Reliability, Sensitivity, and Minimal Detectable Change of a New Specific Climbing Test for Assessing Asymmetry in Reach Technique

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Abstract

Čular, D, Dhahbi, W, Kolak, I, Iacono, AD, Bešlija, T, Laffaye, G, and Padulo, J. Reliability, sensitivity, and minimal detectable change of a new specific climbing test for assessing asymmetry in reach technique. *J Strength Cond Res* XX(X): 000–000, 2018—The aims of this study were to establish intertrial and intersession reliability, sensitivity, and minimal detectable change of a new climbing test specifically for assessing asymmetry in reach technique (TEST). Twenty-four young climbers (16 males and 8 females) participated in this study. The protocol consisted of performing, in counterbalanced random order, 3 tests; TEST, maximum handgrip force, and squat on the bench, in 2 sessions (with 3 trials for each session). TEST performance was expressed as: TEST performance for left hand (TESTL), TEST performance for right hand (TESTR), and absolute symmetry index (ASI). For intertrial and intersession reliability assessment, TESTL and TESTR showed excellent reliability (intraclass correlation coefficients ranged: 0.96–1.00; *SEM*% ranged: 0.07–1.23; and coefficient of variation–CV%: 1.28–2.53). In addition, *SEM*s were smaller than the smallest worthwhile change (SWC) values (SWC% = 1.07 and 0.99 for TESTL and TESTR, respectively), and the minimal detectable change (MDC_{95}) for both sides was small (<4.36 cm). An exception was ASI, which showed low absolute reliability and marginal sensitivity (*SEM*% = 15.13 > SWC% = 8.40 and CV% = 41.98). Pairwise test comparisons revealed no difference between sides. Considering the high reliability and the satisfactory sensitivity, TEST can be used to define individual asymmetry in the performance of the reach technique to the left or the right body side in climbers. However, interpreting data using the ASI index requires caution because it had poor absolute reliability and marginal sensitivity.

Key Words asymmetry index, isometric strength, motor skills, performance, testing

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Introduction

Sport climbing is a highly demanding athletic activity (34) that requires certain morphological characteristics (11) and a high level of mental control (i.e., control of thoughts and emotions, and maintaining a mood in accordance with the goals) (5). A successful climber must also possess technical skills and a high level of physical fitness, such as handgrip and finger grip strength (6,11). Shahram et al. (33) found that movements in sport climbing exert abundant pressure on the musculoskeletal system of the upper limbs because a large percentage of body mass is usually held by one hand, or one or a few fingers, during a climb action. Climbing also requires the skill to be efficient when grabbing a handhold or standing on a foothold at different angles, positions, and postures. By observing the technique performed by a climber athlete (22), the variability of the technique is a discriminative criterion for differentiating the climbers' different level of expertise. In fact, the variability of the climbing technique is detected within and between subjects (10).

Bilateral symmetry (12) denotes symmetry of the left and the right side of the body around the sagittal plane (4). There is proof that during the performance of bilateral movements (of either arms or legs), one side of the body is activated more in overcoming load, in comparison with the other side of the body–mostly targeting stabilization demands (25).

Table 1. Descriptive statistical indicators of morphological variables ($N = 24$).*

Variable	Average	Minimum	Maximum	*SD*	CI 95%
AGE (y)	16.54	9.00	27.00	4.16	14.79–18.30
TI (y)	4.58	1.00	10.00	3.49	3.11–6.06
ATV (cm)	171.56	141.00	189.00	12.16	166.43–176.69
ATT (kg)	60.45	38.00	80.20	12.86	55.02–65.88
ASV (cm)	88.30	74.00	111.00	8.09	84.89–91.72
ABR (cm)	170.96	138.00	200.00	15.16	164.56–177.36
BMI ($kg \cdot m^{-2}$)	20.31	15.10	26.40	2.89	19.09–21.53
FATP (%)	16.06	3.70	26.50	5.86	13.59–18.53
PMM (kg)	48.59	26.90	67.50	11.31	43.81–53.36
TRFATP (%)	12.65	3.00	24.30	5.73	10.23–15.07
TRMM (kg)	27.01	16.00	36.00	5.56	24.66–29.36

*CI = confidence interval; TI = training experience in climbing; ATV = body height; ATT = body mass; ASV = sitting height; ABR = biacromial range; BMI = body mass index; FATP = total percentage of body fat; PMM = total muscle mass; TRFATP = torso percentage body fat; TRMM = torso muscle mass.

