesundheits- und Fitnesssport. Bislang gibt es aber kaum wissenschaftliche Untersuchungen, bei denen ein standardisiertes Testprotokoll eingesetzt oder gar evaluiert wurde. Das Ziel der vorliegenden Untersuchung bestand daher darin, die Reliabilität eines 5-RM Krafttests für den Gesundheits- und Fitnesssport zu bestimmen. Dazu absolvierten 25 gesunde Freizeitsportler (16 Männer, 9 Frauen; 31,5 ± 12,5 Jahre, 177,3 ± 9,1 cm, 73,2 ± 13,4 kg; 17 krafttrainingserfahren, 8 krafttrainingsunerfahren) nach einem Vorbereitungstermin einen 5-RM Krafttest für die beiden Übungen Beinpresse und Beinbeuger zweimal innerhalb von 7 Tagen am gleichen Wochentag und zur gleichen Tageszeit. Es wurden keine signifikanten Unterschiede ($p > 0,05$) der Kraftleistungen zwischen Test und Retest festgestellt, so dass Lern- und Gewöhnungseffekte ausgeschlossen werden konnten. Weiterhin zeigte sich ein sehr hoher Intraklassenkorrelationskoeffizient (ICC > 0,90; $p < 0,001$) sowohl für die Gesamtstichprobe als auch für alle vier untersuchten Teilstichproben (Männer, Frauen, krafttrainingserfahrene Personen, krafttrainingsunerfahrene Personen). Die Variationskoeffizienten waren sehr niedrig und betrugen 2,2 bis 4,7 %. Daraus ergibt sich schlussendlich, dass der vorgestellte Krafttest zur Ermittlung des 5-RM als äußerst zuverlässige Messmethode für den Gesundheits- und Fitnesssport bezeichnet werden kann. Forschungsperspektiven bestehen zum Beispiel in der Bestimmung der Reliabilität des 5-RM Krafttests bei speziellen Zielgruppen wie etwa ältere Erwachsene oder Personen mit besonderen gesundheitlichen Einschränkungen.

Schlüsselwörter: Beinbeuger, Beinpresse, Maximalkraft, Kraftdiagnostik, Krafttraining, Belastungsintensität

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.

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		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 1: Values of 5-RM in kg (mean ± standard deviation) and Wilcoxon signed-rank tests for test and retest.

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

		ICC	CV
Total	Leg press	0.99 (CI: 0.98-1.00)	3.1 %
(n = 25)	Leg curl	0.99 (CI: 0.98-1.00)	3.0 %
Men	Leg press	0.97 (CI: 0.91-0.99)	2.2 %
(n = 16)	Leg curl	0.98 (CI: 0.95-0.99)	2.9 %
Women	Leg press	0.97 (CI: 0.89-0.99)	4.3 %
(n = 9)	Leg curl	0.99 (CI: 0.94-1.00)	3.4 %
Experienced	Leg press	0.98 (CI: 0.94-0.99)	2.7 %
(n = 17)	Leg curl	0.99 (CI: 0.97-1.00)	2.2 %
Inexperienced	Leg press	0.99 (CI: 0.96-1.00)	4.2 %
(n = 8)	Leg curl	0.99 (CI: 0.93-1.00)	4.7 %

Proper alternatives to the 1-RM strength test, particularly in the context of recreational sports, are multiple repetition 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 reliability 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 particularly regrettable as the M-RM strength test is a cornerstone of the frequently applied "individual lifting performance" (ILP) method. In the ILP method, loads of the strength training procedure depend on an M-RM strength test, which is repeated at the beginning of each new mesocycle (22). Therefore, the aim of this study was to assess the test-retest reliability of a 5-RM strength test in recreational athletes.

MATERIALS AND METHODS

Twenty-five healthy recreational athletes (16 men, 9 women) without exercise contraindications participated voluntarily in this study and gave their written informed consent. The participants had an age, body height and body weight of 31.5 ± 12.5 years, 177.3 ± 9.1 cm and 73.2 ± 13.4 kg, respectively. Seventeen participants had at least 3 months strength training experience, whereas eight participants 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 (Star 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 lower 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 approximately 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 questionnaire, where participants had to note their level of fatigue and motivation on a four-point scale. All tests were instructed and supervised 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 separately 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 means ± 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

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 ICC's 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 autors have no conflict of interest.*

