Reliability of 1RM Split-Squat Performance and the Efficacy of Assessing Both Bilateral Squat and Split-Squat 1RM in a Single Session for Non–Resistance-Trained Recreationally Active Men

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Abstract

Urquhart, BG, Moir, GL, Graham, SM, and Connaboy, C. Reliability of 1RM split-squat performance and the efficacy of assessing both bilateral squat and split-squat 1RM in a single session for non–resistance-trained recreationally active men. *J Strength Cond Res* 29(7): 1991–1998, 2015—The purpose of this study was to determine the reliability of 1 repetition maximum (1RM) split squat (SS) and establish the efficacy of collecting 1RM-SS and 1RM bilateral squat (BLS) data in the same session, for a non–resistance-trained recreationally active population. Fourteen males performed a submaximal familiarization session and 5 testing sessions. After familiarization, the 1RM-SS was tested in the following 3 sessions. In session 4, subjects were tested in both 1RM-SS and 1RM-BLS, with half performing SS then BLS and the remainder BLS then SS. In session 5, the testing order was reversed. Reliability statistics calculated included the following: changes in mean across sessions, coefficient of variation calculated from the typical error (TE) scores (%CV_{TE}), and test-retest reliability (intraclass correlation coefficient [ICC]) of 1RM-SS. Statistically significant differences between the mean 1RM-SS in sessions 1 and 2 (2.14 kg, $p = 0.001$), and sessions 1 and 3 (2.86 kg, $p < 0.003$) were found, indicating the requirement for an additional familiarization session before 1RM-SS data collection. The %CV_{TE} was 2.53% and the ICC was 0.97 for the 1RM-SS protocol. Performing SS before BLS tended to increase the mean 1RM-BLS (+2.1%), although the difference was not significant ($p = 0.055$). A reliable measure of 1RM-SS can be determined after 1 submaximal and 1 maximal familiarization session in non–resistance-trained recreationally active men. Analysis of the current data suggests that it is appropriate to perform both 1RM-SS and 1RM-BLS tests within the same testing session if 1RM-SS is performed before 1RM-BLS. However, further testing is warranted to firmly establish the effects of 1RM-SS on subsequent 1RM-BLS.

Key Words retest reliability, variability, random error, unilateral performance

Introduction

Determining baseline measurements and assessing gains in muscular strength are of great importance to athletes, sports scientists, and health professionals alike (13). The most commonly used method of strength assessment is the 1 repetition maximum (1RM) test (10). The 1RM is defined as the maximum load, which can be moved once, through a specific range of motion while maintaining correct technique (17). One repetition maximum testing is a field-based method proven to be a reliable method for assessing maximal muscle strength (10,13,21,20). When compared with laboratory-based strength assessment, 1RM testing is simple to implement and relatively inexpensive. Therefore, in a field-based setting, 1RM testing is seen as the gold standard when assessing maximal muscle strength and is commonly used when devising strength and conditioning programs for clients, patients, or athletes (6). One repetition maximum testing has also been proven to be a reliable method of assessing maximal strength in a wide range of exercises/muscle groups (10,13,18,20,21,23).

To ensure the efficacy of resistance training practices and 1RM assessment methods, it is recognized that exercises incorporated and assessed in relation to training or rehabilitation interventions should closely resemble the movements

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produced while performing sporting or daily living activities due to the specific nature of muscular strength (1,15). Bilateral lower limb training (with the contralateral limbs moving in unison) has been favored by many strength and conditioning coaches, with a greater emphasis being devoted to this stance in the previous research (14). However, many sporting actions and activities of daily living are performed unilaterally. Understanding the necessity for both training and assessment protocols to closely mimic the specific requirements of the sporting activities or functional movements performed in daily living activities, reliable unilateral assessments of lower limb strength are required to establish the relative strength and contribution of individual limbs to said activities. Therefore, an accurate assessment of unilateral muscular strength with adequate reliability is required to determine the efficacy of prescribed training programs for both performance and rehabilitation purposes (10).

