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The Validity and Reliability of the Rear Foot Elevated Split Squat 5RM to Determine Unilateral Leg Strength Symmetry

Abstract

The purpose of this study was to examine the validity and reliability of the Rear Foot Elevated Split Squat (RFESS) five repetition maximum (5RM) test as a field method for measuring unilateral leg strength symmetry. As a validated method of testing symmetry, the RFESS 5RM may be used by Strength and Conditioning coaches and sports medicine staff to measure the presence of imbalances with minimal equipment and time. 26 subjects (age = 23.8 ±4.6 years, mass = 88.1 ±10.7kg, height = 1.79±0.1m) with a minimum two years strength and conditioning experience were recruited. Following a familiarization session, subjects performed an incremental five repetition maximum (5RM) protocol on both legs, on two occasions where 3D motion and force data were collected. Moderate reliability of bar load symmetry was found between test and re-test conditions correlation (ICC = 0.73, 0.33-0.91) with no proportional bias between sessions. Validation of the exercise was analyzed using a correlation between asymmetries in mean set vertical ground reaction forces (vGRF) of the lead foot during the concentric phase, with bar load. When all maximal trials, from both test conditions, were analyzed, a most likely large positive correlation (0.57, 0.30 to 0.76) were found for mean set concentric lead foot vGRF. When a threshold level of load symmetry (96.54% - 103.46%) was applied, a most likely large positive correlation (r = 0.59, 0.14-0.84) between symmetry in lead foot vGRF was found in subjects who exceeded this limit. Conversely, analysis of subjects within the threshold produced unclear correlations. Findings of this study suggest the RFESS is a valid and reliable measure of unilateral leg strength symmetry. Practitioners are recommended to use this exercise to investigate the strength symmetry of athletes, but are guided to note that a threshold level of symmetry (96.54% - 103.46%) may be required to have been exceeded to indicate a true difference in vGRF production.

Key Words:

Between-session; inter-limb differences; single leg; imbalances;

Introduction.

Lower limb strength symmetry is of interest to researchers, strength and conditioning (S&C) coaches, physiotherapists and other sports medicine professionals, as there is evidence to suggest that this may be linked to an increased risk of injury (22) and reduced performance (25). However, the evidence pertaining to strength symmetry and either reduced performance or increase injury risk is equivocal (11). Consequently, a greater knowledge of symmetry and its interaction with both injury and performance is required. Creating a more thorough understanding of the implications of lower limb strength symmetry in athletes would provide clearer guidance to inform S&C coaches. If an S&C coach can identify an athlete with a strength imbalance between limbs, more informed decisions may be made about possible performance deficits and risk to injury. Subsequently, training interventions, for such an athlete, may be individualized to better mitigate these risks and further enhance performance. However, for S&C coaches to respond to a lack of symmetry there must be valid, reliable and practical method for collecting such data.

Previous research into strength symmetry has utilized direct methods of force measurement, such as isokinetic dynamometry (ID) and force plates protocols. ID techniques have been proven to be valid and reliable measures of unilateral strength for knee flexion and extension (ICC's 0.88 – 0.98) and hip flexion and extension (ICC's 0.75-0.95) (1). Alternatively, force plate protocols have measured vertical ground reaction forces (vGRF) through isometric actions such as the isometric mid-thigh pull (IMTP) or back squat and in dynamic actions including the back squat (14) and Rear foot elevated split squat (RFESS) (8). However, assessments which require either ID or force plates maybe impractical in the time taken to conduct this analysis, require additional financial costs, (in excess of that which is required to train an athlete) and require specific expertise to operate. As such using ID or force plate protocols may not provide a practical approach for coaches, in field settings, to collect symmetry data.

Assessment of differences in load, moved during closed kinetic chain exercises, maybe a more accessible option to S&C coaches. Such exercises require no additional equipment, except for those needed to perform the exercise (barbell and plates). Under these conditions the bar load maybe considered a proxy measure of force production. With respect to measuring strength symmetry this may only be performed using unilateral exercises to determine the strength of each limb independently. As such, S&C coaches may consider an axially loaded, closed kinetic chain, dynamic exercise, such as the RFESS as one possible method of measuring leg strength symmetry in athletes (10). Additionally, such an exercise should be correlated to the performance of the athletes, as asymmetries are highly task dependent (17, 23)

