Assessment of Isometric Knee Flexor Strength Using Hand-Held Dynamometry in High-Level Rugby Players Is Intertester Reliable

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Abstract

Objective: To assess intertester reliability of isometric knee flexor strength testing in high-level rugby players with testers of different physical capacity and different methods of dynamometer fixation. **Design:** Reliability study. **Patients:** Thirty noninjured high-level (Tegner Activity Score ≥9) rugby players, free from hamstring injury in the previous 2 months. **Assessment:** Isometric knee flexor strength (in N) in prone 0/15 degrees (hip/knee flexion) and supine 90/90 degrees position. Tests were performed by 1 female and 2 male testers whose upper-body strength was measured with a 6-repetition maximum bench press test. The prone 0/15 degrees measurement was performed with manual and external belt fixation of the dynamometer. **Main Outcome Measures:** Absolute and relative intertester reliability were calculated using intraclass correlation coefficient (ICC) and minimal detectable change. Paired *t*-tests were used to identify systematic measurement error between testers and to test for a difference in recorded knee flexor strength between methods of dynamometer fixation. **Methods:** Isometric knee flexor strength was measured in prone 0/15 degrees (hip/knee flexion) and supine 90/90 degrees position. **Results:** Good intertester reliability was found for all pairwise comparisons (ICC 0.80-0.87). MDCs (as percentage of mean strength) ranged from 15.2% to 25.4%. For tester couples where systematic error was identified, Bland–Altman plots and Pearson correlation coefficients demonstrated no statistically significant correlation between mean knee flexor strength and between-tester difference. There was no significant difference in isometric knee flexor strength between manual and belt fixation of the dynamometer. **Conclusions:** In strong high-level rugby players, hand-held dynamometry for isometric knee flexor strength assessment in prone 0/15 degrees and supine 90/90 degrees position is intertester reliable.

Key Words: isometric, hamstring strength, HHD, peak force, reliability

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INTRODUCTION

Hamstring strength assessment is widely used for screening, injury prognosis, and monitoring of recovery.[1–7] Hand-held dynamometry (HHD) is a portable, relatively cheap, and quick method to assess isometric strength,[8] making it an appealing clinical alternative to isokinetic strength assessment. These measurements can be performed with manual and external belt fixation of the dynamometer.

Intertester reliability of HHD has been questioned when testing strong athletes or when using testers of different physical capacity.[9–13] Hand-held dynamometry requires that the tester is able to oppose the strength of the tested individual. A mismatch in physical capacity between tester and tested individual, which is more likely to occur with strong athletes (eg, high-level rugby players), may produce less valid test results. This mismatch could have implications for intertester reliability, especially with testers of different physical capacity. Thorborg et al[13] found that using testers of different sex and upper extremity strength introduced systematic intertester bias for hip strength assessment using HHD. Mulroy et al[14] raised the same issue in regards to knee extensor strength assessment. However, it is unknown whether these findings can be extrapolated to isometric knee flexor (hamstring) strength assessment, a different muscle group that is tested in different positions.

A mismatch could be overcome by eliminating the influence of the testers' strength, for example with external fixation of the testing device.[15–17] Thorborg et al[16] reported good intertester reliability for isometric hip and knee strength assessments using belt fixation despite using testers of different sex. However, it is unknown whether belt fixation is required for a reliable isometric strength assessment of the knee flexors. Considering the additional equipment and steps needed for belt fixation and the limited amount of time per patient in clinical practice, it is relevant to determine whether belt fixation is necessary for a reliable and valid assessment.

The aim of this study was to evaluate relative and absolute intertester reliability of isometric knee flexor strength assessment in high-level rugby players using testers of different physical

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capacity and different methods of dynamometer fixation. Secondary aims were to evaluate whether there was systematic error in recorded knee flexor strength between testers of different physical capacity and whether testing with external belt fixation resulted in significantly higher knee flexor strength compared with manual fixation of the testing device. Our hypotheses were that (1) differences in physical capacity of testers result in systematic measurement error and (2) testing with external belt fixation of the dynamometer yields systematically higher values than HHD.

