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ORIGINAL RESEARCH REPORT

Validity and Reliability of the Kinvent Handheld Dynamometer in the Athletic Shoulder Test

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Context: Long-lever shoulder strength tests may aid clinical decision-making regarding return to sport after a shoulder injury. The Athletic Shoulder Test (AST) was developed to measure force production in 3 positions of shoulder abduction (90°, 135°, and 180°) using force plates. However, handheld dynamometers (HHDs) are more portable, affordable, and may provide valid and reliable results which would increase the clinical utility of long-lever tests. HHDs vary in shape, design, and their capacity to report parameters such as rate of force production and require further investigation. The aim of this study was to examine the intrarater reliability of the Kinvent HHD and assess its validity against Kinvent force plates in the AST. Peak force (in kilograms), torque (in Newton meters), and normalized torque (in Newton meters per kilogram) were reported. ***Design:*** Validity and reliability study. ***Methods:*** Twenty-seven participants with no history of upper limb injury performed the test in a randomized order using the Kinvent HHD and force plates. Each condition was assessed 3 times, and peak force was recorded. Arm length was measured to calculate peak torque. Normalized peak torque was calculated by dividing torque by bodyweight (in kilograms). ***Results:*** The Kinvent HHD is reliable when measuring force (intraclass correlation coefficient [ICC] $\geq$ .80), torque (ICC $\geq$ .84), and normalized torque (ICC $\geq$ .64) during the AST. The Kinvent HHD is also valid when compared with the Kinvent force plates for force (ICC $\geq$ .79; $r \geq .82$), torque (ICC $\geq$ .82; $r \geq .76$), and normalized torque (ICC $\geq$ .71; $r \geq .61$). There were no statistically significant differences across the 3 trials on analyses of variance ($P > .05$). ***Conclusions:*** The Kinvent HHD is a reliable tool when used to measure force, torque, and normalized torque in the AST. Furthermore, given the lack of significant difference between trials, clinicians can use one test to accurately report relative peak force/torque/normalized torque rather than average 3 separate trials. Finally, the Kinvent HHD is valid when compared with Kinvent force plates.

Keywords: strength assessment, torque, force, return to sport

Key Points

- The Kinvent handheld dynamometer is a reliable and valid measure of the Athletic Shoulder Test.
- Force, torque, and normalized torque measures with the handheld dynamometer are reliable measures of the Athletic Shoulder Test.

Shoulder strength testing is an important contribution to objectively inform clinical decisions when returning an athlete to sport after a shoulder injury.[1] In the assessment of shoulder muscle strength, objective measurement of peak force and torque production can be used in shoulder positions relevant to a sport or activity to compare with normative data or the contralateral limb. Peak force values have been shown to be positively correlated with sport performance, injury reduction, quality of life, daily activities, and are important functional objective outcomes.[1–3] In addition, decreased muscle strength is related to an impaired ability to perform tasks independently at home and in the community, and may predict a future decline in these abilities.[2]

Peak torque describes the force moment and is defined as peak force multiplied by lever arm (in Newton meters).[4] Normalized peak torque is calculated by multiplying peak force by upper limb length, divided by body weight (in Newton meters per kilogram), and is important to consider when comparing shoulder strength across individuals of different body mass and sports.[4] The momentum created around the shoulder will vary between athletes of different body mass, arm length, and strength. This may subject the shoulder to different forces and injury risk.

Force plates and isokinetic dynamometry are reliable and valid tools to measure shoulder force production, but they lack clinical utility due to time, space, and expense constraints.[5–7] Handheld dynamometers (HHDs) are readily available to clinicians, are portable, and affordable.[6–8] When compared with isokinetic dynamometry, the HHD is a valid and reliable tool, with the ability to detect small (1%–3% for minimal detectable change [MDC%]) but clinically relevant changes in force production.[2,5,9] The Kforce muscle controller, (Kinvent) a new HHD, also has the potential to measure and report rate of force development, a

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relevant performance measure that will inform how quickly the athlete can produce force.[10]

Athletes participating in sports such as rugby or swimming require force generation around the shoulder in long-lever positions, and the incidence of shoulder injury in these sports is high.[6,11,12] The Athletic Shoulder Test (AST) is a reliable long-lever force production test performed isometrically in 3 positions of shoulder abduction (90°, 135°, and 180°).[6] More recently, lower cost alternatives, including the Activ Force 5 (Activbody Inc) dynamometer and sphygmomanometer, were used to perform the same AST, with high reliability and validity.[7,13] Although there is early support for valid use of a HHD in the AST, there is a lack of data to validate the use of the Kforce HHD (Kinvent).