McCurdy et al., (21) and McCurdy and Langford (20) have previously reported the RFESS as a reliable measure of unilateral leg strength (1RM ICC, 0.97- 0.99). The study by McCurdy et al., (21) reported mean 3RM values of 98.6kg ± 21.5kg and 1RM 103kg ±21.5kg for the RFESS. When normalized to body mass, these were equivalent to 1.12 kg/kg and 1.17kg/kg. To contextualize this data, Baker and Newton (4) reported 1RM bilateral back squat values of 1.78 kg/kg for elite Rugby League players. When the unilateral strength data reported by McCurdy et al., (21) is compared to bilateral data from Baker and Newton (4) the RFESS compares favorably. The relative load for the unilateral exercise was greater than 50% of an equivalent bilateral exercise. DeForest et al., (14) performed a kinetic comparison of two unilateral closed kinetic chain exercises (Split squat and RFESS), in comparison to the back squat. The study used a single force plate for all exercises, placed under the dominant foot of each subject. No significant differences in peak vGRF were found between the back squat (1414.8 ± 251.0 N) and RFESS (1412.3 ± 258.6 N). The split squat produced significantly lower peak vGRF (1198.6 + 187.9N, $p < 0.05$). Whilst the force output from the non-dominant limb or rear foot data was collected, this study does indicate that the RFESS is comparable the back squat for peak force production. No rear foot data was collected for either the split squat or RFESS, which is a key limitation to their findings. Further research is required into the force production of the rear foot in the RFESS, to better understand the role of each limb in performing this exercise.

Research into the RFESS indicates that it is kinetically comparable to the back squat (14) and is a reliable method for measuring leg strength, through bar load (20, 21), in different populations. Speirs et al (26), reported parity of improvements in 1RM back squat, 1RM RFESS, speed and change of direction ability, when using RFESS or back squat trained groups. However, no research, to date has validated this exercise as a method for determining leg strength asymmetries, nor has any strength measure been investigated for between session reliability. The hypothesis of this study is that the RFESS is a valid measure of unilateral leg strength symmetry. Therefore, the purpose of this study is to examine the validity of using the RFESS 5RM bar load to measure leg strength symmetry and the between sessions reliability of the observed imbalances.

METHODS.

Experimental Approach to the Problem

A between day repeated measures design was used to assess the validity and reliability of the RFESS as a measure of lower limb symmetry. 26 male subjects reported to the laboratory on three occasions to complete familiarization and testing.

Previous research has demonstrated a learning effect for the RFESS (21), therefore visit one was a familiarization session and five repetition maximum (5RM) testing was conducted on visits two and three to the laboratory. Force plates (Kistler 9827C, Kistler Group, Winterthur, Switzerland) were place under the lead and elevated rear foot, 10 Opus cameras recorded bar and joint position through 3D motion capture (Qualysis AB, Gothenburg, Sweden). Reliability was determined by ICC and Bland-Altman analysis of the symmetries in load achieved between test and re-test conditions. To validate the RFESS 5RM as a test of symmetry, Pearson product moment correlation, (PPMC) between asymmetries in both bar load and the set mean vGRF of the lead foot (the mean of mean vGRF from all 5 repetitions per set) was performed on all maximal trials.

Subjects

With institutional ethical approval, 26 male volunteers were recruited, (age = 23.8 ±4.6 years, mass = 88.1 ±10.7kg, height = 1.79±0.1m). All subjects were engaged in a structured S&C program including both bilateral and unilateral exercise and had at least two years supervised training experience. Subjects were excluded from the study if they have experienced a lower limb injury within the previous six months or have had an injury requiring surgery to either limb previously. Of the 26 subjects, who completed the first test condition, nine were unable to meet the re-test condition, due to logistical constraints. These subjects were excluded from all further analysis of reliability.

Procedures

Participation in this study required the subjects to attend a testing facility on three occasions. The first were to perform basic anthropometric measures and familiarization with the exercise protocol and the reserve rating of perceived exertion (RIR-RPE) (28). The second and third visits required the subjects to perform an incremental RFESS 5RM test on both limbs. The subjects were instructed to wear appropriate sports footwear, which were consistent across all trials.

The procedure for testing the RFESS was adapted from DeForest at al., (14). The subjects were positioned with their lead foot on the force platform, under their hips with the rear foot elevated behind them where their toes were placed on the force plate, elevated to 40cm (Figure 2).