Furthermore, during bilateral movements, a so-called bilateral deficit (i.e., the difference in the summed force between contracting muscles alone and contracting contralateral homologous muscles in combination) (30) occurs. In addition, bilateral deficit is characterized by a decrease in maximum voluntary contraction (MVC) force during bilateral activation of homologous muscles, compared with the sum of the forces produced during unilateral MVC of the muscles (29).

Natural ambidexters (i.e., perfect symmetry between both sides) are rare (1). Furthermore, it is known that the asymmetry of the body can be significantly reduced by training both sides of the body similarly (35). As such, optimal symmetry training methods may improve metabolic clearance, isometric strength, and endurance performance (a major determinant of sport rock climbing performance) (18). The fact that the climbers are capable of developing motor skills on the nondominant side of their body may potentially improve climbing performance (7).

Upper-limb movement asymmetries and leg force production asymmetries are thought to be detrimental for the climbers' performance, and may cause risk of injury. By using coefficients of asymmetry (the mean of the relative differences between the right and left side divided by 0.5, multiplied by the sum of right and left side (32)), a coach may determine side dominance and introduce program-efficient training plans to address right-left discrepancies (35). Previous studies in athletics have focused on asymmetries in tennis players (20), by investigating morphological asymmetry of these athletes. Similarly, body asymmetry was assessed in other studies conducted on elite soccer players (24,35). An investigation of soccer players (35) determined a positive effect of training in which technical soccer motor skills were practiced by both feet. Čular et al. (7) investigated the effect of the dominant and nondominant sides of the body on taekwondo performance. The obtained results support the phenomenon that the nondominant side is the place for athletes' improvement in most sports activities, and its identification is of interest to coaches. To the best of our knowledge, this paradigm has never been investigated in climbing.

In this aspect, technological advances and practical uses of devices enabling the assessment of athletes' asymmetry represent an interesting area of research. The availability of valid and reliable specific tests assessing the performance, technique, and asymmetry index of climbers may help coaches and practitioners in structuring individual training plans more efficiently. Therefore, the goal of this study was to validate a specific test for climbers (e.g., a specific climbing test for assessing asymmetry in reach technique–TEST) that will be able to provide indices of performance and asymmetry during reach techniques by the left and the right sides of the body.

Methods

Experimental Approach to the Problem

A cohort-based, randomized, repeated-measures study design was used. The experimental protocol consisted of performing the specific climbing test for assessing the asymmetry in reach technique (TEST) 3 times. One week before baseline testing, a session was conducted to familiarize the participants with the measurement protocol. Both sessions of baseline testing were dedicated to the assessment tests: TEST, maximum handgrip force for both hands, and squat on the bench for both legs.

Subjects

Twenty-four climbers (16 male and 8 female), from the sport climbing club Citius-Altius-Fortius from Split, voluntarily participated in this study. All anthropometric data (age, body height, body mass, sitting height, biacromial range, body

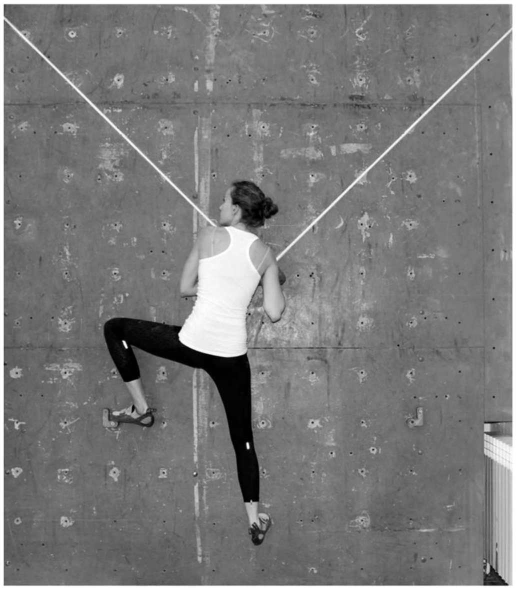

Figure 1. Initial position to the left.