Therefore, the purpose of this study was to (1) assess Kinvent HHD intrarater reliability over the course of 3 trials of the AST, (2) establish the validity of the Kinvent HHD during the AST compared with force plates, and (3) investigate any differences over 3 repetitions of the AST. Force, torque, and normalized torque measurements were recorded.

Methods

Study Design

This paper examines the concurrent validity of the Kinvent HHD in the AST with the Kinvent force plates as the gold standard. Ethical consent was provided by Auckland University of Technology.

Participants

Participants responded to social media posts, advertisements, and verbal invitations from the research team. The inclusion criteria for this study were adults aged between 18 and 55 years of age. Participants were excluded if they had any shoulder pain, or any other neurological or musculoskeletal condition of the upper limb. Individuals who were unable to provide written consent for any other reason (including not fluent in English) were also excluded.

Procedures

Participants' demographics including age, height, arm length, and weight were recorded. Participants were then randomized using an Excel spreadsheet to perform the AST using the dominant/nondominant hand and the Kinvent HHD or force plates. Participants then performed the AST in prone in the I, Y, and T positions without a familiarization test. Familiarization was excluded in order to more closely replicate clinical practice. Furthermore, given the time constraints of clinical practice, we investigated the differences between repeated measures of the I, Y, and T tests. Because of the preprogrammed nature of the application when performing the AST with the force plates, participants performed the I, Y, and T with one hand and then repeated with the other. They repeated this 3 times with 2-minute rest between tasks. Participants performed the I, Y, and T tests with the Kinvent HHD, with randomized dominant/nondominant hands. As with the force plate testing, participants rested for 2 minutes between each test to ensure there was no fatigue.

The Kinvent Muscle Controller is a HHD that measures force up to 90 kg. It transmits wireless to a mobile phone application (KForce) and has a transmission range of 20 m. It weighs 100 g, and a data acquisition frequency at 75 Hz and dimensions of 60 mm × 140 mm × 80 mm.

The Kinvent force plates are 2 force plates with a maximum force of 300 kg each plate. The acquisition frequency is also 75 Hz, wireless transmission range of up to 20 m, and dimensions are 330 mm (L) × 175 mm (W) × 30 mm (H).

Statistical Analysis

Peak force was recorded for each test, then peak torque (force [in Newtons] × arm length [in meters]), and normalized peak torque (force [in Newtons] × arm length [in meters]/body weight [in kilograms]) was calculated for each result.

Data analyses were performed in R (version 4.0.4) and RStudio (version 1.2.1335). Validity and intrarater reliability were examined using intraclass correlation coefficients (ICC) and 95% confidence intervals (95% CIs; ICC2,3). Measurement error and responsiveness of the tests were determined by calculating the standard error of the measurement (SEM) and MDC95 (MDC95: $1.96 \times \sqrt{2} \times \text{SEM}$) with a 95% CI.[14] Concurrent validity between the Kinvent HHD and the force plates was assessed through Pearson r correlations. The differences between the 3 trials were examined using repeated measures analysis of variance. Bonferroni significance correction was utilized to assessed between trial effects whether a main time effect was identified through analysis of variance. Shapiro–Wilk test was utilized to assess data normality. Data were also screened for sphericity. In case of nonnormally distributed data, $\log_{10}$ transformations were completed prior to statistical analyses.

An a priori sample size calculation was performed to determine the number of participants required to show an excellent reliability (ICC = .95) of the Kinvent HHD over the course of 3 measurements. This ICC estimate was based on previous papers[6,13] which utilized digital dynamometers for the AST. The minimum threshold (null hypothesis) for the ICC was set to .80 for a 2-tailed test with an alpha level of .05 and 80% power.[15] The calculations were performed in R (version 4.0.4) and RStudio version (1.2.1335) using the "ICC.Sample. Size" library. With these parameters, the sample size calculated was 12 participants.

Results

Data were collected from 27 participants, 17 of whom were female. The demographics of the participants are reported in Table 1.