INSERT FIGURE 1 ABOUT HERE

The test was concluded, on each limb, when the athlete did not successfully complete five repetitions of an assigned load. The subjects performed each incremental load with alternating limbs first, to avoid bias and possible learning effects due to the cross-education effect (19), achieving the maximal load within five trials. A successful trial was deemed as performing five continuous repetitions with safe and effective technique, within a 30s data collection window. Effective technique was considered to be;

- Subject maintained balance throughout the exercise,
- The heel of the front foot maintained contact with the ground throughout the exercise.
- Only the toe of the shoes of the rear foot were in contact with the force plate

- The subject maintained a neutral posture, and hip angle of approximately 180°, from the rear leg.
- The knee of the rear limb descended below the height of the lead limb knee and achieved a depth approximately equal to the height of the ankle on the lead limb.

If a subject adopted a bilateral stance at any point within the trial or paused longer than two seconds between repetitions, the trial was considered unsuccessful. The load increments ranged from 1kg – 50kg, using International Weightlifting Federation (IWF) accredited discs (Eleiko, Sweden). During data collection, immediate feedback of Mean concentric velocity (MCV) was collected using a PUSH band (PUSH Inc., Toronto, Canada) wearable device on the dominant forearm of the subject, equidistant from the wrist and elbow. Data was transferred to the PUSH™ App, via an iPad (Apple, San Francisco, CA USA). Following each submaximal trial, the participants RIR-RPE value (15, 28) and MCV of fifth repetition was used re-calculate the predicted maximal load. The estimation of maximal load was firstly calculated using the trend line reported by Carroll et al., (12) from barbell velocities observed during back squats of increasing intensities. For the purpose of this study, only the velocity of the 5th repetition was used to calculate estimated load. The final repetition was chosen as this represented the maximal effort of the subjects, for that set. A second calculation was performed using the RIR-RPE value to indicate the percentage of maximum effort. For example, an RPE value of 7 indicated 70% of predicted 5RM load. Where there was disagreement between the calculations for the predicted load, the lower of the two values was used.

The subjects were deemed to have achieved a maximal successful attempt when all five repetitions were completed, the MCV of the fifth repetition was less than or equal to 0.28 m/s (12) and declared an RPE of 9.5 or greater (28). Where only one of these conditions were met, further increments were attempted until the subject achieved these criteria or was unable to successfully perform the following increment.

Data Processing

During all trials, motion was captured through Qualysis Track Manager System at 250Hz (Qualysis AB, Gothenburg, Sweden) using 10 cameras (6 ceiling mounted and 4 floor mounted). During trials two and three reflective markers were placed at either the end of the barbell, in the medio-lateral plane. Kinetic data was recorded from two independent Kistler 9827C force plates at 1000Hz (Kistler Group, Winterthur, Switzerland), the first being integral with the floor under the lead foot, the second mounted on weightlifting blocks, under the rear foot.

Data was extracted and input into Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) and placed in a fourth order low pass Butterworth filter, using Biomechanics toolbar, (27). All further data processing and analysis was performed using R (24), with a code written specifically for this study. The initiation of a repetition was defined as five consecutive increases in the magnitude of negative vertical bar displacement and terminating at the time frame where five consecutive decreases in positive vertical bar displacement occurred. This analysis was performed on the kinematic data taken from 3D motion capture at 250Hz, representing 0.02s. Within each repetition the eccentric and concentric phase were considered to end and start respectively at the time point where maximal negative vertical bar displacement occurs. MCV was calculated as the mean of all instantaneous velocities from the onset of the concentric phase to the end of the repetition.

Analysis of symmetry validity was performed on two levels, firstly, across all maximal trial data. Secondly, maximal data will be divided into more or less symmetrical subjects, using equation 1. The application of a threshold level of detectable symmetry was required, as a consequence of the interval nature of using free weight based loads. Using force plates to precisely measure vGRF, as in the IMTP, reduces the probability that a subject will produce the exact same force on both legs. As a result, these methods of measuring leg strength are unlikely to find symmetrical subjects. However, the use of weight plates restricts the sensitivity of load measurements, and therefore increasing the possibility of producing a symmetrical finding. Strength measurements, using weight plates, require the accurate prediction of the correct increment which may successfully be performed by the subject. The smallest increment possible is 1 kilogram, however, increments may typically be larger than this. The predictive nature of this process is possible source of error. The application of both MCV values and RIR-RPE scales, to predict the possible maximal load were applied to mitigate against this risk. Furthermore, should a subject perform a maximal load on one limb it may serve as an aspirational goal. This could potentially increase motivation to achieve the same load on the contralateral limb, despite this possibly being supra maximal for said limb, increasing the probability of producing a symmetrical outcome.

Equation 1: Symmetry threshold calculation

Symmetry threshold = (Mean load asymmetry – 100) + (1.64 + Standard Error of the Mean).