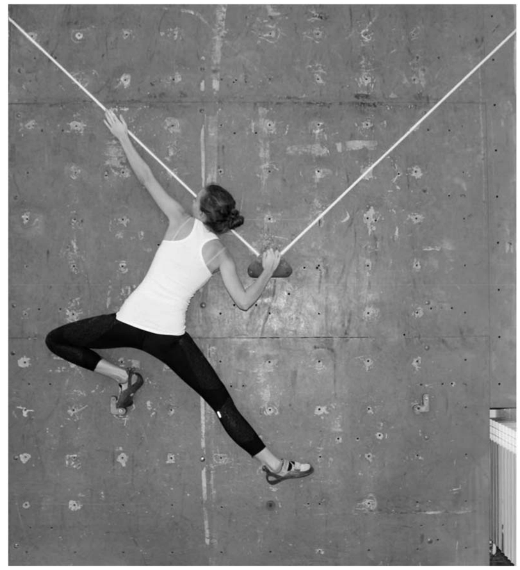

Figure 2. Final position to the left.

mass index, total percentage of body fat, total muscle mass, torso percentage body fat, and torso muscle mass) can be found in Table 1. All participants had a right dominant hand (as the one used for writing) (31). The inclusion criteria for participation in this study were: a minimum weekly training frequency of 3 sessions, or a total time of 180 minutes of climbing activities per week; and more than 1 year climbing training experience, free from any injury or pain that would have prevented maximal effort during testing. All subjects provided their written informed consent to participate in the study after receiving a thorough explanation of the study's protocol, parental signed consent was also obtained. The protocol conformed to internationally accepted policy statements regarding the use of human participants in accordance with the Declaration of Helsinki, and was approved by the University of Split, Faculty of Kinesiology.

Procedures

The protocol consisted of the performance of the 3 tests in counterbalanced random order, with 3 trials for each test. The recovery time was 5 minutes between trials, and 10 minutes between tests. Test and retest protocols were identical. The 2 best attempts of the 3 trials for the first baseline session were kept for analysis of the intertrial reliability of TEST. To examine the intersession reliability and sensitivity of TEST, the best scores of testing sessions 1 and 2 were compared.

Before starting the tests, the participants performed ~15 minutes of warm-up, which included circumduction and flexion/extension of the upper limbs with self-selected intensity, and dynamic stretching (pectorals, trapezius, arm flexor and extensor, and flexors and extensors of the hand/fingers). After the warm-up, the participants recovered for ~5 minutes and then began the tests. Test data were collected at approximately the same time of day (morning) in both sessions (between: 09:00 and 11:00 AM) to eliminate any influence of circadian variations on performance (16). Participants were asked to follow their normal diet, eat a light meal at least 3 hours before each session, sleep normally, and cease any strenuous activity during the 24 hours before the test. The experimenter provided strong verbal encouragement during the tests to obtain maximum efforts from the participants. To ensure the same testing conditions, all participants were tested by the same raters. The test was performed on a specially designed measuring board in an indoor rock climbing center (measurements were taken every 30 minutes during the experiment): temperature 20 ± 0.5° C and humidity 50 ± 10%, monitored using a digital environmental station (Vaisala Oyj, Helsinki, Finland) during the test and the retest sessions.

Specific Climbing Test for Assessing Asymmetry in Reach Technique (TEST): Initial Position. On the measurer's mark, the subject stood in an initial position by placing the right hand on the first handhold, so that the middle finger was placed in the middle of the hold (Figure 1). The subject then placed the left hand on the left edge of the handhold, right next to the right hand, with the right foot placed with its inner edge on the initial foothold. The subject was ready to perform the test when he/she lifted his/her left foot from the surface and placed it on the foothold.