Health professionals such as physical therapists benefit from having the ability to ascertain maximal strength in unilateral exercises such as the unilateral squat or exercises with a unilateral element such as the split squat (SS). Determining an accurate measure of single-leg strength would enable accurate comparisons of the injured limb to the healthy limb; during rehabilitation, this information could prove to be invaluable (13). The SS closely resembles the weight-bearing movements observed in many sporting actions, and many day-to-day tasks performed outside of a sporting context. In addition, individuals (e.g., recreational athletes, youth/academy squad players, injured people with no involvement with sport, etc.) may not have been involved in any previous resistance training. Therefore, there is a requirement to establish the reliability of the 1RM-SS in populations such as non–resistance-trained recreationally active men.

Given the potential benefits to physical therapists, athletic trainers, and coaches, it would be beneficial to have an appropriate functional test, which will reliably assess maximal single-leg strength. To date, there are no studies that have investigated the test-retest reliability of the SS. Specifically, there is little information regarding the contribution of any systematic bias or within-subject variability to an assessment of the overall reliability of a 1RM-SS assessment. Research is required to examine the requirement for familiarization trials, determine the extent of any learning effects, and establish the magnitude and consistency of the within-subject variability of the 1RM-SS performance. Previous studies have shown that with unilateral 1RM testing, there are often large differences found between test sessions (2). Also, Cronin and Henderson (5) suggested that while the test-retest reliability of 1RM in resistance-trained subjects was high ($r = 0.92–0.98$), the reliability of 1RM assessments within novice subjects was less clear. Also, because of the time-consuming nature and additional expenditure required for repeated testing, the efficacy of testing for both unilateral and bilateral measurements of strength over the same session would be of great interest and value to sports coaches and physical therapists alike.

The aims of this study were 4-fold: (a) verify any systematic bias between repeated measurements of 1RM-SS performance, (b) determine the within-subject variability for the 1RM-SS test, (c) establish the test-retest reliability over a number of repeated administrations, and (d) determine whether a reliable assessment of maximal strength could be ascertained when testing both 1RM-SS and 1RM bilateral squat (BLS) within a single session and whether the order in which 1RM-SS and 1RM-BLS protocols are performed influenced the reliability of 1RM-SS or 1RM-BLS values achieved in non–resistance-trained recreationally active men.

Methods

Experimental Approach to the Problem

This study used a single-group repeated-measure design to examine the intersession reliability of 1RM-SS performance, and a single-group randomized crossover design to determine the efficacy of assessing both SS and BLS in a single session for non–resistance-trained recreationally active men. After a familiarization session, the subjects' 1RM-SS was tested on 3 separate occasions, with a minimum of 4, maximum of 5 days between testing. A further 2 data collection sessions were performed, this time both 1RM-SS and 1RM-BLS were measured. For the first of these combined sessions, subjects were randomly assigned to either the SS followed by BLS group (SS/BLS) or the BLS followed by SS group (BLS/SS). During the second of the combined sessions the order in which the testing was undertaken was reversed for both groups. The 1RM-SS data were examined for any systematic bias across all 5 testing sessions by examining changes in the mean values between sessions. Any statistically significant differences between sessions were noted and any session(s) found to be statistically different were excluded from subsequent analysis of within-subject variability and test-retest reliability. The data from the combined SS and BLS testing session were analyzed to determine any effects of performing both tests within the same session on the 1RM-SS and 1RM-BLS attained and to ascertain if the order of test administration affected the values achieved.

Subjects

Fourteen men (mean $\pm$ *SD*: age $= 23 \pm 1.18$ years; height $= 1.81 \pm 0.05$ m; mass $= 79.96 \pm 6.48$ kg) volunteered to participate in this study, which had been approved by the local university ethical review board. Informed consent was obtained from all subjects. Subjects were non–resistance-trained, recreationally active, regularly undertaking sport-specific training 2–3 times per week, and participated in sports, such as soccer, basketball, swimming, and badminton. Subjects were excluded if they had taken part in a regular resistance training program within 2 years before the commencement of the study, to ensure that the subjects complied with the non–resistance-trained criteria for inclusion in the sample population. Health status was assessed through a PAR-Q before commencement of testing and any subject who had been previously advised to avoid physical activity by a health professional or was perceived to possess contraindications including injuries and health concerns was excluded from the study.