The identification and application of a load threshold, for symmetry measures, allows the S&C coach to more accurately determine the true symmetry of their athletes, in this test. As a consequence of the need for such a threshold a second analysis of validity was performed on all maximal trials. Subjects were classified as either more or less symmetrical using the following equation, adapted from Araújo et al., (2).

Symmetry Calculation

Bishop et al., (7-9), have reported the different methods of calculating asymmetries from previous research. These reviews indicate the variance in outcomes between calculations from a standardized data set. Further to this, the reviews justify a difference in approach when using either a unilateral or bilateral exercise. It is suggested that a singular approach is adopted for all unilateral and bilateral tests, respectively. In keeping with this analysis and recommendation, the percentage difference method (9) was used to calculate symmetry of all variables, using equation 1. Data is reported as a score of symmetry which is denoted by 100%, less than 100 indicates the left limb achieved a greater score than the right, conversely greater than 100, the right performed better.

Equation 2: modified percentage difference method of calculating asymmetry, Bishop et al., (9)

((100/(max value))-(min value) x (-1)+100)IF(left<right,1,-1))+100

Statistical Analyses

Inter-test reliability, between tests one and two, was determined using PPMC the level of reliability between tests was assessed using Intra class coefficient, (ICC), and proportional bias between tests through a Bland-Altman test. The reliability, as determined by ICC analysis, was classified according to following criteria; less than

0.5, poor, between 0.5 and 0.75 moderate, between 0.75 and 0.9 good , and greater than 0.90 excellent (18) ICC values was reported with 95% confidence limits. If data were not found to be normally distributed, it was log transformed before any further analysis was completed.

All maximal trials from both sessions were used to analyze the validity of the 5RM RFESS as a measure of leg strength symmetry. Set mean concentric vGRF was used to determine the validity of the test. This value represents the mean of each of the five repetitions mean concentric vGRF, for the set. In line with previous research, (3, 5, 6) validity was determined by the PPMC between bar load and set mean vGRF production, of the lead foot as well as the total set mean concentric vGRF of both limbs. A second assessment of validity was performed on the two sub-groups (asymmetrical and symmetrical). PPMC values was classified according to Cohen's effect sizes (13), using the following criteria: trivial (0.1), small (0.1–0.3), moderate (0.3–0.5), large (0.5–0.7), very large (0.7–0.9), or practically perfect (.0.9). A magnitude-based inferences approach was adopted to report findings. Cohen (13) identified an *r* value of 0.1 as the smallest clinically important correlation, therefore this was set as threshold of analysis for inferences in all correlational analysis. The magnitude based inferences were analyzed, based on the probability that the correlation observed was greater than 0.1 and classified as follows; <0.5% almost certainly not; 0.5-5% very unlikely; 5-25% unlikely; 25-75% possibly; 75-95% likely; 95-99.5% very likely; >99.5% almost certainly, where there is greater than 5% chance of both a negative and positive result, the inference will be deemed unclear. (16).

RESULTS.

The mean bar load of all successful trials from both limbs and test conditions was 84kg ±16.8kg. When normalized to body mass, the loads achieved were 0.96 ±0.18 kg/kg. When bar loads were compared between test and re-test conditions a most likely positive increase (9.3%) in bar load was observed. A most likely very large positive correlation (r =0.93, CL 0.88-0.96) and an excellent level of reliability was found (ICC = 0.93 CL 0.88-0.96).

INSERT TABLE 1 ABOUT HERE

INSERT TABLE 2 ABOUT HERE

Using the equation (equation 2) presented previously, a symmetry threshold of 94.91% - 105.9% was set to differentiate between more and less symmetrical subjects.

Reliability analysis

Analysis of symmetry, of bar load, found a most likely large positive correlation between test conditions (r =0.73, 0.33-0.91), (fig 1), and moderate reliability (ICC 0.73, 0.39-0.89). The symmetry observed in the initial test was 99.67 ±18.77% and 102.84 ± 6.35% under re-test conditions, the standard error was 1.29% The Bland-Altman analysis (fig 2) found a mean difference of 0.26, (-12.44-12.97), indicating no proportional bias between testing days.

INSERT FIGURE 2 ABOUT HERE

INSERT FIGURE 3 ABOUT HERE

Validity analysis

The mean symmetry for bar load, for all maximal trials was 101.08% ±10.13, for the same trials the symmetry in mean set concentric VGRF was 101.76±5.14% (lead foot only) and 101.84±4.33% (lead and rear foot combined). Correlation analysis of symmetry data, from mean vGRF, found a most likely large positive effect for both the lead foot only and when lead and rear foot were combined. When normalized to body weight, most likely large positive correlations were found for both lead foot vGRF and lead and rear foot vGRF, respectively.