Reliability of the AST

The AST test was assessed using both the Kinvent HHD and force plate for the dominant and nondominant side. Reliability of the force values was assessed across 3 trials for each condition and reported in Table 2. Torque and normalized torque reliability were also calculated and reported in Tables 3 and 4, respectively.

Concurrent Validity

The concurrent validity of the HHD against force plate was assessed through Pearson correlation and ICCs (Table 5). The 2 devices were highly correlated across all 3 test positions (I, Y, and T) for the force (in kilograms; $r \geq .82$), torque (in Newton meters; $r \geq .76$), and normalized torque (in Newton meters per kilogram; $r \geq .61$) measurements (see Appendix A). There was moderate to excellent absolute agreement between the HHD and force plate for the force (in kilograms) and torque (in Newton meters) measurements (95% CI ranging from 0.56 to 0.97; see Table 5). There was a wide range in absolute agreement between the HHD and force plate for the normalized torque (in Newton meters per kilogram) measurement (95% CI ranging from 0.39 to 0.95; see Table 5).

Table 1 Demographic Data for the Participants Included

Category	All participants (mean [SD])
Age, y	37 (12)
Height, m	1.7 (0.1)
Weight, kg	72.7 (13.8)
BMI, kg/m^2	25 (3.7)
Arm length, m	0.56 (0.05)
Sex, n (%)	
Male	10 (37)
Female	17 (63)
Dominant hand, n (%)	
Right	25 (93)
Left	2 (7)
Work status, n (%)	
Full time	24 (89)
Part time	3 (11)
Work load, n (%)	
Sedentary	6 (22)
Light	4 (15)
Medium	14 (52)
Heavy	2 (7)
Very heavy	1 (4)

Note: n, number of participants.

Repeated Measures

The AST results were not significantly different across trials using the Kinvent HDD or the Kinvent force plates for the 3 different positions (see Appendix B).

Discussion

Our study shows that the Kinvent HHD is a valid and reliable tool when measuring the force and torque production of the AST in I, T, and Y positions. Lower levels of absolute agreement were reported for normalized torque (Table 5). In addition, our data show that clinicians can perform one test rather than average the results of 3 trials without familiarization in a healthy population. While all studies report the force values for the AST, few studies report torque (in Newton meters)[16] and there is no previous publication of normalized torque. Reporting normalized torque is important because body mass and arm length will be different among athletes.

Other studies have shown good to excellent reliability using a HHD performing the AST.[13,16] Królikowska et al[13] examined the reliability of the AST using the Active 5 and reported good to excellent reliability (ICC = .77–.99). Tooth et al[16] have also examined the reliability of the AST using a HHD, this time utilizing a microFET HHD (MicroFet2; Hoggan Health Industries). These authors reported ICC values between .642 and .923 indicating good to excellent reliability.

Studies have also shown that the use of the HHD is a valid measure of the long-lever AST.[13,16] Królikowska et al[13] reported the Active 5 HHD to be a valid tool in the AST, with Pearson *r* values of between .840 and .875 in females, and .743 and .865 in males. The microFET HHD has also been reported as a valid tool in measuring long-lever forces of the AST with ICC values above .9 for almost all positions.[16] The use of a sphygmomanometer has also been validated and proposed as an alternative to the force plates. In a population of 20 rugby players, the sphygmomanometer was correlated with the force plates, with *r* values between .76 (T) and .81 (Y). However, the use of the HHD may be preferable to a

Table 2 Reliability of the AST Across 3 Trials of Force (in Kilograms)

