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Criterion Validity and Reliability of a New Medicine Ball Rotational Power Test

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Abstract

Hardy, SGJ, Stelzer-Hiller, OW, Edwards, KM, and Freeston, J. Criterion validity and reliability of a new medicine ball rotational power test. *J Strength Cond Res* 39(3): e429–e435, 2025—This study assessed the validity and reliability of 2 medicine ball rotational power assessments, the novel push for maximum velocity by radar (MB_{vel}), and the commonly used push for maximum distance by tape measure (MB_{dis}), against the criterion reference 3-dimensional motion capture (MoCap) to identify the best-practice field-based assessment. Fifteen professional female cricketers volunteered for 2 testing sessions each comprising of a specific warm-up and 24 (12 MB_{vel}, 12 MB_{dis}) maximal throws of a 2-kilogram medicine ball. Radar velocity and tape measure distance were compared with MoCap velocity and projectile motion calculated distance overall, and by dominant and nondominant sides. Statistical analysis included intraclass correlations (ICCs) for accuracy (1, 1) and reliability (3,1), Bland-Altman plots for bias precision and limits of agreement, linear regression (R^2) for variance, and Pearson's (r) for correlation. Significance was set $\alpha = 0.05$. MB_{vel} demonstrated excellent accuracy (ICC = 0.97 [0.97–0.98]), and nearly perfect agreement for bias (−0.09%) and precision (1.49%). Side-to-side analysis showed the same profile for MB_{vel} dominant (ICC = 0.96 [0.95–0.97], bias −0.15%, precision = 1.55%) and nondominant sides (ICC = 0.97 [0.96–0.98], bias −0.05%, precision = 1.53%). MB_{vel} demonstrated excellent reliability overall (ICC = 0.94 [0.82–0.98]) for dominant (ICC = 0.88 [0.69–0.97]) and nondominant sides (ICC = 0.93 [0.80–0.98]). MB_{dis} showed poor accuracy (ICC = 0.38 [0.28–0.47]), large bias (12.43%), lower precision (4.55%), and moderate reliability (ICC = 0.72 [0.32–0.90]). The MB_{vel} assessment validly and reliably measures rotational power performance, enabling practitioners to profile, benchmark, and assess the quality in the field.

Key Words: velocity, field-based, athlete assessment, plyometrics, bat and club sports, velocity-based training

Introduction

Rotational power is associated with performance in a number of sports including baseball, cricket, European handball, golf, tennis, and water-polo (12,17,36,40). The physical quality plays an important role in underpinning multiple athletic tasks across sports including throwing (12,17) and performing bat, club, or racket shots (29,34,36,40). Strength and conditioning programs within these sports commonly use various methods to develop and enhance rotational power to drive athletic performance (5,8,25,27,28,34) including heavy lower and upper-body strength training, plyometric exercises, and medicine balls throws (11,31,34).

Medicine ball throws are the most widely studied method of developing rotational power in athletes across a variety of age groups and performance settings (1,5,8,34). There is strong evidence for both the efficacy of medicine ball throws for power training (1,5,8,34) and the ecological validity of completing high velocity multiplanar movements that are reflective of actions performed in a sport setting (8). For example, the medicine ball rotational throw exercise allows a cricket athlete to take a side-on athletic stance akin to their batting stance in match, hold a 1- or 2-kg medicine ball similar to their individual bat mass, complete a reactive counter-rotation, and explosively throw the ball using a comparable movement pattern with similar timing to the on-field execution of powerfully hitting a ball. Such is the versatility of medicine ball throws that strength and conditioning coaches across various sports use some version of a rotational medicine ball throw to target a variety of sporting actions including batting and overhead throwing in baseball (34,36), pace bowling in cricket (21), and ground stroke play in tennis (29). Given the popularity, efficacy, and effectiveness of medicine ball training for sport-specific movements, the ability to accurately assess medicine ball training would be highly advantageous for practitioners across environments.