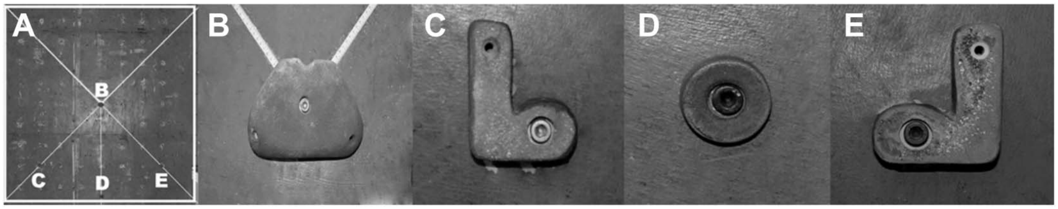

Figure 3. Construction of the "board" for performance testing. A) "Board without holds," (B) "A main handhold," (C) "left foothold"; (D) B "main foothold"; and (E) "right foothold."

Test performance. On the measurer's mark, the subject started performing the test by moving his/her body to the left so that the left knee, hip, and shoulder moved to the left by transferring the center of gravity to the left leg. The subject then moved the right foot from the initial foothold, and the inner edge of the climbing shoe was placed on the part of the rock without the foothold (so-called "friction"), so that the foot was facing the opposite direction from the hand reach. Then, the climber let go of the handhold held by his/her left hand and reached with his/her hand on the measuring tape to the maximum distance.

Final position. In the final position, the climber's center of gravity was transferred to the left side in relation to the initial position, and the subject rested on the left foot and gripped with the right hand (Figure 2). The left hand was placed on the measuring tape and was held still for a minimum of 3 seconds before the result of the maximum reach was read. The right foot was placed on the rock with the inner edge of the climbing shoe facing opposite of the left hand.

Three performance indices were calculated from TEST: (i) TEST performance for left hand (TESTL): specific climbing test of reach for the left hand (cm), (ii) TEST performance for right hand (TESTR): specific climbing test of reach for the right hand (cm), and (iii) ASI: absolute symmetry index (%).

Absolute symmetry index was used to evaluate symmetry between the left and right sides (21):

$$\text{Absolute symmetry index (ASI\%)} = \frac{|\text{TESTR} - \text{TESTL}|}{0.5 \times (\text{TESTR} + \text{TESTL})} \times 100 \qquad 1$$

It should be noted that the lower the levels of ASI indicated more symmetrical sides.

Equipment and installation. The experiment was conducted on an artificial rock that had been specially constructed for the purposes of the experiment. The rock was placed at a 90° angle in relation to the horizontal surface, on a 262 × 262 cm square with marked positions of the handholds, footholds, and measuring tapes. The marked square was horizontal in relation to the surface, with the lower side at a 30-cm distance from the surface (Figure 3A). The main handhold was placed at the point where the diagonals of the square intersect (Figure 3B), and its upper surface was parallel to the board surface and had a dent that marked the position of the middle finger of the gripping hand during test performance. Measuring tapes were placed upward along the diagonals and their starting point (zero) was in the hole for fastening the handhold. The hole on the handhold was 12 mm in diameter. At the lower part of both diagonals, at a 106-cm distance from the hole for the main (A) handhold, footholds with limiters (Figure 3C and E) were placed so that the limiter was vertical to the surface (Figure 3C and E). From the position of fixation of the main handhold, a vertical

Table 2. Intertrial relative and absolute reliability indices of the specific climbing test.*

Variable	Mean ± *SD* Trial 1	Mean ± *SD* Trial 2	$ICC_{3,1}$ (95% CI)	CV%	*SEM* (%)
TESTL (cm)	125.58 ± 21.95	125.73 ± 22.32	0.997 (0.994–0.999)	1.31	0.09 (0.07)
TESTR (cm)	126.21 ± 22.17	126.26 ± 22.80	0.990 (0.977–0.996)	2.53	0.32 (0.25)
ASI (%)	5.26 ± 4.25	5.28 ± 3.73	0.892 (0.767–0.952)	35.20	0.61 (11.57)

*$ICC_{3,1}$ = intraclass correlation coefficient model 3,1; CV = coefficient of variation; TESTL = performance of the reach test for the left body side; TESTR = performance of the reach test for the right body side; ASI = absolute symmetry index.