INSERT FIGURE 4 ABOUT HERE

INSERT TABLE 4 ABOUT HERE

When threshold boundaries of load symmetry (94.91% - 105.9%), were applied, those subjects outside this range were found to have very likely large positive correlation between asymmetries in lead foot vGRF and bar load. The same inference was also found when lead foot vGRF was normalized to body weight. When vGRF of both front and rear foot was combined a most likely very large positive correlation was found to asymmetries in bar load. In the more symmetrical group, the correlation between symmetry in mean vGRF of the lead limb and lead and rear limb combined, to that of bar load, was found to be unclear.

DISCUSSION.

To date, this is the first study to investigate the reliability and validity of a field based, free weight method of measuring unilateral leg strength symmetry. Findings of this study demonstrate that the RFESS 5RM demonstrates both good validity and moderate to excellent reliability. S&C coaches may consider using the RFESS 5RM to determine leg strength symmetry.

Data from test and re-test conditions indicated a most likely very large positive correlation between trials with moderate reliability (ICC= 0.73, 0.46-0.87) and no proportional bias. The reliability of loads between trials in this study (ICC = 0.93) and the loads achieved (84kg ±16.8kg) compare favorably to study previous research (21) (ICC's >0.94, 3RM values 98.6kg ± 21.5kg, 1RM 103kg ±21.5kg). This indicates that the RFESS is a reliable measure of unilateral leg strength, when using 5, 3 or 1RM protocols. However, McCurdy et al., (21) offered no data regarding the symmetry of the subjects in their study. The current study is the only one, to date, to do so, finding moderate reliability between sessions (ICC 0.73, 0.46-0.87). An increase in load was observed between sessions of 9.3% indicating a most likely increase, which may represent a learning effect between tests. Such an effect, which is larger than the magnitude of asymmetry detected, may suggest that the reliability of the test is questionable. The between session reliability of both load lifted and asymmetry though suggests that the increase in strength between sessions did not affect this imbalance and both limbs experienced equals gains. Further research, which incorporates greater familiarization to the exercises may reduce the learning effect between sessions and enhance the reliability of the test.

Koo et al., (18) recommends a sample size of 30 subjects to establish reliability using an ICC analysis. As this study was limited to only 17 subjects, who completed test and re-test conditions, the ability to meet the threshold for good reliability is less probable. Therefore, expanding the sample size may further increase the probability and effect size of the reliability between sessions. The sample, was relatively homogenous being of similar age, gender and training experience. As demonstrated by the learning effect in this study, participation in such a task required a minimum training status to limit possible learning effects between tests. A larger sample size, with greater range of training ages and exposure to the exercise may have also reduced the learning effect reported in this study. The homogeneity of the sample, does restrict the applicability of the findings to similar populations. Further research with either a larger, more general sample or specific targeted groups, which may benefit from the test is warranted.

Furthermore, the challenges of using weight plates to determine performance in the tests further constrains the precision of the test. However, given these constraints the level of reliability fell 0.02 from being classified as good. If the reliability of the load scores are considered in conjunction with the marginal differentiation between moderate and good reliability, S&C coaches may consider the RFESS 5RM to be a reliable method of measuring leg strength symmetry.

The current study sought to use set mean vGRF data to validate the RFESS as the first closed kinetic chain, dynamic, free weight exercise, to measure unilateral leg strength symmetry. The RFESS requires vertical movement of an axially loaded mass, in the sagittal plane, as such, the validity of symmetry in bar load is theoretically linked to differences in set mean concentric vGRF between limbs. The use of PPMC to analyze the relationship between symmetries in bar load and set mean concentric vGRF was applied to determine the validity of the exercise. When all maximal trials, from both test dates, were analyzed, symmetries in both lead foot and total (lead foot + rear foot) set mean concentric vGRF were found to have most likely large positive correlations. This suggests that the RFESS 5RM is a valid measure of unilateral leg strength symmetry, as shown by the ability to produce set mean concentric vGRF.

However, the application of a symmetry threshold, polarized the correlation findings. There were unclear findings in those subjects which fell within this boundary. Conversely, subjects which exceeded the threshold boundary, demonstrated a most likely large positive correlation between asymmetries in bar load and lead foot set mean concentric vGRF. These findings further support the validity of the RFESS 5RM, to measure symmetry in leg strength, but suggests that the test has a level of sensitivity which is ±5.09%, in this sample.