	Trial 1	Trial 2	Trial 3	Average (SD)	ICC (95% CI)	SEM	MDC95
Dominant							
HHD I	9.9 (3.5)	9.8 (3.3)	9.9 (3.4)	9.9 (3.3)	.93 (.88–.97)	0.9	2.49
HHD Y	8.8 (2.8)	8.9 (3.0)	8.8 (2.9)	8.8 (2.9)	.94 (.89–.97)	0.72	1.99
HHD T	8.0 (2.7)	8.1 (2.9)	8.1 (2.6)	8.1 (2.7)	.95 (.91–.98)	0.62	1.71
Force plate I	10.7 (4.3)	10.6 (4.0)	10.4 (4.0)	10.6 (4.0)	.95 (.9–.97)	0.91	2.53
Force plate Y	8.7 (2.4)	8.8 (2.4)	8.8 (2.8)	8.8 (2.5)	.92 (.86–.96)	0.72	2.01
Force plate T	7.6 (2.4)	7.9 (2.5)	8.1 (2.7)	7.8 (2.5)	.91 (.84–.96)	0.76	2.11
Nondominant							
HHD I	9.8 (3.5)	9.3 (3.2)	9.4 (3.2)	9.5 (3.2)	.93 (.86–.96)	0.87	2.42
HHD Y	8.7 (2.7)	8.6 (3.1)	8.9 (3.5)	8.8 (2.9)	.80 (.66–.89)	1.4	3.87
HHD T	7.8 (2.3)	7.7 (2.6)	7.9 (2.6)	7.7 (2.4)	.93 (.88–.97)	0.66	1.83
Force plate I	10.3 (3.6)	10.5 (4.2)	10.4 (3.8)	10.4 (3.7)	.92 (.86–.96)	1.09	3.02
Force plate Y	8.7 (2.9)	8.9 (3.1)	8.9 (2.9)	8.9 (2.9)	.95 (.91–.98)	0.66	1.84
Force plate T	7.7 (2.1)	8.0 (2.7)	8.0 (2.4)	7.9 (2.4)	.92 (.86–.96)	0.69	1.9

Abbreviations: AST, Athletic Shoulder Test; CI, confidence interval; HHD, handheld dynamometer; ICC, intraclass correlation coefficient; MDC, minimal detectable change; SEM, standard error of measurement.

Table 3 Reliability of the AST Across 3 Trials of Torque (in Newton Meters)

	Trial 1	Trial 2	Trial 3	Average (SD)	ICC (95% CI)	SEM	MDC95
Dominant							
HHD I	55.16 (21.92)	53.3 (21.17)	54.56 (22.08)	54.56 (22.08)	.95 (.90–.98)	4.86	13.47
HHD Y	48.28 (17.41)	48.98 (19.33)	48.67 (18.38)	48.67 (18.38)	.96 (.92–.98)	3.68	10.19
HHD T	43.92 (16.8)	44.47 (18.39)	44.42 (16.06)	44.42 (16.06)	.96 (.92–.98)	3.42	9.49
Force plate I	58.19 (26.43)	57.94 (25.84)	57.72 (25.79)	57.72 (25.79)	.96 (.93–.98)	5.20	14.43
Force plate Y	47.24 (15.69)	47.88 (15.73)	48.6 (18.37)	48.6 (18.37)	.94 (.89–.97)	4.08	11.30
Force plate T	41.15 (15.01)	43.31 (15.63)	44.58 (17.18)	44.58 (17.18)	.92 (.85–.96)	4.53	12.57
Nondominant							
HHD I	53.57 (23.2)	50.8 (22.3)	50.66 (20.2)	50.66 (20.2)	.95 (.91–.98)	4.90	13.59
HHD Y	47.27 (18.4)	47.24 (20.1)	49.41 (21.8)	49.41 (21.8)	.84 (.72–.92)	8.06	22.35
HHD T	42.3 (14.8)	41.34 (16.9)	43.71 (17)	43.71 (17)	.94 (.89–.97)	3.93	10.89
Force plate I	56.15 (24)	57.85 (29)	57.67 (26.7)	57.67 (26.7)	.95 (.91–.98)	5.96	16.52
Force plate Y	47.32 (19.6)	49.24 (20.2)	48.53 (18.3)	48.53 (18.3)	.96 (.93–.98)	3.87	10.74
Force plate T	41.37 (13.1)	43.62 (15.1)	43.42 (15.1)	43.42 (15.1)	.93 (.87–.97)	3.95	10.94

Abbreviations: AST, Athletic Shoulder Test; CI, confidence interval; HHD, handheld dynamometer; ICC, intraclass correlation coefficient; MDC, minimal detectable change; SEM, standard error of measurement.