Table 3. Intersession relative and absolute reliability indices and MDC_{95} of the specific climbing test.*

Variable	Mean ± *SD*		$ICC_{3,1}$ (95% CI)	CV%	*SEM* (%)	SWC (%)	MDC_{95} (%)
	Session 1	Session 2					
TESTL (cm)	126.27 ± 21.93	130.24 ± 20.69	0.948 (0.883–0.977)	5.37	1.57 (1.23)	1.38 (1.07)	4.36 (3.40)
TESTR (cm)	127.05 ± 22.08	130.75 ± 21.39	0.957 (0.903–0.981)	4.96	1.32 (1.03)	1.28 (0.99)	3.67 (2.85)
ASI (%)	4.62 ± 3.63	4.62 ± 3.98	0.870 (0.724–0.942)	41.98	0.70 (15.13)	0.39 (8.40)	1.94 (41.95)

*CI = confidence interval; $ICC_{3,1}$ = intraclass correlation coefficient model 3,1; CV = coefficient of variation; SWC = smallest worthwhile change; MDC_{95} = minimal detectable change at 95% confidence interval; TESTL = performance of the reach test for the left body side; TESTR = performance of the reach test for the right body side; ASI = absolute symmetry index.

line was drawn to the surface and a hole was drilled at a 125-cm distance from where initial foothold of regular circular shape was placed (Figure 3D). The surface for the test performance was secured by a mat 5 cm thick and 3 × 1 m long. The handholds and footholds were specially designed for the purposes of this experiment by the "Vulkan" hold manufacturer; the name of the series is "A set of handholds and footholds for the reach test."

Handgrip Strength (Right Hand and Left Hand). This test was performed according to the handgrip strength protocol, described by España-Romero et al. (17). Both hands (i.e., left and right) were evaluated. The hand to be tested first was randomly chosen. The Takei Hand Grip Dynamometer (Takei A5401 Digital Hand Grip Dynamometer, Niigata city, Japan; error 0.001 gr) is a digital tool with an adjustable grip span.

Squat on the Bench (Right Leg and Left Leg). This test was performed according the protocol described by Čular et al. (8). The test was completed when the subject could not stand up correctly anymore and remained sitting on the chair. The test result was expressed as the number of correct repetitions of standing up and sitting down on the chair. The subjects performed a maximum number of repetitions, and the test was not time-limited. The procedures were repeated on the opposite leg.

Statistical Analyses

Data analyses were performed using SPSS version 23.0 for Windows. Mean values and *SDs* were calculated after verifying the normality of distributions using Kolmogorov-Smirnov statistics. Dependent *t*-tests were used to evaluate the equality of mean values for left and right side climbers' TEST, maximum handgrip force, and squat on the bench tests, and it was also used to investigate systematic bias. Estimates of effect size (Cohen's *d*), mean differences, and 95% confidence intervals (CIs) protected against type 2 errors. The relative reliability of TESTL, TESTR, and ASI was determined by calculating the intraclass correlation coefficient model 3,1 ($ICC_{[3,1]}$), and the absolute reliability was expressed in terms of *SEM* and coefficients of variation (CVs). The sensitivity of the test was assessed by comparing the smallest worthwhile change (SWC) and *SEM*, using the thresholds proposed by Liow and Hopkins (23). Minimal detectable change at 95% CI (MDC_{95}) was also calculated for TESTL, TESTR, and ASI indices. Heteroscedasticity was examined. Significance for all the statistical tests was accepted at $p < 0.05$ (Table 2).

