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Operation of the Basketball Jump Shooting Accuracy Test: Intra- and inter-rater reliability of scoring procedures and floor and ceiling effects for test performance

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ABSTRACT

The purpose of this study was to determine the intra- and inter-rater reliability of scoring procedures used in the newly developed Basketball Jump Shooting Accuracy Test (BJSAT) and assess for floor and ceiling effects in test performance. Thirty-one semi-professional basketball athletes completed four trials of the BJSAT. The BJSAT contains one jump shot at eight different locations, equally distributed across two- and three-point shots. Intra-rater reliability was determined by assessing the level of agreement between scores live in-person and watching captured video by the same assessor. Inter-rater reliability was determined by examining the level of agreement between two assessors who separately scored the BJSAT while watching captured video. Descriptive statistics and Cohen's kappa (κ) were calculated to quantify the intra- and inter-rater reliability of the BJSAT. Floor and ceiling effects in scoring outcomes were analyzed to evaluate the suitability of the BJSAT. Significance for the study was set at $p < 0.05$. Intra-rater reliability demonstrated an *almost perfect* ($\kappa = 0.85$, $p < 0.01$) agreement between scores (12.6 ± 2.5 vs 13.1 ± 2.8). The agreement for inter-rater reliability was rated as *substantial* (12.3 ± 2.5 vs 13.5 ± 2.9, $\kappa = 0.70$, $p < 0.01$). Floor and ceiling effects were absent in the BJSAT indicating the assessment is suitable for semi-professional basketball athletes. The BJSAT is an assessment where one or multiple assessors can reliably score shooting performance for functions including player monitoring, to assess the efficacy of interventions aimed at improving skills and to assist with team selection across the season.

Keywords: assessment, skill, technique, agreement, team sports

INTRODUCTION

Basketball is a court-based sport that requires athletes to repeatedly execute technical skills in combination with other movements [1]. Shooting is one such skill, with the jump shot the predominant shot type in basketball. In fact, jump shots accounted for 67% of all shots attempted in the 2014-15 National Basketball Association (NBA) season, demonstrating it is readily executed during high-level basketball competition [2]. Jump shooting involves a two-handed shot executed while jumping from two legs and directly influences team success in basketball. In this regard, superior two- and three-point field goal percentage increases a team's probability of winning [3]. It is therefore important for basketball practitioners to have access to court-based tests that effectively assess jump shooting performance.

To date, few assessments have been developed evaluating shooting performance from two- and three-point distances in combination; providing limited options for basketball practitioners to assess shooting ability across various game-relevant distances in a single test. Existing assessments either contain too few shots across two- and three-point locations [4] compared to the average number of shots attempted by athletes during competition [5] or possess ambiguous instructions of the assessment protocols regarding the number of jump shot attempts required at each location [6], which may diminish reproducibility of testing in practice. Scoring criteria have been previously utilized in basketball shooting assessments; however the information presented in the scoring system was not clearly defined creating confusion for the scorer [7]. Another criteria meanwhile contained seven potential scores including characteristics requiring measurement of the distance between the basketball and the basket, which may prove difficult to use in practical scenarios when scoring performance during an assessment [8]. In response to these limitations of existing tests, the authors recently developed the Basketball Jump Shooting Accuracy Test (BJSAT) and examined for validity and reliability outcomes.

The validity and reliability of the BJSAT has been supported with the test demonstrating a significant, *large* difference ($d = 0.99$, $p < 0.01$) between two- and three-point shots with superior accuracy demonstrated from two-point distance [9]. This finding supports the content validity of the BJSAT and demonstrates the assessment elicits similar differences in shooting accuracy relative to distance from the basket compared to those observed in game situations given accuracy for two-point shots is superior to accuracy for three-point shots during game-play [10, 11]. Relative reliability across four trials of the BJSAT was rated as *moderate* (ICC = 0.71, $p < 0.01$), while absolute reliability was above the accepted benchmark (CV = 16.2%) [9]. A slightly larger CV is not uncommon due to the inconsistencies of skill accuracy throughout competition where basketball athletes can experience periods of a game with high shooting accuracy followed by periods of poor shooting accuracy [5]. Furthermore, the CV exhibited by the BJSAT is superior than other skill-based sports tests presented in the literature [12, 13].