The data from this study supports the hypothesis that the RFESS 5RM is a valid and reliable method of measuring unilateral leg strength symmetry, based on lead foot vGRF data. However, whilst the there is good evidence supporting the exercise based on lead foot data, marginally stronger relationships were found between bar load combined front and rear foot vGRF were found (r = 0.53 lead, 0.67 lead + rear foot). The data from this study found that a mean of 84.41% ±5.40 of force was produced by the lead foot during the exercises. However, when applying the effect size limits recommended by Cohen (13), both these variables are classified as high and neither resulted in a different magnitude based inference. The inability to draw different inferences between these two variables may indicate that the role of the rear foot does not perform a significant role in the concentric phase of this exercise. This conclusion may be further supported by the low variability in (CV = 6.4%) in lead foot force distribution across all maximal trials. Further research is required to better understand the role of the rear foot in this exercise, specifically in relation to different submaximal loads, to examine if the role of the rear limb changes with increasing intensity.

All subjects in this study had a minimum of two years structured resistance training prior to data collection. However, none had previously performed the RFESS to maximal level and reported different loading methods in previous training experience. McCurdy et al., (21) reported significant changes ($p > 0.05$) in RFESS performance between trials, indicating that a learning effect had taken place, which is in agreement with the findings of this study. Despite the inter-test differences in loads, in this study, the results were found to be reliable and no bias in symmetry was found. As a result, the use of more experienced subjects may further increase the reliability observed in this and similar studies but may not influence the symmetries found.

PRACTICAL APPLICATIONS.

The findings from the current study indicate that the RFESS is a reliable method of determining unilateral leg strength in a field setting. Furthermore, when using the percentage difference method of calculation, the asymmetries observed in bar load are indicative of an athlete's symmetry in producing vGRF. From the sample used in this study, a threshold boundary of symmetry was observed of ±5.09%. The RFESS 5RM appears to lack sensitivity to symmetry below this level and therefore athletes within this range may not be considered to be asymmetrical. S&C coaches may be able to implement this protocol to both find a valid and reliable measure of their athlete's leg strength and their degree of symmetry

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Figures

Figure 1: Demonstration of the configuration for data collection in the RFESS 5RM

Figure 2: Scatter plot of test and re-test symmetry (%) in subjects performing a 5RM RFESS

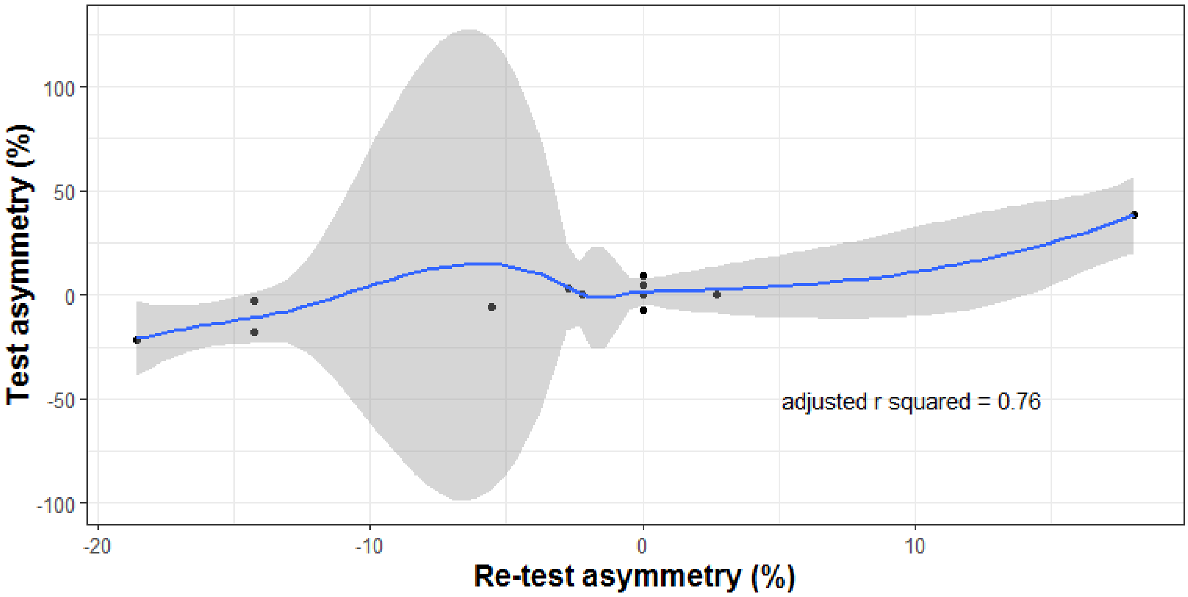

Test asymmetry (%)
100
50
0
-50
-100
-20
-10
0
10
Re-test asymmetry (%)
adjusted r squared = 0.76