Results

Intertrial Reliability of the Specific Climbing Test

The pairwise analysis of TESTL, TESTR, and ASI indices revealed no significant difference in between trials

Table 4. Comparison of mean values between the right and left sides.*

Variables	Left side	Right side	*p*	Cohen's *d*
Specific climbing test (cm)	130.93 ± 21.12	131.38 ± 21.45	0.802	0.05
Maximum handgrip force (kg)	36.85 ± 14.13	37.47 ± 14.30	0.351	0.20
Squat on the bench (pcs)	9.79 ± 7.59	10.29 ± 11.18	0.672	0.11

*The values are presented as mean ± *SD*.

(p: 0.67–0.95; d: 0.01–0.09 [trivial]). Moreover, performance for both sides (i.e., TESTL and TESTR) and ASI showed a high degree of ICC between trials ($ICCs_{[3,1]}$ was 1.00, 0.99, and 0.89, respectively). TESTL and TESTR showed an excellent absolute reliability (*SEM*%: 0.07–0.25; CV: 1.31–2.53). Contrarily, ASI showed low absolute reliability (*SEM*% = 11.57 and CV % = 35.20). In addition, there was no heteroscedasticity in the raw data (r: −0.21 to 0.29; p: 0.17–0.33).

Intersession Reliability and Sensitivity of the Specific Climbing Test

TESTL and TESTR showed an excellent reliability ($ICCs_{[3,1]}$: 0.95–0.96 and *SEM*%: 2.85–3.40). However, TEST showed a satisfactory sensitivity. Hence *SEM* values were approximately equal to SWC values (SWC% = 1.07 and 0.99 for TESTL and TESTR, respectively). In addition, the MDC_{95} for both sides were small (<4.36 cm) (Table 3). In accordance with intertrial results, ASI showed poor absolute reliability (*SEM*% = 15.13 and CV% = 41.98) and marginal sensitivity (*SEM*% = 15.13 > SWC% = 8.40 and MDC_{95}% = 41.96). Heteroscedasticity coefficients for TESTL, TESTR, and ASI were all small and nonsignificant ($r = 0.18$ [$p = 0.40$], $r = 0.11$ [$p = 0.61$], and $r = 0.19$ [$p = 0.39$], respectively).

Comparison of the Specific Climbing Test and Strength Tests Between Right and Left Sides

A pairwise sample t-test revealed no difference between sides (Table 4) for TEST ($p = 0.802$; $d = 0.05$ [trivial]), maximal handgrip strength ($p = 0.351$; $d = 0.20$ [small]), and squat on the bench ($p = 0.672$; $d = 0.11$ [trivial]). The corresponding stepwise regression equations are shown in Table 4.

Discussion

The aims of this study were to establish the intertrial and intersession reliability, sensitivity, and minimal detectable change of a new specific climbing test for assessing asymmetry in reach technique (TEST). To the best of the authors' knowledge, this is the first reported evaluation of TEST. The main findings of this study were that TEST is highly reliable and sensitive for assessing symmetry in reach technique. However, the ASI had poor absolute reliability and marginal sensitivity.

By providing reliable and valid assessments, climbing coaches can advance training programs while limiting injury prevalence. The variability between trials may be considered to be intrinsic variation because it provides a basic indication of the variation independent from other sources of error (13). The intertrial variability is free of methodological errors, cannot be reduced, and thereby serves as an appropriate baseline for comparisons (14,26). The intertrial reliability of TEST performance is important to ensure that observed differences between testing trials are not due to systematic bias, such as a learning effect, fatigue, or random error due to possible biological or mechanical variations. The intertrial variability is usually caused by the emotional state of subjects between the trials, and by their level of experience with the measuring system (26). However, between-day reliability represents an important aspect of performance testing. Poor reliability might result in different scores for the examinee across the 2 test administrations, which may be conducted with erroneous data interpretation (9).