Procedures

Subjects attended a total of 6 sessions (1 familiarization, 5-1RM testing sessions). The first 3 testing sessions (after the familiarization session) used a test-retest method to make an assessment of reliability of the 1RM-SS test alone. The final 2 testing sessions required subjects to perform both SS and 1RM-BLS in a randomized crossover technique.

Familiarization

The familiarization session included a full and thorough verbal explanation of testing protocol, and subjects were informed of what would be expected from them throughout the study, including any potential adverse effects caused by resistance training (19). Subjects were guided through both the SS and BLS exercises with no additional load on the 20-kg standard Olympic barbell (13). The subjects then practiced the techniques to become familiar with both the SS and the BLS techniques, with instruction provided by a trained weightlifting coach. The dominant leg was selected to perform the lift for the SS exercise; this was determined to be the leg with which the subjects preferred to kick a ball (13). It was important to the study that subjects felt comfortable with both squat techniques and gained experience lifting a reasonably heavy load to minimize any subsequent learning effect (16). During the familiarization session a 90° angle was measured at the knee, along the length femur and tibia, and the measurement of the distance from the gluteal fold to the ground was recorded. Similar to the methods used by McCurdy et al. (13), a height-adjustable device was setup for each subject and used to give direct feedback to the subject of when they had reached the required squat depth (Figure 1). This process was carried out and measurements recorded for the both SS and for the BLS. A measurement of the distance from the back of the shoe of the front foot to the front of the shoe of the back foot was recorded. This distance was marked on the floor with masking tape for each individual subject before each testing session, to retain consistency of body position between sessions. Any deviation from this distance would alter the required angle at the knee joint to make contact with the height-adjustable device. The position of the height-adjustable device was also marked with masking tape to ensure the device made contact with the same point of the leg each session; further ensuring a 90° angle at the knee was reached with each attempt. The final component of the familiarization session involved collecting data that enabled an accurate prediction of 1RM for each subject (26). Subjects were asked to select a load, which they believed would elicit fatigue in 10 or fewer repetitions before being instructed to complete as many repetitions with the selected load until they were unable to continue. Loss of technique during exercise was deemed as an unsuccessful lift. If it was thought that fatigue had not caused loss of proper technique and a mishap had caused the deviation in technique or if the number of successful lifts exceeded 10 repetitions, the test was deemed void and had to be repeated over another session (9). Predicted 1RM was then calculated using the Wathan (26) 1RM prediction formula $\{1RM = 100 \times \text{rep wt}/[48.8 + 53.8 \times \exp(-0.075 \times \text{reps})]\}$.

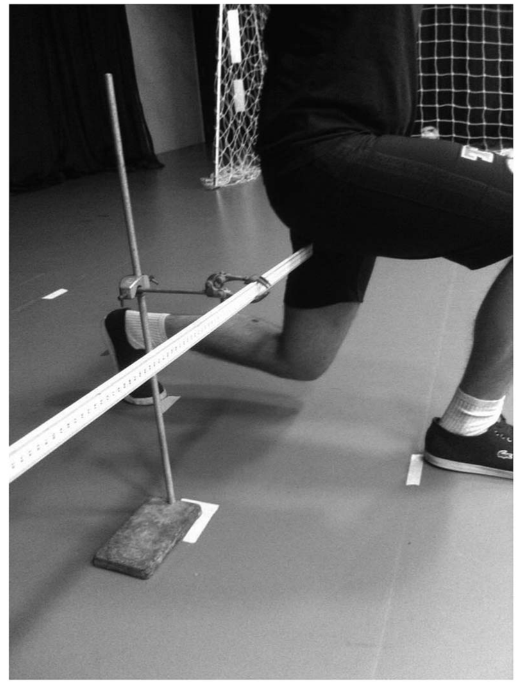

Figure 1. Split-squat experimental setup.