Table 4 Reliability of the AST Across 3 Trials of Normalized Torque (in Newton Meters per Kilogram)

	Trial 1	Trial 2	Trial 3	Average (SD)	ICC (95% CI)	SEM	MDC95
Dominant							
HHD I	0.74 (0.21)	0.72 (0.22)	0.73 (0.21)	0.73 (0.21)	.92 (.85–.96)	0.06	0.17
HHD Y	0.65 (0.16)	0.66 (0.19)	0.66 (0.17)	0.66 (0.17)	.92 (.85–.96)	0.05	0.14
HHD T	0.6 (0.17)	0.6 (0.18)	0.61 (0.16)	0.61 (0.16)	.94 (.89–.97)	0.04	0.12
Force plate I	0.78 (0.25)	0.78 (0.25)	0.77 (0.25)	0.77 (0.25)	.93 (.86–.97)	0.07	0.18
Force plate Y	0.64 (0.16)	0.65 (0.16)	0.66 (0.18)	0.66 (0.18)	.90 (.81–.95)	0.05	0.15
Force plate T	0.56 (0.15)	0.59 (0.16)	0.6 (0.19)	0.6 (0.19)	.88 (.77–.94)	0.06	0.16
Nondominant							
HHD I	0.72 (0.22)	0.68 (0.2)	0.68 (0.19)	0.68 (0.19)	.90 (.82–.95)	0.06	0.18
HHD Y	0.64 (0.15)	0.63 (0.18)	0.67 (0.28)	0.67 (0.28)	.64 (.43–.81)	0.13	0.35
HHD T	0.57 (0.13)	0.56 (0.15)	0.59 (0.16)	0.59 (0.16)	.89 (.80–.95)	0.05	0.14
Force plate I	0.76 (0.24)	0.77 (0.28)	0.77 (0.25)	0.77 (0.25)	.92 (.85–.96)	0.07	0.20
Force plate Y	0.64 (0.18)	0.66 (0.19)	0.66 (0.18)	0.66 (0.18)	.92 (.85–.96)	0.05	0.14
Force plate T	0.56 (0.12)	0.59 (0.18)	0.59 (0.15)	0.59 (0.15)	.88 (.78–.94)	0.05	0.15

Abbreviations: AST, Athletic Shoulder Test; CI, confidence interval; HHD, handheld dynamometer; ICC, intraclass correlation coefficient; MDC, minimal detectable change; SEM, standard error of measurement.

sphygmomanometer, as the reliability of the sphygmomanometer has not been reported.

Previous papers have reported that familiarization is required to obtain reliable/valid results with this test.[6,13] However, their maximum change between repeated measures is below our MDC95 suggesting that the difference may not be clinically relevant despite being statistically significant.[6] In contrast to the findings of Tooth et al[16] (who also did not perform a familiarization), our study shows that is not essential to familiarize people prior to testing. We did not undertake familiarization prior to testing, and there was no significant difference between the repeated measures of all positions across the 3 trials ($P > .05$, see Appendix B). This is of particular relevance to those working in a clinical setting who are required to deliver objective measures within significant time constraints. In addition, due to small levels of variation within trials, clinicians could use only one trial to reliably measure force, and calculate torque, and normalized torque.

Normalized torque incorporates the body mass and lever arm length of the participant to allow more accurate comparison between subjects.[4] This may be of particular relevance in situations when forward propulsion of the athlete's body while the distal limb is fixed/trapped/tackled and may create injury. This may be of interest to clinicians working in contact/collision sports, where the force of impact is influenced by body weight. In other sports such as swimming, long-lever tests measure force production in a position which replicates the arm entry propulsion phase of the swim stroke.[17] Normalized AST torque may be relevant in other sports such as tennis, volleyball, handball, and cricket (bowlers); but further research is required in these populations. For within-person analysis, clinicians are advised to use absolute values

Table 5 Force (in Kilograms), Torque (in Newton Meters), and Normalized Torque (in Newton Meters per Kilogram) ICCs of the AST With 95% CI Between HHD and Force Plate for Dominant and Nondominant Hand in the I, Y, and T Positions