METHODS

Participants were recruited from Dutch rugby clubs participating in the top domestic league. Participants were eligible if they were male rugby players aged between 16 and 35 years, playing at least on a competitive level (≥9 on the Tegner Activity Scale), and were free from hamstring injury in the past 2 months. This study was exempted from ethical review by the Medical Ethics Committee (METC, Amsterdam UMC, Amsterdam, the Netherlands, project W18_246). All participants provided written informed consent, and their rights were protected.

Testers

Isometric knee flexor strength was assessed by 2 male testers (M1: 185 cm, 92 kg and M2: 195 cm, 117 kg), and 1 female tester (F: 167 cm, 60 kg). All testers were right dominant. Upper-body strength was measured by a 6-repetition maximum bench press (6RMBP) test according to the testing protocol of Wong et al.[18] Weight increments were 2.5 kg per set instead of 2 kg in the original 6RMBP testing protocol.

Isometric Knee Flexor Strength Assessment

Isometric knee flexor strength (in N) was measured using a Hoggan MicroFET2 (Hoggan Scientific, LLC, Salt Lake City, UT). Testers received identical instructions and were trained until they were familiar with the protocol and able to perform the assessment independently.

Knee flexor strength assessment consisted of 2 testing positions that have been shown to be clinically relevant with regard to hamstring injury prognosis and monitoring of recovery progression[5,7]; prone 0/15 degrees (0 degrees hip flexion and 15 degrees knee flexion) and supine 90/90 degrees (90 degrees hip flexion and 90 degrees knee flexion). Prone 0/15 degrees was performed twice, once with manual fixation of the dynamometer and once using external belt fixation. No belt fixation was used for the supine 90/90 degrees position due to lack of a feasible method without compromising the practicality of HHD (ie, using a frame or additional equipment).

For the prone 0/15 degrees position, the participant was lying in a prone position, with the feet just hanging over the edge of the bench—which was adjustable in height. With the ankle in neutral position, the tester passively flexed the knee to 15 degrees and placed the dynamometer at the heel of the participant. When a belt was used for fixation (Figure 1A), another tester ensured that the belt and dynamometer transducer were in line with the direction of force applied by the participant. For manual fixation, the tester held the dynamometer with both hands to oppose the participant's effort (Figure 1B). To minimize the number of repetitions that participants had to perform potentially leading to a fatigue effect, only 2 testers performed measurements with belt fixation.

For the supine 90/90 degrees position (Figure 1C), the participant was lying in a supine position. A belt was used to prevent the pelvis from being lifted off the bench, and the participant was instructed to hold the bench with both hands. The tester passively flexed the hip and knee to 90 degrees flexion and placed the dynamometer at the heel of the participant with the dominant hand. The tester's nondominant hand supported their dominant hand, and the elbow of the dominant arm was placed on the ipsilateral iliac crest to counter the participant's effort.

There were no significant rest periods between the 3 efforts during testing in a single position. To minimize influence of muscle fatigue, the left leg was used for the prone 0/15 degrees measurement and the right leg for the supine 90/90 degrees