The valid and reliable assessment of rotational power is critical to strength and conditioning practice among rotational athletes. Periodic assessment of this physical capacity allows practitioners to describe and benchmark individual and team performance, and evaluate the effectiveness of rotational power training programs. For practitioners seeking to use field-based assessments, the proxy measures of medicine ball throws for maximum distance by visual inspection (17,23,28,30,33,37) and throws for maximum velocity by radar device (12,34,36) are the dominant choices, followed by cable pulley rotations for power by linear position transducer (40) and external dynamometer (1). Although laboratory-based testing has the ability to quantify rotational power, research to date has centered on the motion capture and subsequent kinematic outcomes of athletes completing sporting movements rather than specifically designed rotational power assessments (22,26,34).

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Despite the seemingly broad array of available testing options, the current set of rotational power assessments are deficient in their ability to support elite sport performance. The field-based assessments use throw methods without criterion reference validity and reliability, spurious performance data, or protocols requiring seated or kneeling positions wholly unreflective of many sporting actions that practitioners are seeking to support. Laboratory-based testing yields highly accurate information but requires specialist equipment and a significant time cost, both of which are not feasible for practitioners in elite environments.

Given that rotational power is an important quality in many sports that practitioners regularly seek to enhance to drive athletic performance, there is a clear need to establish an accurate and reliable way to measure this capacity, to better support strength and conditioning programs through evidence-based practice. Therefore, the purpose of this study was to assess the validity and reliability of both a novel rotational power test the medicine ball push for maximum velocity (MB_{vel}) and the commonly used assessment the medicine ball push for distance (MB_{dis}) and identify the best-practice field-based measure to assess rotational power by proxy.

Methods

Experimental Approach to the Problem

This study was designed to assess the validity and reliability of 2 medicine ball rotational power tests MB_{vel} and MB_{dis}, which use proxy measures of velocity and distance, in comparison with the gold-standard criterion reference of three-dimensional motion capture (MoCap) (Vicon Vero; Vicon Motion Systems, Oxford, United Kingdom). A 2-kg medicine ball mass was chosen to reflect the average senior professional cricket bat mass of 1–2 kg in line with methods used in previous baseball research (35), and to be within the range of medicine ball masses previously used in similar rotational power assessments from 1 to 6 kg (17,28,35,36). Subjects volunteered from the senior women's New South Wales (NSW) state cricket team and attended 2 testing sessions separated by 1 week. No familiarization sessions were included because of the subjects' vast previous exposure to the MB_{vel} and MB_{dis} tests, respectively, with Cricket NSW using both assessments as part of a regular in-house performance testing battery across the past 2 seasons. Intra- and interday reliability were determined via the intraclass correlation (ICC), bias and precision were calculated using Bland-Altman plots, and the coefficient of variation (CV) and SEM were evaluated for both tests.

Subjects

Fifteen cricketers from the NSW professional senior women's state cricket team volunteered to participate in this study (mean ± *SD*: age 23.24 ± 3.76 years, height 169.9 ± 6.3 cm, body mass 71.4 ± 11.9 kg, training age 4.80 ± 3.95 years). All subjects were older than 18.0 years (range: 19.29–30.80 years) and were free from injury at the time of data collection. All subjects were professional athletes competing at a senior state or national level and regularly completed comprehensive physical preparation programming including strength and power training using medicine ball throw work twice per week. This study was approved by the University of Sydney Human Research Ethics Committee (Project Number 2022/466), and before providing informed consent, all subjects were presented with information regarding the study protocol, inclusion criteria (senior professional female cricketer, free from injury), and the benefits and risks of volunteering.

Procedures

Data collection occurred over 2 testing sessions separated by 7 days. During the first session, age, body mass, height, dominant batting hand, number of years played professionally, and highest professional level played were recorded for all subjects. Both sessions consisted of the same physical performance warm-up routine and the same volume of test repetitions on each side (left and right) for MB_{vel} and MB_{dis} conditions. Both sessions were conducted at the same time of day, and subjects were directed to continue with their normal nutrition and hydration schedule.