	Trial 1	Trial 2	Trial 3
Force, kg			
Dominant			
I	0.86 (0.72–0.94)	0.81 (0.62–0.91)	0.86 (0.72–0.93)
Y	0.87 (0.73–0.94)	0.89 (0.78–0.95)	0.91 (0.81–0.96)
T	0.87 (0.74–0.94)	0.93 (0.84–0.97)	0.89 (0.78–0.95)
Nondominant			
I	0.89 (0.78–0.95)	0.82 (0.55–0.92)	0.79 (0.56–0.90)
Y	0.92 (0.82–0.96)	0.92 (0.83–0.96)	0.82 (0.64–0.91)
T	0.84 (0.69–0.93)	0.84 (0.68–0.93)	0.90 (0.80–0.96)
Torque, N·m			
Dominant			
I	0.89 (0.76–0.95)	0.83 (0.64–0.92)	0.88 (0.75–0.95)
Y	0.89 (0.77–0.95)	0.91 (0.80–0.96)	0.92 (0.81–0.96)
T	0.89 (0.76–0.95)	0.93 (0.85–0.97)	0.89 (0.77–0.95)
Nondominant			
I	0.92 (0.82–0.96)	0.86 (0.64–0.94)	0.82 (0.57–0.92)
Y	0.94 (0.87–0.97)	0.93 (0.86–0.97)	0.85 (0.69–0.93)
T	0.87 (0.73–0.94)	0.87 (0.73–0.94)	0.92 (0.82–0.96)
Normalized torque, N·m/kg			
Dominant			
I	0.83 (0.65–0.92)	0.75 (0.51–0.89)	0.81 (0.62–0.91)
Y	0.79 (0.58–0.90)	0.86 (0.71–0.94)	0.84 (0.67–0.93)
T	0.83 (0.64–0.92)	0.89 (0.76–0.95)	0.83 (0.65–0.92)
Nondominant			
I	0.86 (0.71–0.94)	0.75 (0.43–0.89)	0.71 (0.39–0.87)
Y	0.85 (0.69–0.93)	0.86 (0.71–0.94)	0.75 (0.51–0.88)
T	0.74 (0.49–0.88)	0.75 (0.50–0.88)	0.87 (0.72–0.94)

Abbreviations: AST, Athletic Shoulder Test; CI, confidence interval; HHD, handheld dynamometer; ICC, intraclass correlation coefficient.

because of greater sensitivity to change. For comparison of athletes within a particular sport, normalization is required to take into account variation in body mass. Further analysis of the predictive ability of normalized torque (as well as torque and force) is urgently needed.

While arm length was reported in this study, previous studies have reported force rather than torque. A possible limitation of the AST and the previously published research is that it may be influenced by the length of the lever arm, and this has not been accounted for. Furthermore, while the AST has been correlated with quality of life,[18] it has not been shown to be predictive of injury. Clinicians should be aware of these limitations when they are educating patients regarding the clinical relevance of this test. In addition, we assessed the reliability of the I, Y, and T tests over the course of 3 trials rather than calculating an average. We believe that this is more representative of what is done in clinical practice due to time restrictions. Finally, we assessed the reliability within the same day and in an asymptomatic population.

A further limitation of this long-lever AST is that it is a planned response to an auditory cue. This does not accurately represent the sporting activity when the athlete's limb is often unexpectedly perturbated with minimal advanced preparation. Ball carriers have been shown to be at less risk of injury when the contact is expected compared with when the ball carrier was unaware (relative risk ratio = 0.14, [95% CI, 0.03–0.66], $P = .012$).[19] Thus, although the I, Y, and T positions of the AST may represent positions of shoulder injury in sport,[6] to contend that this test represents the motor programming and planning that athletes undertake when the arm is perturbated may be erroneous. In addition, the forces generated with the HHD and force plates are well below that generated in contact and collision.[20] Finally, there is limited research which has investigated the AST test and its applicability in noncontact sports.

With regard to this specific testing, the data presented in this study are that reported from the KForce app and not independently derived from the raw data. While this may lead to a margin of error, it was decided that clinicians will report the value from the app rather than analyze the raw data extracted for the device. Thus, it is more clinically applicable to report the data from the app, rather than calculate values from the raw data. Current limitations of the KForce app also include low levels of frequency transmitted to the app which prevent accurate calculation of rate of force data.[10]

Conclusions

The Kforce HHD can be used to reliably measure the AST in I, Y, and T positions and is a valid measure of force and torque in these positions. The role of torque and normalized torque in injury risk requires further investigation. Clinicians can use one test when using the KForce in an asymptomatic population (eg, preseason screening) as there is minimal variability across 3 tests.