Figure 3: Bland-Altman plot of test and re-test symmetry (%) in subjects performing a 5RM RFESS

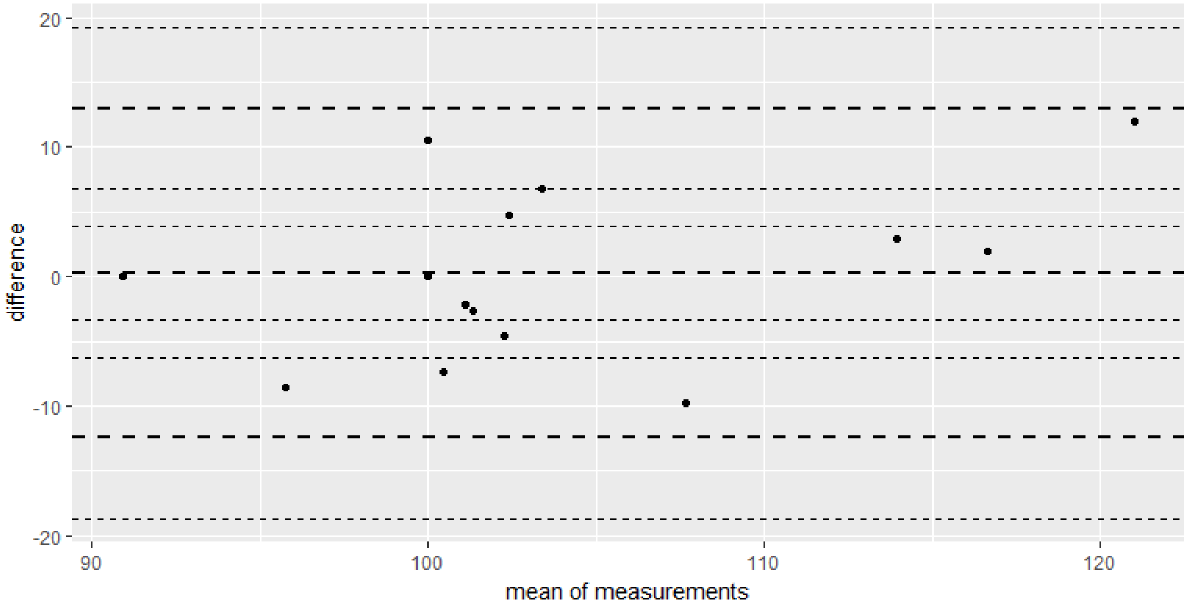
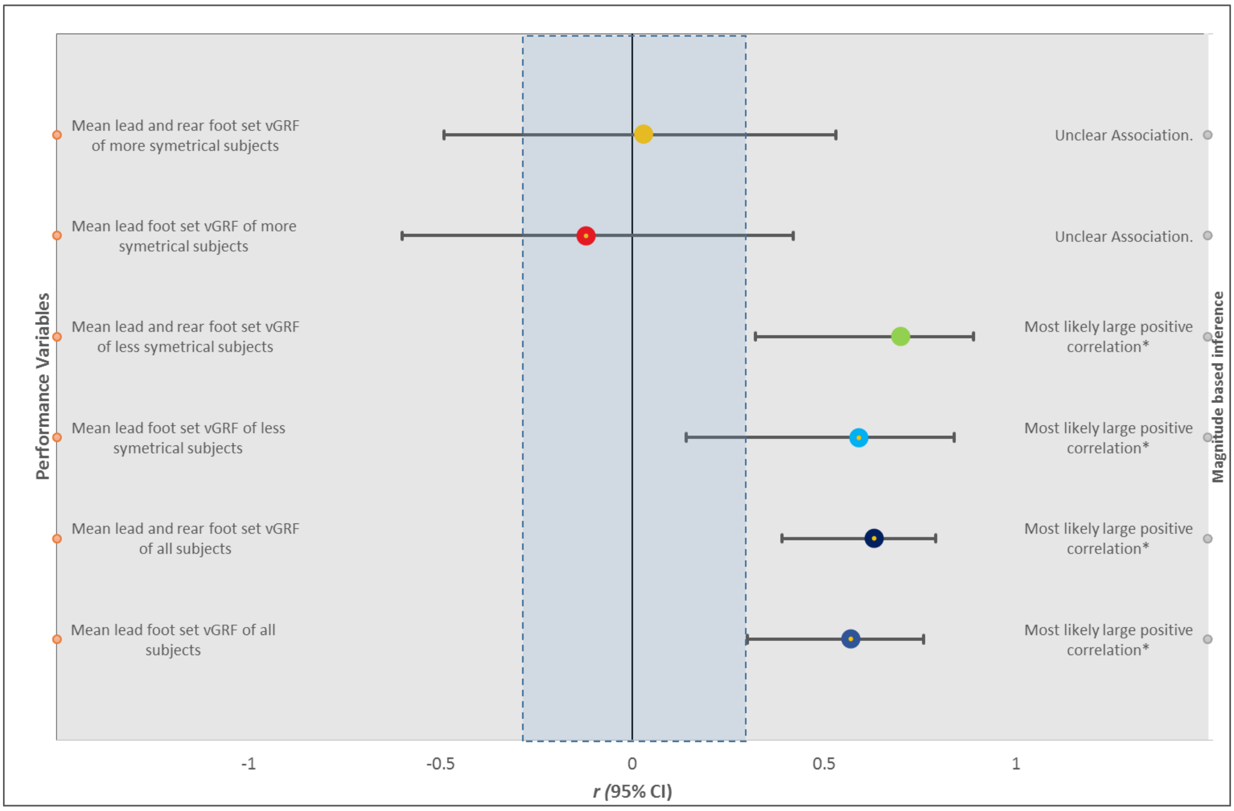