Although the BJSAT has demonstrated the ability to discriminate shooting accuracy between two- and three-point shots and has displayed test-retest reliability over multiple trials, the assessment has yet to be examined for important technical aspects of test operation, intra- and inter-rater reliability and floor and ceiling effects. Intra-rater reliability appraises the reliability of a single assessor to score test performance on multiple occasions while inter-rater reliability refers to the level of agreement between two different assessors scoring the same test [14]. Meanwhile, floor and ceiling effects represent the number of athletes who occupied the lowest or highest score (or range of scores) possible [15]. Development of a jump shooting assessment that utilizes shooting location data to replicate the variable shots attempted during games [16] and possesses adequate intra- and inter-rater reliability is essential for practitioners to measure the efficacy of technically-focussed training interventions and quantify changes in performance. Consequently, it is necessary for skill tests to possess intra- and inter-rater

reliability because these aspects of test operation demonstrate reliable scores are awarded on each occasion the test is undertaken by the same or different assessors.

Therefore, this study aims to: (1) determine the intra- and inter-rater reliability of the BJSAT and (2) determine whether floor and ceiling effects are encountered in performance during the BJSAT.

METHODS

Subjects

Male (n = 12) and female (n = 19) semi-professional basketball athletes were recruited from two State Basketball League (SBL) Australian clubs (age: 22.3 ± 5.7 yr [range: 15-37 yr], playing experience: 13.5 ± 6.9 yr). All playing positions were represented in this observational study, including guards (n = 14), forwards (n = 14) and centers (n = 3). All athletes provided informed consent and were free from any injury or illness at the time of testing. All study procedures were approved by an Institutional Human Research Ethics Committee (approval number 017115F). Athletes were informed of the risks of the study before signing an approved informed consent form. Parental and/or guardian consent was obtained from athletes under the age of 18 years.

The Basketball Jump Shooting Accuracy Test

The BJSAT is an assessment that evaluates jump shooting accuracy from game-specific court locations combining two- and three-point shot distances. This configuration better replicates in-game shooting patterns compared to existing assessments that involve successive shot attempts from a single distance [17, 18]. The BJSAT was developed using publicly available datasets showing the most frequent court locations in which jump shots were attempted during basketball competition [16]. From these data, eight shot locations were chosen for inclusion in the BJSAT with an equal number of shots attempted from two- and three-point distances

(Figure 1). Four shot locations are replicated on the right and left sides of the court with athletes executing one jump shot from each location. One jump shot is attempted from each location during each trial of the BJSAT because successive shots are rarely attempted from the same location and distance during games [19]. The BJSAT is an assessment with pre-determined shooting locations and explicit instructions regarding testing protocols to enhance the reproducibility of the assessment by various populations.

INSERT FIGURE 1 AROUND HERE

Testing Procedures

Testing was conducted on indoor, hardwood basketball courts prior to scheduled training sessions during the final week of a 4-month preseason phase. A portable, extendable camera recording at a sample rate of 60 Hz (Sony HDR-CX220; Eye Tower; SA, Australia) was positioned on the half-court line with full view of the basket and backboard during each BJSAT trial. A demonstration of the BJSAT was given to athletes prior to testing in addition to a 5-min general warm-up and 2-min shooting warm-up. Each athlete performed four trials of the BJSAT with 2 min of passive rest between trials. Four trials were completed to increase the number of shots attempted for reliability analyses. Furthermore, four trials of the BJSAT provides each athlete more shot attempts compared to the average demonstrated during game-play providing a strong representation of each athlete's shooting accuracy across a greater number of shots, which may negate the brief periods of good and poor shooting accuracy that can occur intermittently when less shots are assessed [5]. Athletes began each trial between the half-court line and three-point line (Figure 1). A holding apparatus standing 1 m above the ground delivered the basketballs (size 6 for female athletes and size 7 for male athletes; TF-1000 Legacy; Spalding; KY, United States of America and Wilson Solution, Wilson; NSW,

Australia) to athletes at each shot location. In total, 8 basketballs were used during each trial of the BJSAT with one basketball placed atop of each apparatus at the beginning of each trial. This approach was employed because the focus of the test is on the skill of jump shooting rather than other preceding activities that may increase inter-subject variability such as receiving a pass or dribbling the basketball. All shots were attempted within a marked area (60 cm x 60 cm). If a jump shot was attempted with one or both feet outside of the marked area, athletes continued the trial; however immediate verbal instruction was given to ensure both feet were placed within the marked area for the remainder of the trial. Consistent verbal encouragement was given to all athletes to ensure movement between shot locations was performed as fast as possible.