One Repetition Maximum Testing Procedures

Before the commencement of 1RM testing, subjects were instructed to perform dynamic stretches to help to prevent injury without impeding strength testing performance (27). The dynamic stretches included 10 squats, 10 lunges, and 10 butt kicks; this was completed twice (16). Further warm-up was included as part of the incremental testing protocol, which gradually increased load until 1RM was established.

Subjects attended 5 testing sessions separated by a minimum of 4 days. The protocol for each 1RM test required subjects to perform 5 repetitions at 60% of their individual predicted 1RM (p1RM), 3 repetitions at 75% p1RM, 2 repetitions at 85% p1RM, 1 repetition at 90% p1RM, and 1 repetition at 100% of p1RM. If the subject successfully lifted 100% of their p1RM, the load was then increased by approximately 2%, that is, 102% of p1RM (minimum increment, 2.5 kg). If the subject was again successful, the load was further increased by 2%. This increase in load was repeated no more than 4 times as fatigue could factor in the subjects' performance. If the subject successfully accomplished lifting 108% of p1RM, then the session was void and the session was repeated after a rest period of at least 5 days, and after alterations to the p1RM was made. All subjects achieved 1RM in less than 108% of p1RM. Correct technique was continuously monitored, any deviation from this was deemed as an unsuccessful lift and that load had to be attempted again before the load was increased. Between each attempted lift, a rest period of 4 minutes was given to minimize the effects of fatigue (12,18). The 1RM testing sessions were all conducted at the same time of the day to avoid circadian rhythm causing biological changes, which could affect performance (3). Trials were completed under the instruction of the same qualified weightlifting coach throughout to maintain consistency of measurements (3).

Split-Squat Protocol

The SS was performed as a free weight exercise with a men's Olympic barbell (20 kg). The feet were positioned a stride apart, the correct distance was marked on the ground with masking tape for each individual from information gathered from the familiarization session. The lead knee remained in line with the toes throughout the exercise. Subjects squatted until they reached the desired 90° angle at the knee of the leading leg, with the height-adjustable device providing feedback to both subject and researcher. Loss of balance resulting in the heel of the leading foot lifting off the ground was deemed as a failed attempt, as was any other deviation from the described technique.

Bilateral Squat Protocol

The BLS was performed as a free weight exercise with a men's Olympic barbell (20 kg). The feet were positioned parallel and placed roughly shoulder width apart with toes angled to approximately 30° lateral rotation of the foot. Knees remained in line with the toes throughout the exercise. Subjects squatted until they reached the desired 90° angle at the knee with the height-adjustable device providing feedback to both subject and researcher. Loss of balance resulting in heels lifting off the ground was deemed as a failed attempt, as was any other deviation from the described technique.

During the final 2 testing sessions where both SS and BLS were performed in the same session, a rest period of 5 minutes was specified between the end of the first 1RM protocol and the beginning of the next 1RM protocol in line with recommendations for time between maximal attempts (12,18). However, there is no precedent for this as the efficacy of undertaking 2 mechanically similar 1RM exercises within the same session has not been examined. Given that the subsequent protocol for the assessment of 1RM required a series of warm-up lifts (75, 85, and 90%) with rest periods in between, there was approximately 20 minutes between maximal lift attempts.

Statistical Analyses

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS for Windows, version 20.0; SPSS Inc., Chicago, IL, USA) Mean and *SD* were calculated as measures of central tendency and spread of data. A one-way repeated-measures analysis of variance (ANOVA) with the Bonferroni corrections was used to assess the change in 1RM-SS mean scores over the first 3 repeated sessions to determine the presence of any systematic bias. Pairwise comparisons were used to determine any statistically significant difference in 1RM-SS between testing sessions. Once any systematic bias had been removed from the data, the typical error (TE) was calculated using the methods outlined by Hopkins, and the coefficient of variation (% CV_{TE}) was calculated from the TE and mean values. The test-retest reliability (intraclass correlation coefficient [ICC] (7,8)) and the confidence limits (95% CL) for all the reliability statistics (TE, $\%CV_{TE}$, and ICC