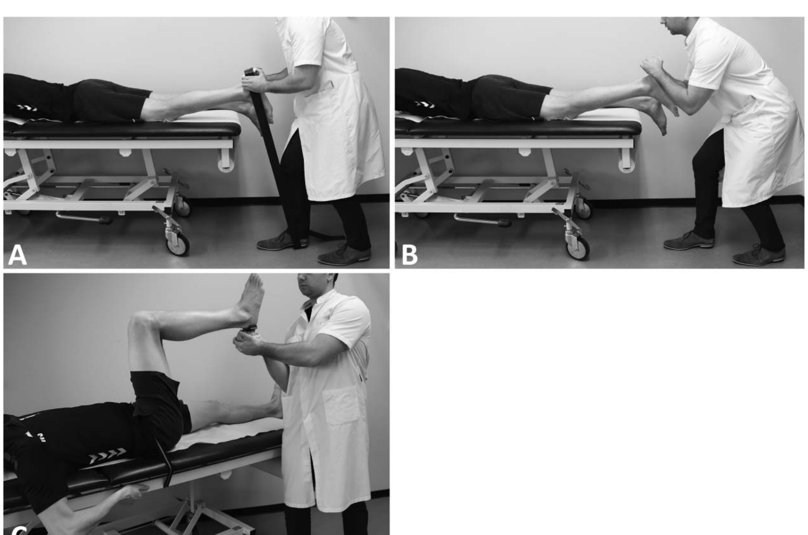

Figure 1. Prone 0/15 degrees with external belt fixation (A) versus manual fixation (B). Supine 90/90 degrees with manual fixation (C).

TABLE 1. Mean (±SD) isometric Knee Flexor Strength for All Testers Per Testing Position and Method of Dynamometer Fixation

Position	Dynamometer Fixation	Mean (±SD) Isometric Knee Flexor Strength (N)			
		Overall	M1	M2	F
Prone 0/15 degrees	Manual	341.7 ± 65.8	357.0 ± 60.9	333.9 ± 70.0	334.1 ± 65.7
Prone 0/15 degrees	Belt	341.3 ± 72.6	355.5 ± 75.4	327.1 ± 68.0	
Supine 90/90 degrees	Manual	437.4 ± 67.2	448.9 ± 67.2	441.0 ± 68.9	422.2 ± 64.9

F, female tester, M1, male tester 1, M2, male tester 2.

measurement, alternating between both legs during testing. Tester and fixation method order were randomized by drawing lots.

Participants were instructed to gradually build up force in the first second of a 3-second maximum effort and were verbally encouraged during each effort. The highest recorded value of 3 repetitions was recorded by a fourth person that was not one of the testers.

Statistical Analysis

With an expected ICC of 0.85[5,7] and a 95% confidence interval of ±0.1, the calculated sample size was determined at 30 participants.[19]

Statistical analysis was performed with SPSS (version 23.0; SPSS, Chicago, IL). Normality of data, either for descriptive statistics or for use in subsequent analyses, was evaluated by graphical assessment of histograms and normal Q–Q plots. ICCs were calculated using a two-way random-effects model with the agreement definition ($ICC_{2,1}$). ICCs were used to determine whether there was poor (<0.50), moderate (0.50-0.75), or good (>0.75) relative reliability.[20] The standard error of measurement (SEM) and minimal detectable change (MDC) were calculated to determine absolute reliability. SEM was calculated as $SD \times \sqrt{1 - ICC}$, and MDC was calculated as $1.96 \times \sqrt{(2)} \times SEM$. SEM and MDC were also given as a percentage of the average test value. Bland–Altman plots were constructed and paired *t*-tests were performed to visualize and test for systematic error between testers of different physical capacity and different methods of dynamometer fixation. When paired *t*-tests identified systematic error for a tester couple, Pearson correlation coefficients were calculated to test for a correlation between knee flexor strength and between-tester differences. The level of significance was set at $\alpha = 0.05$.

RESULTS

Thirty male rugby players with a mean age of 24 ± 4 years and median weight of 94 (interquartile range: 85-100) kg were included. The bench press test revealed a 6RMBP of 77.5, 97.5, and 37.5 kg for testers M1, M2, and F. Mean isometric knee flexor strength of the rugby players is shown in Table 1.

Relative and Absolute Reliability

Relative and absolute reliability are presented in Table 2. Good relative intertester reliability was found for the prone 0/15 degrees and supine 90/90 degrees measurements. Good relative intertester reliability was found for all pairwise comparisons. SEM and MDC as a percentage of mean recorded strength values ranged from 5.5% to 9.2% and 15.2% to 25.4%, respectively.