The BJSAT utilizes a scoring criteria with possible scores ranging from 0-3 for each shot (Table 1), a criteria with parameters similar to that utilized in both basketball [7] and other team sport skill assessments such as the Australian Football Kicking (AFK) test [20]. Test performance was determined by summing the scores from each of the eight shot locations. For intra-rater reliability, one assessor scored the BJSAT live and again watching video footage across all trials for all athletes with 9-12 months separating scoring occasions to minimize retention of performances by the assessor. For inter-rater reliability, two assessors watched the same video footage separately and scored the BJSAT across all trials for all athletes. The assessors were aware of the testing and scoring protocols before scoring the assessment and both assessors had prior experience in evaluating skill assessments in sport. Assessors were not permitted to pause or re-watch video footage at any time to mimic a live assessment. Two assessors scored the BJSAT, with only one assessor being present in-person at each testing session. The assessor stood between shot location three and five (Figure 1) underneath the camera to allow clear view of all shot locations. The assessor who was not present at testing sessions, assessed the BJSAT using video footage.

Table 1. Scoring criteria for the Basketball Jump Shooting Accuracy Test.

Criteria	Score
Basketball travels through the basket without touching the rim or backboard.	3
Basketball makes contact with the rim or backboard before travelling through the basket.	2
Basketball makes contact with the rim or backboard but does not travel through the basket.	1
Basketball does not make contact with the rim or backboard and does not travel through the basket.	0

Statistical Analyses

Descriptive statistics (mean ± standard deviations) were calculated for intra- and inter-rater reliability across all trials with an average reported for each type of reliability. Descriptive statistics were calculated to describe performance during the BJSAT for each method of scoring. Agreement between scores for intra- and inter-rater reliability analyses was determined using Cohen's kappa (κ), a statistic which indicates the level of agreement beyond chance [21]. The following criteria were used to classify outcomes: *poor*, <0.20; *fair*, 0.21-0.40; *moderate*, 0.41-0.60; *substantial*, 0.61-0.80; and *almost perfect*, >0.80 [22]. Floor and ceiling effects for intra- and inter-rater reliability were also examined by categorizing BJSAT scores into quartiles (e.g. scores of 0-6 were placed in the first quartile) and calculating the proportion of scores in each quartile for each trial. This effect was examined because of the importance in identifying whether scores group at either the lowest or highest possible ranges when developing scored testing protocols. A grouping of scores at either end indicates the test is not suitable for the population assessed. Statistical analyses were undertaken using Statistical Package for Social Sciences (SPSS) software (v 25.0; IBM Corp., Armonk, NY, USA) with significance set at $p \leq 0.05$. De-identified scores were made available to the athletes and coaches 2 weeks after each testing session.

RESULTS

Mean ± standard deviation BJSAT scores and reliability statistics are shown in Table 2. Intra-rater reliability was rated as *almost perfect* while inter-rater reliability was rated as *substantial*. Floor and ceiling effects are illustrated in Figure 2 for intra-rater reliability and Figure 3 for inter-rater reliability. As demonstrated, 98% of intra-rater reliability and 97% of inter-rater reliability scores were grouped in the second and third quartiles across all trials where BJSAT scores ranged from 7 to 18 for a single trial. In turn, 2% of intra-rater reliability and 3% of inter-rater reliability scores were allocated to quartile four where BJSAT scores ranged from 19 to 24 for a single trial. Meanwhile, no athletes were allocated to quartile one for any of the intra- and inter-rater reliability trials where BJSAT scores ranged from 0 to 6 for a single trial. The greatest discrepancy was observed for inter-rater reliability scores, in particular in trials one and three. In trial one, 71% of the cohort were allocated to quartile two by the first assessor compared to 52% of the cohort by the second assessor with remaining scores allocated to quartile three for both assessors. Meanwhile in the third trial, the first assessor allocated 42% of the cohort to the second quartile with the remaining scores allocated to the third quartile. The second assessor meanwhile allocated 16% of the cohort to the second quartile, 74% to the third quartile and 10% to the fourth quartile.

Table 2. Intra- and inter-rater reliability statistics across four trials of the Basketball Jump Shooting Accuracy Test.