20
10
0
-10
-20
difference
90
100
110
120
mean of measurements

Figure 4: Forest plot showing the correlation (r + 95% CL) between bar load and mean set vGRF asymmetry in all, less and more symmetrical subjects.

- Significant p = <0.05


Performance Variables
Mean lead and rear foot set vGRF of more symetrical subjects
Mean lead foot set vGRF of more symetrical subjects
Mean lead and rear foot set vGRF of less symetrical subjects
Mean lead foot set vGRF of less symetrical subjects
Mean lead and rear foot set vGRF of all subjects
Mean lead foot set vGRF of all subjects
Unclear Association.
Unclear Association.
Most likely large positive correlation*
Most likely large positive correlation*
Most likely large positive correlation*
Most likely large positive correlation*
Magnitude based inference
-1
-0.5
0
0.5
1
r (95% CI)

Tables

Table 1: Mean data for all successful trials of the RFESS 5RM, between different trials.

	Test		Re-test	
	Left	Right	Left	Right
Mean bar load (kg)	80.9±15.2	82.0±16.37	89.5±16.3	88.8±18.2
Mean bar load, normalised to body mass (kg/kg)	0.92±0.17	0.94±0.19	1.0±0.2	0.99±0.2

Table 2: Mean kinetic data from all maximal RFESS 5RM trials, pooled from both test and re-test conditions.

	Mean (±SD)
Mean lead foot only vGRF (N)	1423.97 ±195.59
Mean lead foot only vGRF (BW)	1.64 ±0.23
Mean rear foot only vGRF (N)	266.79 ±80.60
Mean rear foot only vGRF (BW)	0.31±0.09
Mean lead and rear foot vGRF (N)	1700.95 ±246.20
Mean vertical Force (Lead and rear foot vGRF) (BW)	1.95 ±0.28
Mean vGRF Distribution toward the lead foot (%)	84.41 ±5.40

1

Table 4: Magnitude based inference data from Pearson correlation analysis of mean vGRF and bar load symmetry d

Variable	r (95% CL)	Inference	% Positive	% Trivial	% Negative
Mean lead foot set vGRF of all subjects	0.57, (0.30 to 0.76)	Most likely large positive correlation*	99.90%	0.10%	0.00%
Mean lead and rear foot set vGRF of all subjects	0.63, (0.39 to 0.79)	Most likely large positive correlation*	100%	0.00%	0.00%
Mean lead foot set vGRF of less symmetrical subjects	0.59, (0.14 to 0.84)	Most likely large positive correlation*	98.10%	1.60%	0.30%
Mean lead and rear foot set vGRF of less symmetrical subjects	0.70, (0.32 to 0.89)	Most likely large positive correlation*	99.70%	0.30%	0.00%
Mean lead foot set vGRF of more symmetrical subjects	-0.12, (-0.60 to 0.42)	Unclear Association.	15.60%	30.70%	53.70%
Mean lead and rear foot set vGRF of more symmetrical subjects	0.03, (-0.49 to 0.53)	Unclear Association.	37.40%	35.10%	27.50%

3

4