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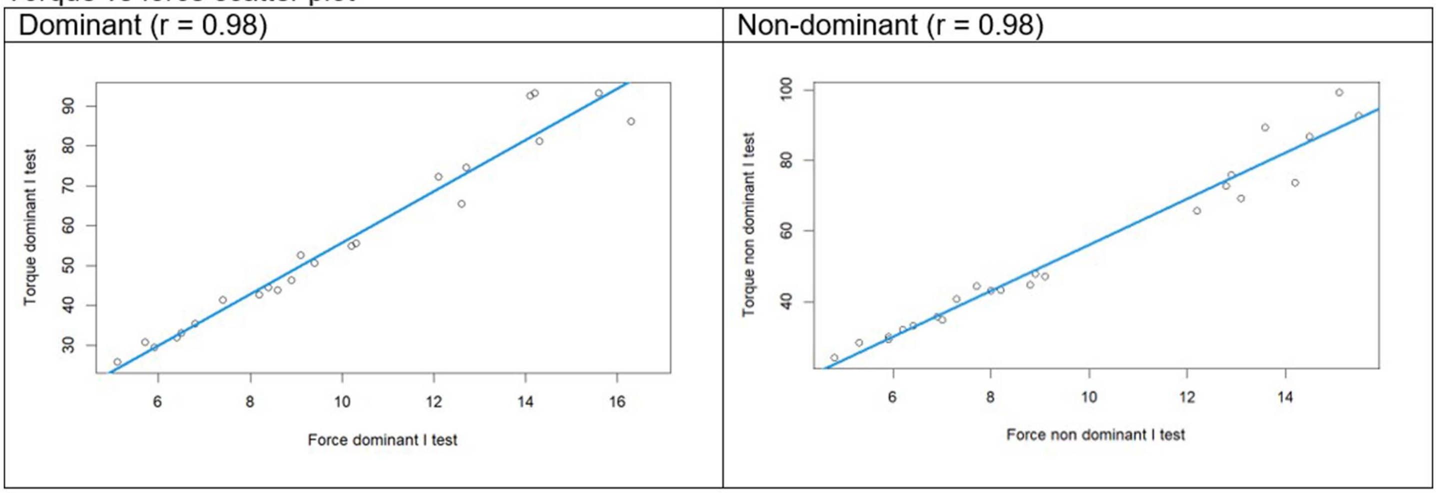
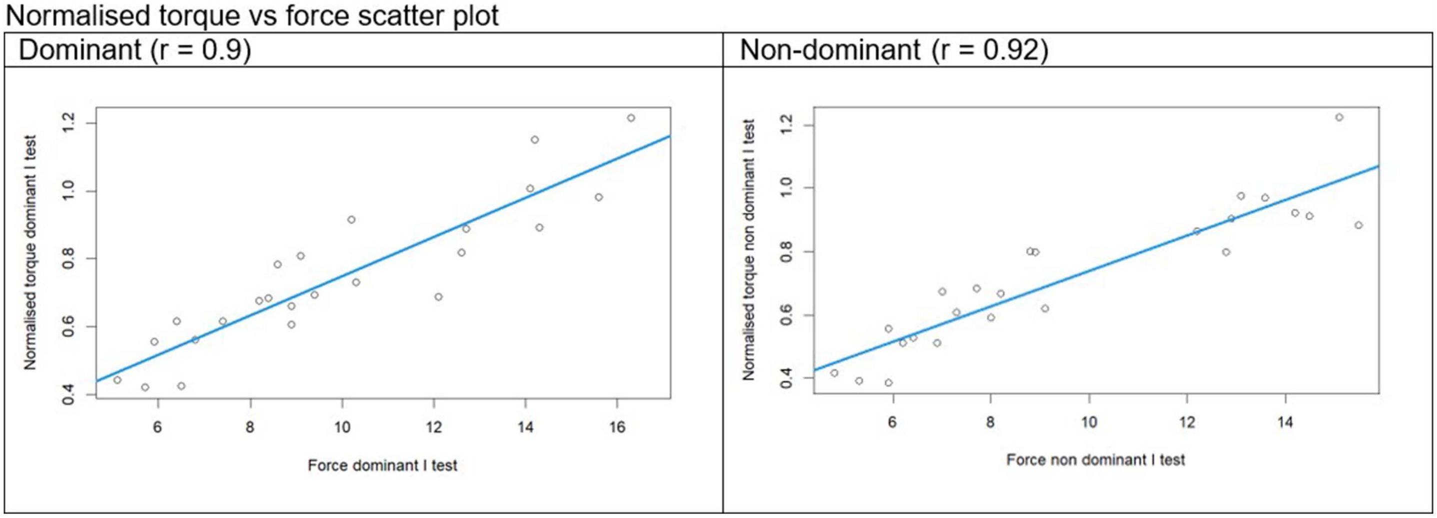
Appendix A: Correlations Between the HHD and Force Plates for Force, Torque, and Normalized Torque