Each testing session began with subjects completing a specific prescribed warm-up routine consisting of dynamic stretching and mobility, general strength movements, and plyometrics (for details see Supplemental Digital Content 1, http://links.lww.com/JSCR/A554). Subjects then performed a rotational power assessment consisting of 24 total (12 MB_{vel} and 12 MB_{dis}) maximal effort throws of a 2-kg medicine ball. Throws were completed in sets of 6 per round comprising of 3 left-and right-sided efforts randomly ordered for each subject. Throws were conducted using a carousel queue where a subject completed 1 throw and then proceeded to rest, whereas the rest of the group completed a single effort each. This method ensured a rest time of 60–70 seconds between maximal effort throws inside each set in line with previous medicine ball throw research (17,33). In addition, subjects were allocated 3 minutes of rest after completing each set for a given condition as an additional safeguard against fatigue over the 24 maximal effort throws required in each session.

The condition for the first set of throws was randomly allocated as either MB_{vel} or MB_{dis}. The following 3 sets then alternated condition based on the first allocation (for example, set 1 = MB_{vel}, therefore, set 2 = MB_{dis}, set 3 = MB_{vel}, set 4 = MB_{dis}). The alternating condition design was used as an additional safeguard against fatigue to ensure that upon randomization neither protocol was allocated consecutively to sets 3 and 4.

For all testing throws across both conditions, subjects were instructed to follow the protocol below. A kinogram of the protocol is shown in Figure 1.

- Subject stands in side-on "athletic stance" with lateral edge of front shoe aligned with zero-point tape line on laboratory floor, rear arm the assigned pushing arm
- Subject holds medicine ball at shoulder height in contact with chest, uses front arm to support mass of ball from underneath, rear arm is cocked with hand placed on the back of ball
- Subject completes throw by rapidly counter-rotating away from throw direction in transverse plane with feet fixed on floor before immediately rotating back and explosively pushing ball forwards, completing any follow through movement of body and feet after ball release

Specific cues were given to subjects for each test type. For MB_{vel} trials, subjects were instructed to "explosively push the ball as fast and as hard as possible towards the radar gun." For MB_{dis} trials, subjects were instructed to "explosively push the ball as fast and as hard for the longest possible distance."

All trials used a three-dimensional 16-camera motion analysis system (Vicon Vantage; Vicon Motion Systems) to record subject hand and medicine ball kinematic data at a sampling rate of 240 Hz. Reflective markers were placed on both wrists and hands for all subjects at the ulnar and radial styloids and dorsally at the

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Figure 1. Kinogram displaying the medicine ball rotational power throw for velocity MB_{vel} assessment.

second and fifth metacarpophalangeal joints using a 4-marker hand model, and an additional fifth marker was placed on the back of the left hand to differentiate sides. Reflective markers were also placed on the medicine ball using a 5-marker model with 4 markers at an equal distance around the widest circumference of the ball and a fifth marker positioned at a location with a different surface distance to each of the 4 equally spaced markers. Marker trajectory data were filtered using a low-pass Butterworth filter with a cutoff frequency of 18 Hz and exported to Visual 3D (C-Motion, Inc., Germantown, MD) for analysis.

Center of gravity (CoG) models were created for the medicine ball and both hands. Position, velocity, and projection angle data for all trials were determined using the laboratory coordinate system and 2 events during each throw: point of release (P_{rel}) defined as the first frame at which the medicine ball and hand CoG models separated and increased distance apart, and point of release +5 frames ($P_{rel\ +\ 5}$) as the frame 5 additional frames forward in the trial. Height of release was calculated as the vertical distance from the laboratory floor to medicine ball CoG at P_{rel}. Horizontal (left and right) and vertical (up and down) projection angles were calculated via a 5-frame medicine ball CoG trajectory from P_{rel} to $P_{rel\ +\ 5}$. Maximum velocities in each of the x, y, and z (v_x, v_y, v_z) directions were calculated as the peak value of medicine ball CoG velocity averaged over 5 frames from P_{rel} to $P_{rel\ +\ 5}$. The maximum velocity for MB_{vel} trials was calculated as the resultant velocity of $v_x + v_y + v_z$. Throw distance for MB_{dis} trials was calculated as the horizontal distance from P_{rel} to first landing by projectile motion ignoring the effects of air resistance and spin as per similar work completed in shot put (16,20).