REFERENCES

1. **Abdul-Hameed U, Rangra P, Shareef MY, Hussain ME.** Reliability of 1-repetition maximum estimation for upper and lower body muscular strength measurement in untrained middle aged type 2 diabetic patients. Asian J Sports Med. 2012;3:267-273.
2. **Baechle TR, Earle RW, Wathen D.** Resistance training. In: Baechle TR, Earle RW, eds. Essentials of strength training and conditioning. 3rd ed. Champaign, IL: Human Kinetics; 2008: 381-412.
3. **Behm DG, Button DC, Butt JC.** Factors affecting force loss with prolonged stretching. Can J Appl Physiol. 2001;26:262-272. doi:10.1139/h01-017
4. **Dohoney P, Chromiak JA, Lemire D, Abadie BR, Kovacs C.** Prediction of one repetition maximum (1-RM) strength from a 4-6 RM and a 7-10 RM submaximal strength test in healthy young adult males. J Exerc Physiol Online. 2002;5:54-59.
5. **Drust B, Waterhouse J, Atkinson G, Edwards B, Reilly T.** Circadian rhythms in sports performance – an update. Chronobiol Int. 2005;22:21-44. doi:10.1081/CBI-200041039
6. **Fowles JR, Sale DG, MacDougall JD.** Reduced strength after passive stretch of the human plantarflexors. J Appl Physiol. 2000;89:1179-1188.
7. **Hopkins WG.** Measures of reliability in sports medicine and science. Sports Med. 2000;30:1-15. doi:10.2165/00007256-200030010-00001
8. **Kraemer WJ, Ratamess NA, Fry AC, French DN.** Strength testing: development and evaluation of methodology. In: Maud PJ, Foster C, eds. Physiological assessment of human fitness. 2nd ed. Champaign, IL: Human Kinetics; 2006: 119-150.
9. **Levinger I, Goodman C, Hare DL, Jerums G, Toia D, Selig S.** The reliability of the 1RM strength test for untrained middle-aged individuals. J Sci Med Sport. 2009;12:310-316. doi:10.1016/j.jsams.2007.10.007
10. **Marschall F, Fröhlich M.** Überprüfung des Zusammenhangs von Maximalkraft und maximaler Wiederholungszahl bei deduzierten submaximalen Intensitäten. Deut Z Sportmed. 1999;50:311-315.
11. **Marschall F, Ruckelshausen B.** Dient Dehnen der Verletzungsprophylaxe? Eine qualitative Metaanalyse. Spectrum Sportwiss. 2004;16:31-47.
12. **O'Hara JP, Thomas A, Seims A, Cooke CB, King RF.** Reliability of a high-intensity endurance cycling test. Int J Sports Med. 2012;33:18-25. doi:10.1055/s-0031-1284340
13. **Power K, Behm D, Cahill F, Carroll M, Young W.** An acute bout of static stretching: effects on force and jumping performance. Med Sci Sports Exerc. 2004;36:1389-1396. doi:10.1249/01.MSS.0000135775.51937.53
14. **Rankin G, Stokes M.** Reliability of assessment tools in rehabilitation: an illustration of appropriate statistical analyses. Clin Rehabil. 1998;12:187-199. doi:10.1191/026921598672178340
15. **Requena B, García I, Requena F, Saez-Saez de Villarreal E, Pääsuke M.** Reliability and validity of a wireless microelectromechanicals based system (keimoveTM) for measuring vertical jumping performance. J Sports Sci Med. 2012;11:115-122.
16. **Reynolds JM, Gordon TJ, Robergs RA.** Prediction of one repetition maximum strength from multiple repetition maximum testing and anthropometry. J Strength Cond Res. 2006;20:584-592.
17. **Schlumberger A, Schmidtbleicher D.** Grundlagen der Kraftdiagnostik in Prävention und Rehabilitation. Manuelle Med. 2000;38:223-231. doi:10.1007/s003370070022

18. **Sedliak M, Finni T, Cheng S, Haikarainen T, Häkkinen K.** Diurnal variation in maximal and submaximal strength, power and neural activation of leg extensors in men: multiple sampling across two consecutive days. Int J Sports Med. 2008;29:217-224. doi:10.1055/s-2007-965125
19. **Seo DI, Kim E, Fahs CA, Rossow L, Young K, Ferguson SL, Thiebaud R, Sherk VD, Loenneke JP, Kim D, Lee MK, Choi KH, Bemben DA, Bemben MG, So WY.** Reliability of the one-repetition maximum test based on muscle group and gender. J Sports Sci Med. 2012;11:221-225.
20. **Shimano T, Kraemer WJ, Spiering BA, Volek JS, Hatfield DL, Silvestre R, Vingren JL, Fragala MS, Maresh CM, Fleck SJ, Newton RU, Spreuwenberg LP, Häkkinen K.** Relationship between the number of repetitions and selected percentages of one repetition maximum in free weight exercises in trained and untrained men. J Strength Cond Res. 2006;20:819-823.
21. **Shrout PE, Fleiss JL.** Intraclass correlations: uses in assessing rater reliability. Psychol Bull. 1979;86:420-428. doi:10.1037/0033-2909.86.2.420
22. **Strack A, Eifler C.** The individual lifting performance method (ILP). A practical method for fitness- and recreational strength training. In: Gießing J, Fröhlich M, Preuss P, eds. Current results of strength training research. Göttingen: Cuvillier; 2005: 153-163.
23. **Taylor JD, Fletcher JP.** Reliability of the 8-repetition maximum test in men and women. J Sci Med Sport. 2012;15:69-73. doi:10.1016/j.jsams.2011.07.002
24. **Weir JP.** Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. J Strength Cond Res. 2005;19:231-240.

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