Torque vs force scatter plot



Normalised torque vs force scatter plot



Appendix B

Table B1 Differences Between 3 Trials for the Force (in Kilograms) AST

	F statistics	*P*	Bonferroni corrected *P*	Generalized eta squared
ASTDominantHandHeldI	0.438	.648	7.776	.000678
ASTDominantHandHeldY	0.229	.796	9.552	.000364
ASTDominantHandHeldT	0.189	.829	9.948	.000227
ASTDominantForcePlateI	0.643	.53	6.36	.000771
ASTDominantForcePlateY	0.109	.897	10.764	.000197
ASTDominantForcePlateT	3.265	.046*	.552	.007
ASTNonDominantHandHeldI	2.732	.093	1.116	.004
ASTNonDominantHandHeldY	0.426	.596	7.152	.001
ASTNonDominantHandHeldT	0.773	.467	5.604	.001
ASTNonDominantForcePlateI	0.013	.987	11.844	.00003
ASTNonDominantForcePlateY	1.696	.193	2.316	.002
ASTNonDominantForcePlateT	2.057	.138	1.656	.003

Abbreviation: AST, Athletic Shoulder Test. Note: Bonferroni correction obtained by multiplying *P* value by the number of tests performed (n = 12).
*$P < .05$.

Table B2 Differences Between 3 Trials for the Torque (in Newton Meters) AST

	F statistics	*P*	Bonferroni corrected *P*	Generalized eta squared
ASTDominantHandHeldI	1.352	.269	3.228	.001
ASTDominantHandHeldY	0.034	.967	11.604	4.07E-05
ASTDominantHandHeldT	0.632	.536	6.432	.000668
ASTDominantForcePlateI	0.201	.818	9.816	.000205
ASTDominantForcePlateY	0.199	.821	9.852	.000272
ASTDominantForcePlateT	3.945	.027*	.324	.007
ASTNonDominantHandHeldI	2.912	.081	.972	.003
ASTNonDominantHandHeldY	0.679	.466	5.592	.002
ASTNonDominantHandHeldT	1.258	.294	3.528	.002
ASTNonDominantForcePlateI	0.04	.961	11.532	6.23E-05
ASTNonDominantForcePlateY	1.765	.183	2.196	.002
ASTNonDominantForcePlateT	1.938	.156	1.872	.002

Abbreviation: AST, Athletic Shoulder Test. Note: Bonferroni correction obtained by multiplying *P* value by the number of tests performed (n = 12).
*$P < .05$.

Table B3 Differences Between 3 Trials for the Normalized Torque (in Newton Meters per Kilogram) AST

	F statistics	*P*	Bonferroni corrected *P*	Generalized eta squared
ASTDominantHandHeldI	1.352	.269	3.228	.003
ASTDominantHandHeldY	0.034	.967	11.604	.00008
ASTDominantHandHeldT	0.632	.536	6.432	.001
ASTDominantForcePlateI	0.201	.818	9.816	.000373
ASTDominantForcePlateY	0.199	.821	9.852	.000508
ASTDominantForcePlateT	3.945	.027*	.324	.012
ASTNonDominantHandHeldI	2.912	.081	.972	.006
ASTNonDominantHandHeldY	0.679	.466	5.592	.003
ASTNonDominantHandHeldT	1.258	.294	3.528	.003
ASTNonDominantForcePlateI	0.04	.961	11.532	.0001
ASTNonDominantForcePlateY	1.765	.183	2.196	.004
ASTNonDominantForcePlateT	1.938	.156	1.872	.004

Abbreviation: AST, Athletic Shoulder Test. Note: Bonferroni correction obtained by multiplying *P* value by the number of tests performed (n = 12).
*$P < .05$.