In addition, for comparison with field-based measurement techniques, MB_{vel} trials used a radar gun (Stalker ProIIs; Applied Concepts, Inc., Plano, TX) set to continuously transmit positioned 5 m directly in front of the subject's lead foot at a height of 1.5 m to measure the maximum velocity for each throw, and MB_{dis} trials used a tape measure with the zero line at the lateral edge of the lead foot and distance extending straight out along the laboratory floor with visual identification of the distance upon first landing for each throw. Power was not directly measured for either condition with velocity and distance used as proxy measures.

Statistical Analyses

All statistical analysis was completed using *R* (version 4.2.3; RStudio, Boston, MA). A total of 672 trials were completed during data collection. And 45 trials (6.7%) were omitted because of missing data (e.g., marker occlusion), resulting in 627 successful trials (316 MB_{dis} + 311 MB_{vel}) available for analysis. Data were first checked for normality using Shapiro-Wilk testing before the mean and *SD* for all outcome variables were calculated (Table 1). An ICC power analysis was conducted using a minimum acceptable reliability = 0.80, expected reliability = 0.90, $\alpha = 0.05$, and $\beta = 0.20$ and showed that a minimum of $n = 58$ throws per assessment type were required to reach statistical significance.

The CV and *SEM* were calculated for MoCap, radar velocity, and tape measure distance for all trials. Condition accuracy and reliability were determined via ICCs (1, 1) and (3,1), respectively, and interpreted as excellent >0.9, good 0.75–0.9, moderate 0.5–0.75, and poor <0.5 (19). Bias, precision, and upper and lower limits of agreement were established using Bland-Altman plots (3,13). Bias was calculated as the mean difference between MoCap and each condition, precision as the *SD* of the difference between MoCap and each condition. Variance and correlation between MoCap and each condition were calculated using linear regression (R^2) and Pearson's correlation (*r*). Pearson's *r* was interpreted as large 0.50–0.70, very large 0.70–0.90, and nearly perfect >0.90 (15). Data were then split into dominant and nondominant throws by classifying the assigned rear pushing arm according to each subjects' dominant batting hand before the analysis above was then repeated in full. Significance for all analyses was set a priori at $\alpha = 0.05$.

Results

The radar assessment method demonstrated excellent accuracy (ICC = 0.97 [0.97–0.98]) compared with MoCap, whereas the distance method showed poor accuracy (ICC = 0.38 [0.28–0.47]). MB_{vel} displayed nearly perfect agreement with MoCap for both bias (−0.09%) and precision (1.49%), whereas MB_{dis} yielded large bias (12.43%) and lower precision (4.55%). The relative variation and *SEM* were calculated to be CV = 4.19%, *SEM* = 0.08 $km{\cdot}h^{-1}$ for MB_{vel} and CV = 9.55%, *SEM* = 0.05 m for MB_{dis}. MB_{vel} demonstrated excellent between-session reliability compared with MoCap (ICC = 0.94 [0.82–0.98]), whereas MB_{dis} showed moderate reliability (ICC = 0.72 [0.32–0.90]). The side-to-side analysis of MB_{vel} throws follows the same profile as the overall MB_{vel} analysis above for both dominant (ICC = 0.96 [0.95–0.97], bias −0.15%, precision = 1.55%, CV = 2.32%, *SEM* = 0.07 $km{\cdot}h^{-1}$) and nondominant (ICC = 0.97 [0.96–0.98], bias −0.05%, precision = 1.53%, CV = 2.57%, *SEM* = 0.07 $km{\cdot}h^{-1}$) throws. Across multiple sessions, both dominant (ICC = 0.88 [0.69–0.97]) and nondominant (ICC = 0.93 [0.80–0.98]) MB_{vel} assessments have confirmed good to excellent reliability. The full set of results comparing MoCap to MB_{vel} and MB_{dis} conditions are shown in Table 2, and plots of the Bland-Altman analysis of bias and precision are shown in Figure 2.