Systematic Error Between Different Testers

There were statistically significant between-tester differences (ie, systematic error) in knee flexor strength in both testing positions. Systematic error was found for tester couples with the exception of prone 0/15 degrees (M2 & F, hand-held) and supine 90/90 degrees (M1 & M2, hand-held) (Table 2). For tester couples where systematic error was identified, Bland–Altman plots and Pearson correlation tests demonstrated no statistically significant correlation between mean knee flexor strength and between-tester difference (Figure 2).

TABLE 2. Intertester Reliability and Systematic Error for Isometric Knee Flexor Strength Assessments (Hip Flexion/Knee Flexion)

Position	Testers	Dynamometer Fixation	$ICC_{2,1}$ (95% CI)	SEM (N)	MDC (N)	SEM, %*	MDC, %*	Paired *t* Test
Prone 0/15 degrees	Overall	Manual	0.83 (0.68-0.91)	27.5	76.1	8.0	22.3	
Supine 90/90 degrees	Overall	Manual	0.84 (0.70-0.92)	26.8	74.3	6.1	17.0	
Prone 0/15 degrees	M1 & M2	Manual	0.84 (0.51-0.94)	26.4	73.3	7.7	21.2	$P < 0.001$
Prone 0/15 degrees	M1 & F	Manual	0.80 (0.49-0.91)	28.6	79.2	8.3	22.9	$P = 0.001$
Prone 0/15 degrees	M2 & F	Manual	0.83 (0.68-0.92)	27.4	76.0	8.2	22.8	$P = 0.982$
Prone 0/15 degrees	M1 & M2	Belt	0.82 (0.42-0.93)	31.2	86.5	9.2	25.4	$P < 0.001$
Supine 90/90 degrees	M1 & M2	Manual	0.87 (0.75-0.94)	24.5	67.8	5.5	15.2	$P = 0.221$
Supine 90/90 degrees	M1 & F	Manual	0.85 (0.31-0.95)	25.6	70.8	5.9	16.3	$P < 0.001$
Supine 90/90 degrees	M2 & F	Manual	0.80 (0.58-0.90)	30.1	83.3	7.0	19.3	$P = 0.014$

CI, confidence interval; F, female tester; ICC, intraclass correlation coefficient; M1, male tester 1; M2, male tester 2.
**Percentage of mean.*