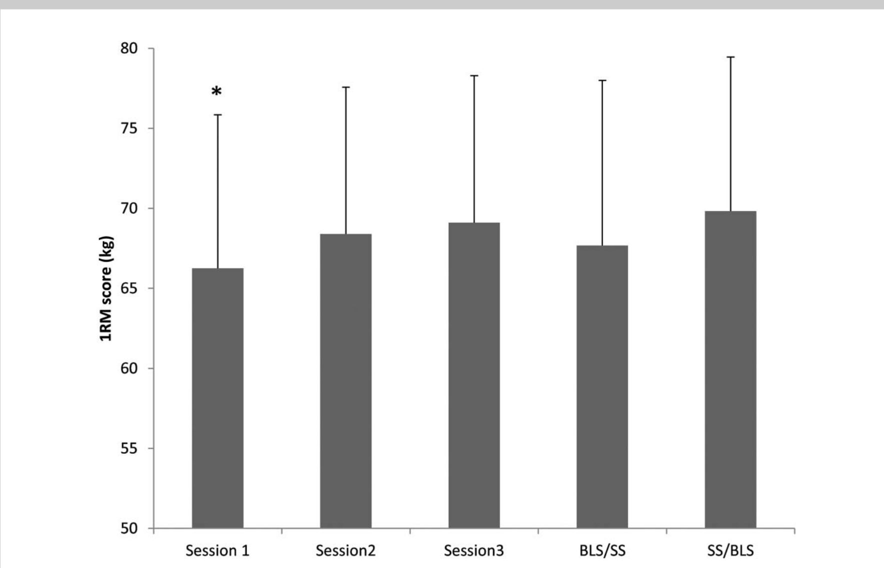

Figure 2. Mean split-squat 1RM for each of the 5 testing sessions. Values displayed are mean ± *SD*. *Statistically significant difference between the mean score of session 1 and sessions 2 and 3. BLS/SS = 1RM-SS data from same session bilateral squat followed by split squat; SS/BLS = 1RM-SS data from same session split squat followed by bilateral squat ($n = 14$).

Table 1. Measures of reliability for the unilateral squat: within-subject variability and test-retest scores.*†

UL 1RM	Mean	*SD*	TE	L95% CI	U95% CI	CV%	L95% CI	U95% CI	ICC	L95% CI	U95% CI
Trials 2–3	68.8	9.2	1.08	0.78	1.74	1.57	1.14	2.56	0.99	0.96	1.00
Trials 2–5	68.8	9.6	1.74	1.40	2.35	2.71	2.18	3.67	0.97	0.94	0.99
Trials 4–5	68.8	10.0	1.82	1.32	2.93	2.73	1.97	4.44	0.97	0.93	0.99

*1RM = 1 repetition maximum; SS = split squat; TE = typical error; CV = coefficient of variation; ICC = intraclass correlation; U95% CI = upper 95% confidence interval; L95% CI = lower 95% confidence interval.

†Mean and *SD* of the SS 1RM (1RM-SS) data for sessions 2 and 3 combined, sessions 2 through 5 combined, and sessions 4 and 5 combined. The TE and the ICC are also shown with their respective U95% CI and L95% CI for the respective values.

[3,1]) were calculated using the methods proposed by Hopkins (8). The SS and BLS data from the final 2 testing sessions were organized into the 2 groupings SS/BLS and BLS/SS, and separate paired samples *t*-tests were performed on the SS and BLS data to determine the effects of performing both tests in the same session. The α value was set at 0.05.

Results

Figure 2 shows the mean 1RM-SS scores over each of the 5 sessions. Systematic bias was found in the 1RM-SS data with statistically significant differences between session 1 and session 2, and session 1 and session 3 identified ($p = 0.003$ and $p = 0.001$, respectively).

The data from 1RM-SS session 1 were removed from all further statistical analyses. The TE, CV%, and ICC statistics were subsequently calculated for the following 2 SS testing sessions, with the TE = 1.08 (95% CL = 0.78–1.74), $\%CV_{TE}$ = 1.57% (95% CL = 1.14–2.56), and the ICC = 0.99 (95% CL = 0.96–1.00). The TE, CV%, and ICC statistics were also calculated for sessions 2–5 and for sessions 4–5 only (Table 1).