Discussion

The purpose of this study was to assess the validity and reliability of 2 medicine ball rotational power assessments MB_{vel} and MB_{dis} with the aim of identifying an effective field-based test. The results

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Table 1

Descriptive statistics of mean ± *SD* for 3-dimensional motion capture (MoCap) outcome measures of resultant velocity, projected distance, horizontal projection angle, vertical projection angle, and height of release for all medicine ball velocity (MBvel) and medicine ball distance (MBdis) trials.

	Resultant velocity Mean ± *SD* ($km \cdot hr^{-1}$)	Projected distance Mean ± *SD* (m)	Horizontal projection angle (−ve = left of thrower, +ve = right of thrower) Mean ± *SD* (°)	Vertical projection angle (+ve = up, −ve = down) Mean ± *SD* (°)	Height of release Mean ± *SD* (m)
MB_{vel} (n = 311)	35.19 ± 2.20	—	0.56 ± 4.01	6.08 ± 3.21	1.52 ± 0.08
Dominant (n = 157)	36.14 ± 2.31	—	−1.44 ± 3.53	5.89 ± 3.17	1.51 ± 0.08
Nondominant (n = 154)	34.22 ± 2.09	—	2.60 ± 3.41	6.27 ± 3.26	1.53 ± 0.09
MB_{dis} (n = 316)	33.93 ±2.18	10.62 ± 1.23	1.82 ± 3.79	19.22 ± 4.14	1.74 ± 0.11
Dominant (n = 161)	34.97 ± 1.80	11.10 ± 1.06	0.74 ± 3.41	19.24 ± 4.04	1.73 ± 0.11
Nondominant (n = 155)	32.85 ± 2.03	10.13 ± 1.20	2.93 ± 3.86	19.20 ± 4.26	1.76 ± 0.11

clearly demonstrate that only MB_{vel} accurately measured rotational power (ICC = 0.97 [0.97–0.98]), and that MB_{dis} lacked the accuracy (ICC = 0.38 [0.28–0.47]) to be used in the field. The results further establish the MB_{vel} condition's efficacy, showing accurate assessment of both dominant (ICC = 0.96 [0.95–0.97]) and nondominant (ICC = 0.97 [0.96–0.98]) throws. When both conditions were assessed for reliability over multiple sessions (Table 2), MB_{vel} (ICC = 0.94 [0.82–0.98]) outperformed MB_{dis} (ICC = 0.72 [0.32–0.90]) and maintained good to excellent reliability for dominant (ICC = 0.88 [0.69–0.97]) and nondominant (ICC = 0.93 [0.80–0.98]) throws.

Bland-Altman analysis of both conditions (Figure 2) revealed a strong contrast in profiles of bias and precision. Across overall, dominant, and nondominant analyses, MB_{vel} repeatedly demonstrated nearly perfect agreement with MoCap for both bias (−0.05 to −0.15%) and precision (1.49–1.55%). Comparing MB_{vel} with common assessments in elite sport settings including countermovement jump height (39) (bias = −3.05%, precision = 8.52%) and back squat mean concentric bar velocity (10) (bias = −3.64%, precision = 2.05%), the level of error calculated is exceptionally low. It is noted that across all MB_{vel} trials, there was a small yet consistent overestimation by radar versus MoCap (Table 2). Given the already established global and multisport accuracy and reliability of radar technology (4,7,9,14,24,32), it is unlikely that the bias recorded here represents a true difference between measurement systems. Another potential explanation of the bias may be found in review of calculation differences between systems. Specifically, MoCap resultant velocity was calculated as the average peak velocity over 5 frames from P_{rel} to $P_{rel + 5}$, whereas radar recorded a maximum instantaneous velocity reached for the full duration of each trial at a collection frequency of 34.7 GHz. The use of instantaneous (absolute maximum) and 5-frame average (average peak maximum) velocities in this way provide a plausible explanation for the small bias identified.

The difference in results between MB_{vel} and MB_{dis} is significant given the widespread use of the MB_{dis} condition among strength and conditioning professionals (albeit using different throw techniques) both in research settings and across performance environments (8,17,23,27,28,30). This is the first study to evaluate the validity and reliability of distance-based medicine ball throws as a measure of rotational power. These findings call into question the accuracy of such approaches, with significant implications for strength and conditioning practitioners currently using this assessment method. The lack of criterion reference validity and reliability research and the recurrent use of distance-based throw assessments in publication have led practitioners to assume that distance-based assessments can accurately measure performance. In the context of the results shown for MB_{dis} above, this is not the case, and without known bias and precision, environments using throws for distance should interpret results with caution.