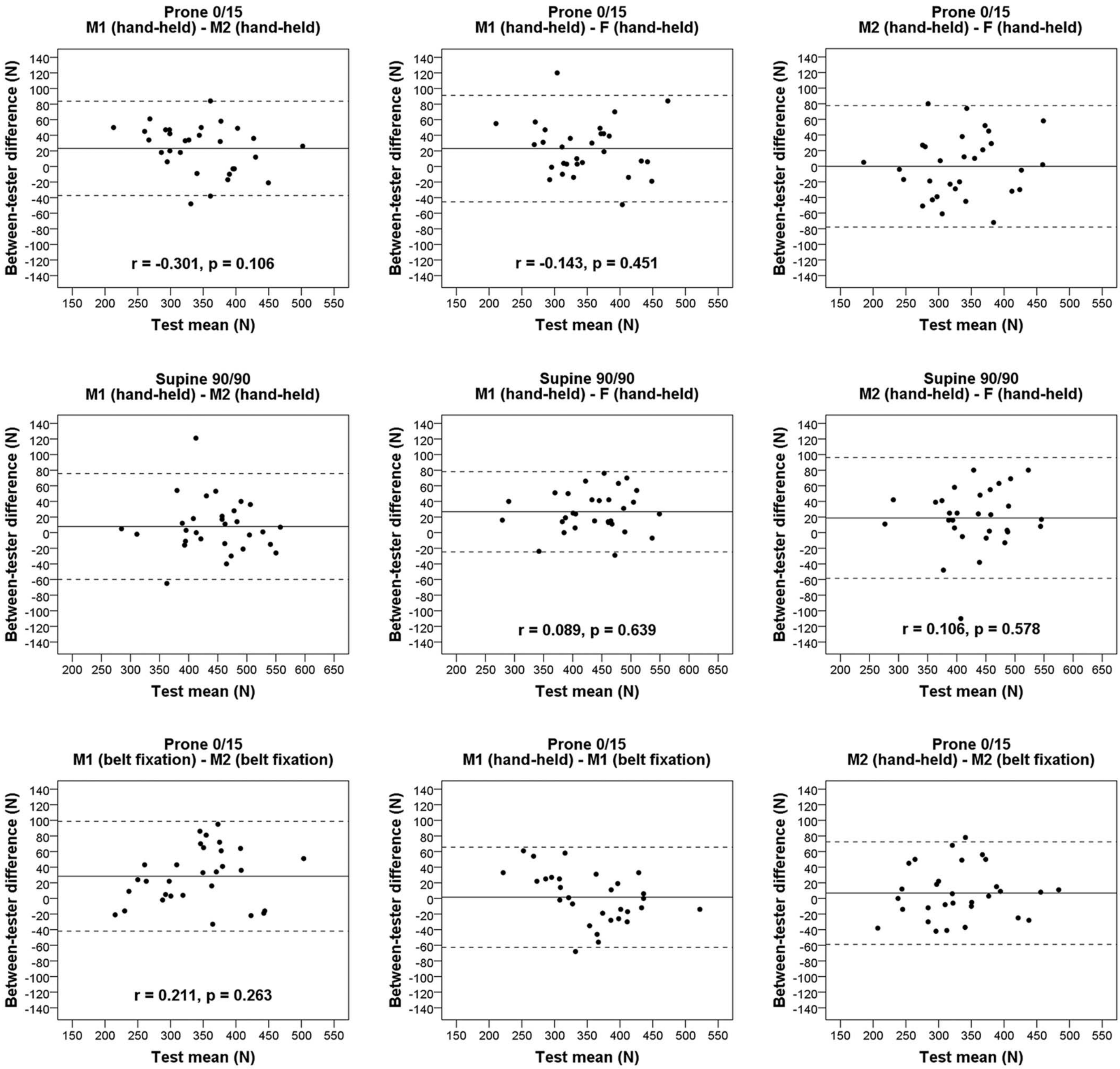

Figure 2. Bland–Altman plots demonstrating between-tester differences and their relation with knee flexor strength for both testing positions (hip flexion/knee flexion). For pairwise comparisons with systematic error according to paired *t*-tests, Pearson correlation tests demonstrated no statistically significant correlation between knee flexor strength and between-tester difference.

Systematic Error Between Methods of Dynamometer Fixation

There was no statistically significant difference in isometric knee flexor strength in prone 0/15 degrees between manual and external belt fixation of the dynamometer (M1: P = 0.799, M2: P = 0.275).

DISCUSSION

The most important finding was that isometric knee flexor strength measurements (prone 0/15 degrees and supine 90/90 degrees) are intertester reliable in strong high-level rugby players despite differences in physical capacity of testers. There is no added value of external belt fixation of the dynamometer for reliable isometric knee flexor strength measurements.

Participants in our study averaged notably higher isometric knee flexor strength than in most studies that included noninjured participants and/or sides.[5,7,11,16,17,21–23] The comparison with previous studies is limited by the differences in testing positions and study populations. Absolute and relative intertester reliability of hand-held isometric knee flexor strength assessment correspond reasonably well with other studies using similar testing positions.[5,7] Using HHD, Reurink et al[5] reported an ICC of 0.73 and an MDC of 26% (prone 0/15 degrees), and Whiteley et al[7] reported ICCs of 0.89 to 0.90 with MDC%s of 19% to 20% (mid range and outer range). Thorborg et al[16] used external belt fixation of the dynamometer and reported an ICC of 0.84 and an MDC% of 25% (prone 0/0 degrees). Hickey et al[21] used a construction involving a metal frame for external belt fixation of the dynamometer and reported ICCs of 0.90 to 0.91 and an MDC of 61 to 63 N (supine 90/90 degrees, dominant and nondominant leg). Our results fall in between those studies with ICCs of 0.83 to 0.84 and MDC%s of 17% to 22%.