The ICC can be used to assess relative reliability, which indicates the maintenance of group position (rank order) on the tests across the 2 measures (9). With ICC scores ranging from 0.87 (good) to 1.00 (excellent), TEST (e.g., TESTL, TESTR, and ASI) demonstrated a high intertrial and intersession relative reliability. A weakness of ICC is that it is affected by the heterogeneity of the sample (37). Therefore, an examination of the *SEM*, which provides an absolute index of reliability, is needed (37) to confirm the ICC's results. The *SEM* is not affected by intersubject variability (37) and provides an estimate of measurement error. In addition, if data are homoscedastic, which is the case in all parameters of this study (r: −0.21–0.29; p: 0.33–0.61), *SEM* analysis may be more useful for establishing absolute reliability (2). With heteroscedastic data, CV analysis is recommended (2). *SEM* % values lower than 5% may be interpreted as good absolute reliability (28). Using the same idea, intertrial and intersession *SEM*% of this investigation ranged from 0.07% to 1.23% for both TESTL and TESTR performances. The CVs of TESTL and TESTR ranged from 1.31 to 5.37% and 2.53–4.96%, respectively, which can be considered good (<10%) (2), whereas ASI had a poor absolute reliability (*SEMs*% <5% and CVs% <10%).

We also calculated the likelihood that differences in TEST outcomes were substantial (i.e., SWC larger than the *SEM*). As for TESTL and TESTR, *SEM*s were approximately equal to the SWC values (Table 3), indicating that the measurements have a "satisfactory" potential to detect real changes in the performance output of the body. By contrast, the SWC for the ASI (8.40%) was smaller than the parallel *SEM* (15.13%) (Table 3). The lack of contralateral climbing experience is a factor that may have influenced the results. Assessment of an apparent change in performance depends on the magnitude of the change in score relative to error size (MDC_{95}) (19). The MDC_{95} values for TESTL, TESTR, and ASI were 4.36 cm, 3.67 cm, and 1.94%, respectively. Thus, a change in TESTL, TESTR, and ASI scores exceeding 4.36 cm, 3.67 cm, and 1.94%, respectively, can be accepted as a true response (2), and one can be 95% confident that a true change has occurred beyond measurement error in climbers.

Pairwise comparisons revealed no difference between left and right sides for TEST ($p > 0.05$; *d*: [trivial]). Similar results were achieved in the maximal handgrip strength test ($p = 0.351$; $d = 0.20$ [small]) and squat on the bench test ($p = 0.672$; $d = 0.11$ [trivial]). This is likely associated to the specific functional demands in terms of climbing techniques that involve 4 supports (i.e., the hands and legs) (15). The maximal handgrip strength, and consequently the forearm muscles' strength, has represented as a good predictor of climbing performance (3,15,36). Conjointly, strength and power of the lower limbs were a physical requirement of paramount importance for overall climbing performance (27). Hence, this consistency between the results of the 3 tests (i.e., TEST, maximal handgrip strength, and squat on the bench) confirms the sensitivity of TEST to detect the difference in performance between climbers' sides.

The results confirm that the newly constructed specific measuring instrument (i.e., TEST) has good metric characteristics and can be used to assess the level of asymmetry between left and right reaching techniques. In summary, the use of TEST on both body sides, due to its highly reliable and satisfactory sensitivity, can be confirmed for defining individual asymmetry in the performance of the reach technique to the left or the right body side on a sample of athletes involved in sport climbing. However, interpreting data using the ASI index requires caution because it had poor absolute reliability and marginal sensitivity. Finally, the results of this study open up the possibility for further research in the area of asymmetry in sport climbing, and to arrive at more precise and quality conclusions, future studies should involve a larger number of subjects of different ages.

Practical Applications

Due to its simplicity in terms of performance, the small amount of equipment required to be performed, the cost-effective field, and the possibility of simultaneous testing of multiple subjects in a relatively short period, this test can be a popular field-specific test for climbers. In addition, based on its high reliability and satisfactory sensitivity, this test is suitable for application in monitoring, evaluating, and programming the transformation processes of symmetry in reach skills for climbers.

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