The superior performance of MB_{vel} compared with MB_{dis} can be broken down into 2 areas: (a) condition specific constraints and (b) the measurement systems. Condition specific constraints are best understood by an ecological dynamics approach (2,6,18), where the movement outcome (medicine ball throw) is a product of the interaction between constraints of the environment, task, and organism, and subsequent self-organization of the subject to execute the task. MB_{vel} and MB_{dis} contain 2 differences in constraints: the condition specific cue either to push as hard and as fast as possible (MB_{vel}) or for the longest distance possible (MB_{dis}), and the measurement equipment as either radar gun or tape measure line. The results in Table 1 demonstrate that these differences contribute to different performance results for each condition. During MB_{dis} trials, subjects were unable to optimize their throw trajectory for best possible distance, producing an overall vertical projection profile of 19.2 ± 4.1°, well below values identified in shot put, optimal angle 42°, and range of angles for elite throwers 26–41° (20). The inability of subjects to throw in the ideal range of trajectories significantly impacts the distance thrown and consequently the MB_{dis} condition's ability to measure true maximum rotational power. In addition, all types of MB_{dis} throws also displayed a comparatively lower MoCap mean peak resultant velocity versus MB_{vel} throws, despite both conditions being cued as maximum efforts and resultant velocity being summed in all 3 vector directions. A feasible explanation for these different results could be that the radar gun more effectively constrains subjects to throw maximally at a single target in space compared with the extended tape measure line as a target throwing plane. These findings demonstrate that subjects completing MB_{dis} throws were unable to optimize their task execution producing throws at lower resultant velocities with suboptimal projection angles. The MB_{dis} outcome measures of resultant velocity and distance, therefore, underrepresent true maximal rotational power expression and show that MB_{dis} is reliant on elements of skill in combination with power to meet task constraints. Conversely, MB_{vel} does not experience this same limitation and is better able to purely measure rotational power expression.

The measurement systems used to assess rotational power for each condition play a key role in contributing to the significantly different accuracy of radar (ICC = 0.97 [0.97–0.98]) and tape

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Table 2
Mean ± *SD* throw velocity for MB_{vel} and throw distance for MB_{dis} by three-dimensional motion capture (MoCap) and radar or tape measure.*

			ICC (1, 1)		Bland-Altman			ICC (3,1)			
			Accuracy radar		Bias	Precision	Linear regression	Reliability vs. MoCap		Reliability vs. radar	
Test type	MoCap Mean ± *SD* (km·h^{-1})	Radar Mean ± *SD* (km·h^{-1})	Mean (CI)	Classification	Mean diff, km·h^{-1} (%)	±*SD* of diff, km·h^{-1} (%)	R^2 (*r*)	Mean (CI)	Classification	Mean (CI)	Classification
MB_{vel}											
Overall	35.12 ± 1.47	35.15 ± 1.54	0.97	Excellent	−0.03 (−0.09%)	0.52 (1.49%)	0.95 (0.97)	0.93	Excellent	0.94	Excellent
n = 311	CV = 4.19, SEM = 0.08	CV = 4.38, *SEM* = 0.09	0.97–0.98		LoA: −1.06 to 1.00		*p* = 0.00	0.80–0.98		0.82–0.98	
Dominant hand	36.06 ± 0.83	36.10 ± 0.93	0.96	Excellent	−0.05 (−0.15%)	0.53 (1.55%)	0.92 (0.96)	0.90	Good	0.88	Good
n = 157	CV = 2.32, *SEM* = 0.07	CV = 2.59, *SEM* = 0.07	0.95–0.97		LoA: −1.09 to 0.99		*p* = 0.00	0.72–0.97		0.69–0.97	
Nondominant hand	34.14 ± 0.87	34.16 ± 0.98	0.97	Excellent	−0.02 (−0.05%)	0.52 (1.53%)	0.94 (0.97)	0.94	Excellent	0.93	Excellent
n = 154	CV = 2.57, *SEM* = 0.07	CV = 2.88, *SEM* = 0.08	0.96–0.98		LoA: −1.04 to 1.01		*p* = 0.00	0.81–0.98		0.80–0.98	
			ICC (1, 1)		Bland-Altman			ICC (3,1)			
	MoCap Mean ± *SD* (m)	Tape measure Mean ± *SD* (m)	Accuracy tape measure Mean (CI)	Classification	Bias Mean diff m (%)	Precision ±*SD* of diff m (%)	Linear regression R^2 (r)	Reliability vs. MoCap Mean (CI)	Classification	Reliability vs. tape measure Mean (CI)	Classification
MB_{dis}											
Overall	10.54 ± 1.00	9.24 ± 0.71	0.38	Poor	1.31 (12.43%)	0.48 (4.55%)	0.90 (0.95)	0.72	Moderate	0.72	Moderate
n = 316	CV = 9.55, *SEM* = 0.05	CV = 7.69, *SEM* = 0.04	0.28–0.47		LoA: 0.37–2.26		*p* = 0.00	0.32–0.90		0.32–0.90	