The mean scores for 1RM-BLS are displayed in Figure 3; no significant difference was found in 1RM-BLS between combined BLS/SS (84.11 ± 12.03 kg) and SS/BLS (85.90 ± 10.40 kg) testing sessions ($p = 0.055$). However, a statistically significant difference ($p = 0.008$) was found in 1RM-SS between the combined BLS/SS (67.70 ± 10.30 kg) and SS/BLS (69.80 ± 9.60 kg) testing sessions.

Discussion

No previous study has investigated the reliability of 1RM-SS testing when performed as a free weight exercise. This study set out to determine the reliability of 1RM-SS in a group of non–resistance-trained recreationally active men. The aims of this study were 4-fold. First, this study set out to verify any systematic bias between repeated measurements of 1RM-SS performance. The differences in 1RM-SS performance between session 1 and session 2 (mean difference: 2.14 kg; $p = 0.003$) and 3 (mean difference: 2.86 kg; $p = 0.001$) were statistically significant. The apparent increase between session 1 and sessions 2 and 3 suggested a learning effect, leading to improved performance in the sessions 2 and 3 in comparison with session 1. The novice subjects used within this study required practice to become familiar with the technique

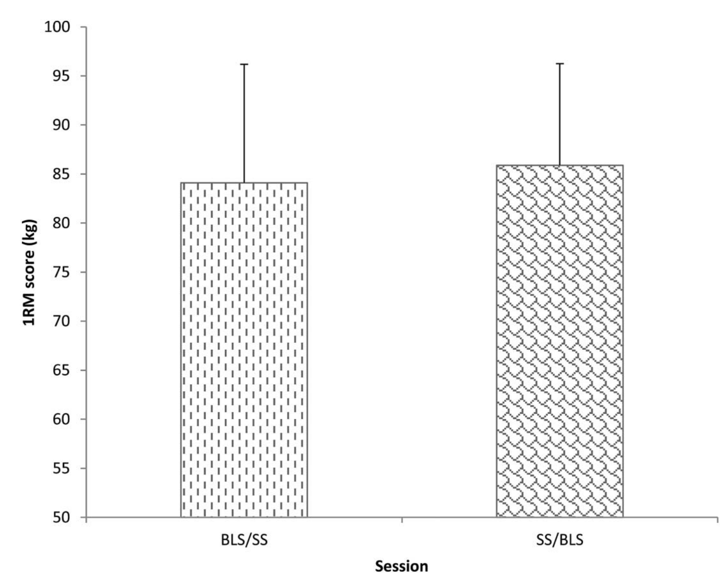

Figure 3. Mean bilateral squat 1RM performance recorded during SS/BLS and BLS/SS testing sessions. Values displayed are mean ± *SD*. BLS/SS = same session bilateral squat followed by split squat; SS/BLS = same session split squat followed by bilateral squat ($n = 14$).

involved in this resistance exercise, and this may be a consequence of the increased postural control required while maintaining correct technique in a unilateral exercise such as the 1RM-SS. An attempt to reduce systematic bias was made with the inclusion of a submaximal familiarization session before 1RM testing sessions. The difference in 1RM-SS between session 1 and sessions 2 and 3 suggested that the inclusion of this submaximal familiarization session was insufficient to eliminate any systematic bias caused by a learning effect. No measure(s) of delayed onset of muscle soreness (DOMS) were recorded within the subjects after the respective testing sessions. Although there was improvement between session 1 and session 2, suggesting no influence of DOMS on 1RM-SS, the extent of the improvement may have been magnified if a greater time period was given between repeated 1RM tests, to ensure a full recovery between 1RM assessments. Therefore, to eliminate any systematic bias when obtaining the 1RM-SS of non–resistance-trained recreationally active men, 2 familiarization sessions (submaximal and maximal) are required before obtaining a reliable measure. In addition, future studies should examine whether a longer time period (greater than 5 days) between 1RM testing session effects influence 1RM values achieved. A greater learning effect was observed in Ploutz-Snyder and Giamis (18), where 3 sessions were required before ascertaining reliable measure of knee extension 1RM in untrained women. Likewise, McCurdy et al. (13) initially designed their experimental protocol believing that 2 sessions of a modified unilateral squat 1RM testing would be sufficient to ascertain a reliable measure. However, an additional third session was required to capture a reliable measure of 1RM. In both Ploutz-Snyder and Giamis (18), and McCurdy et al. (13), the increase in performance between the first 2 sessions was attributed to a learning effect. The implications of the systematic bias found with this study are discussed further (below) with respect to aim 4.