Minimal Detectable Change

The MDC (as a percentage of the mean recorded strength value) in the current study is relatively high, ranging from approximately 17% to 22%. Minimal detectable change is the minimal intertester difference that falls outside measurement error. A difference between testers that is larger than the MDC is considered a real difference in isometric knee flexor strength. In clinical practice, this does not pose a problem in a setting where larger changes in strength can be expected over time, for example, during the course of a postoperative rehabilitation. When smaller differences are anticipated, however, this translates into a difficulty in distinguishing between measurement error and actual change between measurements. The MDC values in the current study correspond well with those reported in studies with weaker participants.[5,7,16] Relatively high MDCs are therefore not directly attributable to a mismatch between physical capacity of the tester and tested individual.

Mechanical Advantage Instead of External Belt Fixation

Our testing positions offer sufficient mechanical advantage for testers to reliably test strong individuals with testers of different physical capacity and without external belt fixation of the dynamometer. There are several arguments to support this claim. First, good reliability was found for all pairwise comparisons with testers of different physical capacity. Second, any systematic error that was identified between different testers was not significantly correlated with magnitude of knee flexor strength, arguing against tester's physical capacity (ie, upper-body strength) as a causative factor. Differences in upper-body strength between testers as potential explanation for systematic error would result in increasing between-tester differences with increasing knee flexor strength. This was not the case in this study. Although systematic error between testers in our study should not be ignored, it should not be attributed to differences in physical capacity between testers. Potential other causes could be minor differences in technique or (leg) positioning, verbal encouragement, and even tester's physical appearance. Third, hand-held testing did not result in significantly lower isometric knee flexor strength than with external belt fixation of the dynamometer. Belt fixation of the dynamometer has been reported to result in high intertester reliability[16,21] and could theoretically improve intertester reliability by taking the tester's strength out of the equation. Based on our data, this is not the case for the prone 0/15 degrees measurement. While this may seem counterintuitive, belt fixation may be associated with its own limitations. It can be challenging to line up the dynamometer exactly in the direction of the force applied by the participant, thereby potentially influencing measurement results.

Strengths and Limitations

Strengths of this study include quantification of testers' physical capacity, high knee flexor strength within our study population, close resemblance to clinical practice, and randomization of tester order and testing position. As in clinical practice, no rest periods between efforts were included, testers were of different physical capacity, and all measurements used in this study are easily applicable in clinical practice.

This study has one main limitation. Ideally, this study would have included belt fixation of the HHD in the supine 90/90 degrees position. Then, a conclusion regarding validity of the manually fixated measurement in strong individuals could be drawn, as with the prone 0/15 degrees position. This comparison was not included for 2 reasons. First, this study aimed to evaluate reliability of measurements used in our daily clinical practice in strong individuals. Belt fixation for this position would require a construction hanging above the tested leg,[21] thereby compromising the advantages of HHD and limiting clinical applicability. Second, as the number of maximum contractions would significantly increase with an additional testing position, the number of repetitions was kept to a necessary minimum to minimize a potential fatigue effect. Adding significant rest periods between efforts would mean deviating from our clinical practice and thereby limit the external validity of any conclusions drawn. Participants and testers were not blinded, which could have introduced bias.

Implications for Clinical Practice

Intertester reliability of hand-held isometric knee flexor strength dynamometry in strong athletes is good, independent of testers' physical capacity. In a setting where larger changes in strength can be expected over time, different testers with different upper-body strength may perform the measurements. For the prone 0/15 degrees position, belt fixation of the dynamometer is not required.

CONCLUSIONS

In strong high-level rugby players, isometric knee flexor strength measurements in prone 0/15 degrees and supine 90/90 degrees position are intertester reliable, regardless of testers' physical capacity and regardless of method of dynamometer fixation.

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