*Coefficient of variation (CV) and SEM for MoCap, radar, and tape measure. Assessment accuracy represented by intraclass correlation (ICC). Bias and precision shown by Bland-Altman measures of mean difference and *SD* of the difference between measures. Variance and correlation represented by linear regression (R^2 and Pearson's *r*). Assessment reliability represented by ICC.

measure (ICC = 0.38 [0.28–0.47]). The radar device records an instantaneous maximum velocity without reliance on practitioner input, whereas the tape measure system requires the expert eye of a practitioner to both identify point of landing and estimate distance thrown. The use of expert human eye presents a significant source of potential error given the range of horizontal and vertical projection angles and the subsequent variation in ball trajectories thrown by subjects. During MB_{dis} trials, practitioners are required to account for throws projected across a range of distances forward and multiple meters to the left or right of the central measurement line. During MB_{vel} trials, the radar device performs the equivalent of this task to deal with variation in projection for velocity throws. Although neither method can replicate the criterion measurement of resultant velocity from all 3 vectors with both constrained to the forward direction, the use of human eye for distance trials may explain the contribution of measurement systems to condition accuracy.

As previously mentioned, the ecological validity of physical performance assessments is an important consideration in elite sport environments. Practitioners aim to use assessments that are reflective of an athlete's sporting actions, as seen by the continued use of various medicine ball assessments despite limited or no validity and reliability research available. Practitioners are also often interested in assessing either side-to-side differences or dominant side performance for a given assessment, particularly in unilateral sports such as cricket, tennis, golf, baseball, and softball. This requires the given assessment to have suitable accuracy and reliability on both dominant and nondominant sides to meaningfully compare results and capably detect differences in performance. The MB_{vel} protocol addresses these requirements and provides the most comprehensive assessment of accuracy, bias, precision, and reliability available for rotational power assessments in the literature (Table 2). The MB_{vel} condition is also highly accurate on both sides, with each following the same bias and precision profile as the MB_{vel} overall statistics discussed above, and across multiple testing sessions, both have confirmed reliability to repeatedly assess rotational power (Table 2). In comparison, the alternate assessments currently available in the literature: seated cable rotation via external dynamometry (1) and kneeling cable lift via linear transducer (40) are unable to meet the demands of practitioners in performance settings described above. Both assessments lack ecological validity in their use of seated or kneeling positions and are nonrepresentative of rotational power-based sporting actions completed in standing. Both assessments demonstrate limited accuracy and reliability statistics, with neither using a criterion reference measure, seated cable rotation reporting ICC reliability (0.95–0.97) with no measure of accuracy, and the kneeling cable lift reporting CV (7.4–16.3%) and ICC reliability (0.74–0.94). Furthermore, neither assessment has demonstrated capability to measure side-to-side differences in performance. The MB_{vel} protocol represents a significant progression in the rotational power literature, and in supporting practitioners to accurately assess the capacity in the field.