The second aim of this study was to determine the within-subject variability for the 1RM-SS test. Once the systematic bias was eliminated by removal of the data from the first session, the TE and CV_{TE}% were determined for the data from sessions 2 and 3 1RM-SS tests. Very few other studies have reported the within-subject variability for measures of 1RM assessment, limiting the possibilities for comparison. Only Levinger et al. (10) and Symons et al. (25) provided data for the $\%CV_{TE}$. Other studies (23) have reported %CV for 1RM testing, calculated as the mean 1RM divided by the sample *SD*. However, Hopkins (8) recommended that the coefficient of variation be reported as the $\%CV_{TE}$ to enable direct comparison between data sets. The $\%CV_{TE}$ (1.57%) value for the 1RM-SS was lower than those reported (10) for untrained middle-aged individuals performing repeated 1RM tests in a series of testing modalities (chest press [$\%CV_{TE} = 6.5\%$], leg press [$\%CV_{TE} = 3.3\%$], lat pull down [$\%CV_{TE} = 3.4\%$], tricep push down [$\%CV_{TE} = 5.3\%$], knee extension [$\%CV_{TE} = 6.0\%$], seated row [$\%CV_{TE} = 3.4\%$], and bicep curl [$\%CV_{TE} = 7.2\%$]). The $\%CV_{TE}$ data for the 1RM-SS were considerably lower than those reported (25) for maximum strength testing in the knee extensor of older women, with $\%CV_{TE}$ ranging from 7 to 11%. The interpretation and acceptability of the 1.57 $\%CV_{TE}$ as indicative of a high level of reliability of the 1RM-SS test is dependent on the level of precision required. Although lower values of $\%CV_{TE}$ are always desirable, the within-subject variability may be adequate to determine any changes over the course of a training intervention in future studies examining unilateral strength.

The third aim of this study was to establish the test-retest reliability of 1RM-SS over a number of repeated administrations. An analysis of the ICC value for sessions 2 and 3 (ICC = 0.99; 95% CL = 0.96–1.00) suggested that the test-retest reliability (stability) of the 1RM-SS data was similar to those values reported in previous studies examining the reliability of assessments of maximal strength (10,23,25). According to Smith and Hopkins (24), the normally reported thresholds for the ICC (0.1, 0.3, 0.5, 0.7, and 0.9 for low, moderate, high, very high, and nearly perfect, respectively) to indicate its magnitude, may not be applicable in the analysis of athletic performance. Smith and Hopkins (24) suggested that ICC values of 0.14, 0.36, 0.54, 0.69, and 0.83 to indicate low, moderate, high, very high, and nearly perfect thresholds, respectively, are more appropriate. Irrespective, the 0.99 ICC value reported for the 1RM-SS represents nearly perfect test-rest reliability. However, Connaboy et al. (4) suggested that the ICC value should not be viewed in isolation; both measures of within-subject variability and test-retest reliability should be considered together when determining the efficacy of a particular measure in relation to its reliability for future use in further research. Therefore, given both the comparatively low 1.57 $\%CV_{TE}$ and nearly perfect 0.99 ICC, the combination of 1 submaximal and 1 maximal familiarization sessions before collecting 1RM-SS enables the collection of a reliable measure of 1RM-SS.