The MB_{vel} assessment is a new tool for practitioners to use in environments where there is a requirement to measure, benchmark, or track change in rotational power performance. This study has built on the pilot work of various velocity-based throw protocols currently in the literature without validation (12,17,34,36) and is the first study that has successfully validated both the accuracy and reliability of a rotational medicine ball throw for velocity in comparison with the criterion reference of MoCap. This is also the first study specifically assessing rotational medicine ball throws in the transverse plane, with previous

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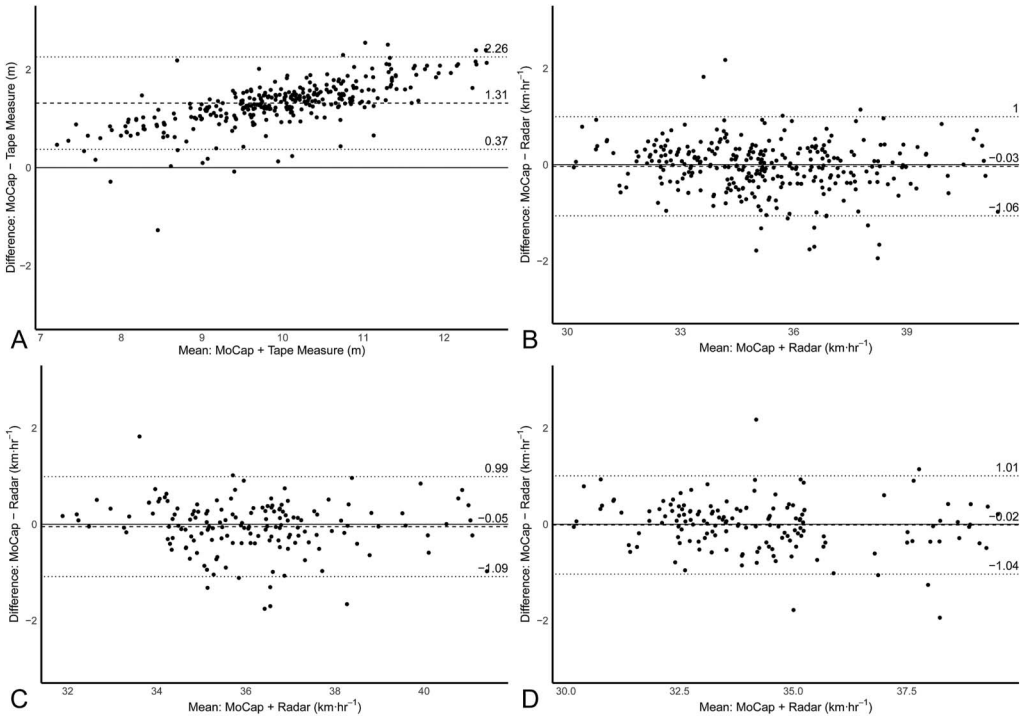


Figure 2. Bland-Altman plots for MB_{dis} and MB_{vel} assessments. Solid line = line of zero difference between measurement systems. Dashed line = bias calculated as the difference between 3-dimensional motion capture (MoCap) and tape measure or radar. Dotted lines = upper and lower limits of agreement (LoA) calculated as bias ± 1.96 · *SD* of the difference between measures (precision). A) MoCap versus MB_{dis}, (B) MoCap versus MB_{vel}, (C) MoCap versus dominant MB_{vel}, and (D) MoCap versus nondominant MB_{vel}.

publications limited to overhead and chest-based throws (33,38). Finally, the MB_{vel} assessment is the first rotational power test in the literature with established accuracy, bias, precision, and reliability across both dominant and nondominant sides (Table 2).

Practical Applications

The MB_{vel} assessment is a valid and reliable way to measure both dominant and nondominant side rotational power performance in elite sport settings using velocity as a proxy measure. This field-based test requires only a radar gun, tripod, and 2-kg medicine ball and permits practitioners to move from laboratory to performance environments while still accurately assessing rotational power. The test enables practitioners to describe the rotational power profile of both individual athletes and teams, establish benchmarks specific to a given performance setting, and evaluate the effectiveness of program interventions.

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