Finally, the fourth aim was to determine whether a reliable assessment of maximal strength could be ascertained when testing 1RM-SS and 1RM-BLS within a single session and whether the order in which 1RM-SS and 1RM-BLS protocols are performed influences the reliability of SS or 1RM-BLS values achieved in non–resistance-trained recreationally active men. There was a statistically significant difference ($p = 0.008$) in the 1RM-SS between the BLS/SS testing session (67.70 ± 10.30 kg) and SS/BLS testing session (69.80 ± 9.60 kg). The statistically significant increase in 1RM-SS when performed before the 1RM-BLS in comparison with the values achieved when the 1RM-SS was performed after the BLS 1 RM demonstrated that the non–resistance-trained recreationally active men cannot attain the same level of 1RM-SS after previously undertaking a 1RM-BLS protocol; with an apparent 2.1 kg (3.2%) decrease in 1RM-SS. This decrease in 1RM-SS values attained after the completion of the 1RM-BLS protocol suggests that performing the 1RM-BLS reduced the force production capabilities in some way (muscular fatigue, reduced neural activity, etc.). However, identifying the exact mechanism is beyond the scope of this study. Furthermore, analysis of the differences between 1RM-SS in the SS/BLS session and 1RM-SS in session 2 ($p = 0.36$) and session 3 ($p = 0.11$) revealed no statistically significant differences in 1RM-SS values, suggesting that when 1RM-SS is performed before 1RM-BLS, a reliable measure can be attained. Therefore, the efficacy of performing both 1RM-SS and 1RM-BLS in the same session to determine a reliable measure of both is only questioned when a 1RM-BLS protocol is performed before determining 1RM-SS.

In comparison, the analysis of the 1RM-BLS performance between the BLS/SS and SS/BLS testing sessions revealed that the difference in 1RM-BLS was found to be close to a statistically significant value ($p = 0.055$), with a mean increase in 1RM-BLS of 1.79 kg (2.1%) when 1RM-SS was performed before undertaking the BLS 1 RM protocol. The 2.1% improvement in 1RM-BLS when undertaken directly after an assessment of 1RM-SS might suggest either a process of facilitation, such as postactivation potentiation (PAP) (22), whereby performing the 1RM-SS protocol produced an ergogenic response to elicit higher 1RM-BLS values. The potential for a PAP response occurs as a consequence of an increase in the Ca^{2+} sensitivity of the myofilaments (11), in response to increased phosphorylation of myosin regulatory light chains, which ultimately leads to greater myosin cross bridge activity (22). However, the difference may also occur as a consequence of the inherent within-subject variability ($\%CV_{TE}$) within the measure of 1RM-BLS, especially given the nonsignificant difference in 1RM-BLS between sessions ($p = 0.055$). Therefore, when 1RM-SS is conducted before 1RM-BLS, both assessments of 1RM provide a statistically accurate representation of the respective values of maximal effort in both SS and BLS. However, given the relatively small sample size ($n = 14$), and the proximity of the p value ($p = 0.055$) to a statistically significant value ($p \leq 0.05$), further analysis is recommended to minimize the possibility of a type II error and more confidently determine the efficacy of ascertaining both 1RM-SS and 1RM-BLS in the same session for non–resistance-trained recreationally active men. Finally, further research is required to establish the reliability of measuring the 1RM-SS, and the 1RM-SS and 1RM-BLS together in the same session for other (male/female/novice/resistance trained) populations to determine their efficacy, any systematic bias, the within-subject variation, and the test-retest reliability.

Practical Applications

According to the data presented in this study, a reliable measure of 1RM-SS can be established in non–resistance-trained recreationally active men after the completion of a submaximal and a maximal familiarization testing session. The TE and $\%CV_{TE}$ 1RM-SS data from this study can be used to ascertain the smallest worthwhile change required when examining the efficacy of a particular program of resistance training or a remedial exercise intervention (7), when using the 1RM-SS as an indicative measure of performance. The use of the these data will enable practitioners to establish whether any changes in a pre-post measure of 1RM-SS are outside the noted range of within-subject variability and representative of an actual change in unilateral strength. In addition, the TE and ICC values reported in this study can be used to help determine the sample size of future empirical studies, which seek to use the 1RM-SS as a measure of maximal unilateral strength (7). Although the data from this study indicate that 1RM-SS and 1RM-BLS can be tested in a single session when 1RM-SS is tested before 1RM-BLS, the ambiguity of the results suggested that further research is required to properly establish the efficacy of test both 1RM-SS and 1RM-BLS together.

Acknowledgments

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