Reliability approach	n	Mean ± SD	Reliability statistics	
			κ (95% CI)	*p*
Intra-rater Reliability				
Intra-rater (live)	31	12.6 ± 2.5	0.85 (0.82-0.88)	<0.01
Intra-rater (video)	31	13.1 ± 2.8		
Inter-rater Reliability				
Inter-rater (assessor 1)	31	12.3 ± 2.5	0.70 (0.67-0.73)	<0.01
Inter-rater (assessor 2)	31	13.5 ± 2.9		

Note: SD = standard deviation; κ = Cohen's kappa; CI = confidence intervals.

INSERT FIGURE 2 AROUND HERE

INSERT FIGURE 3 AROUND HERE

DISCUSSION

The BJSAT is an assessment tool which involves alternating shots from two- and three-point distances, commonly executed in basketball game-play [16]. During game-play, successive jump shots are rarely attempted from the same distance, with shots instead attempted ad-hoc from a range of locations and distances [19]. Given the scoring criteria utilized in the BJSAT is based on the accuracy of scores awarded by each assessor, the scoring process should possess acceptable intra- and inter-rater reliability for consistent use in practice. Intra-rater reliability is recognized as an important measurement property indicating the quality of an assessment [14]. For intra-rater reliability, the BJSAT rated as *almost perfect* (κ = 0.85, p <0.01). This outcome confirms a strong agreement between scores determined by the same assessor live in-person and watching

captured video in real time. Consequently, performance during the BJSAT can be reliably scored by the same assessor across the season either live or following the test via video capture.

Inter-rater reliability for the BJSAT was *substantial* ($\kappa = 0.70$, $p < 0.01$), demonstrating a strong agreement between the scores determined by two different assessors. This finding indicates that different assessors can be interchangeably used to reliably score the BJSAT. The inter-rater reliability of the BJSAT was similar to that reported for another skill-based team sport test, the AFK test [20]. The AFK test examines field kicking accuracy in Australian football for three different kicking distances. Like the BJSAT, the AFK test utilizes a scoring criteria based on the accuracy of scores provided by the assessors with the assessment also demonstrating *substantial* inter-rater reliability ($\kappa = 0.80$) [20]. This finding for the BJSAT is important as scoring procedures may limit inter-rater reliability, thereby restricting the broader application of the test in practice due to the necessity for the same assessor to score the test on each occasion. However, the present data indicate the scoring system proposed for the BJSAT provides acceptable levels of inter-rater reliability supporting the use of interchangeable assessors when administering the test across the season.

Floor and ceiling effects provide further information about an assessment allowing for accurate reproduction [15]. Floor and ceiling effects were absent suggesting the BJSAT is a suitable assessment for male and female semi-professional basketball athletes. Detection of a floor effects indicate a test may be too difficult for the athletes being assessed, which may limit the test's ability to provide meaningful analysis of performance. Meanwhile, presence of ceiling effects indicate athletes could master the test relatively quickly, limiting the ability to track meaningful changes in performance longitudinally.

Despite the novelty of the present findings for reliable shooting assessment in basketball athletes, some limitations were encountered. First, due to a lack of reliable match statistics, shooting performance during the BJSAT and actual competition was not able to be

correlated to indicate ecological validity. However, given the aim of this study focussed on reliability of the scoring procedures, future research is encouraged to examine the correlation between shooting performance during the BJSAT and competition. Second, the BJSAT contains shot attempts from pre-determined locations unlike shot attempts during game-play which are in response to various stimuli. The assessment was developed in this manner to allow for time-efficient skill testing protocols. Finally, shooting data from the NBA was utilized to determine the BJSAT shot locations, which may not be representative of common shot locations in competitions such as the SBL. However, detailed shooting location data similar to that provided for the NBA was not available for other basketball competitions including the SBL.

CONCLUSION

The BJSAT is a skill assessment that assesses shooting accuracy from authentic court locations that are commonly encountered during basketball game-play. The intra- and inter-rater reliability of the BJSAT were *almost perfect* and *substantial*, respectively. Therefore, basketball practitioners can monitor jump shooting performance of athletes using the BJSAT with the knowledge that reliable scores can be determined either by the same assessor or different assessors when administered across different time-points during the season. Jump shooting accuracy of basketball athletes can therefore be reliably evaluated by assessors using the BJSAT for various functions including player monitoring, to assess the efficacy of technique-oriented interventions and for team selection. Additionally, floor and ceiling effects were absent in BJSAT performance demonstrating the assessment was suitable for semi-professional basketball athletes.

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DECLARATION OF CONFLICTING INTERESTS

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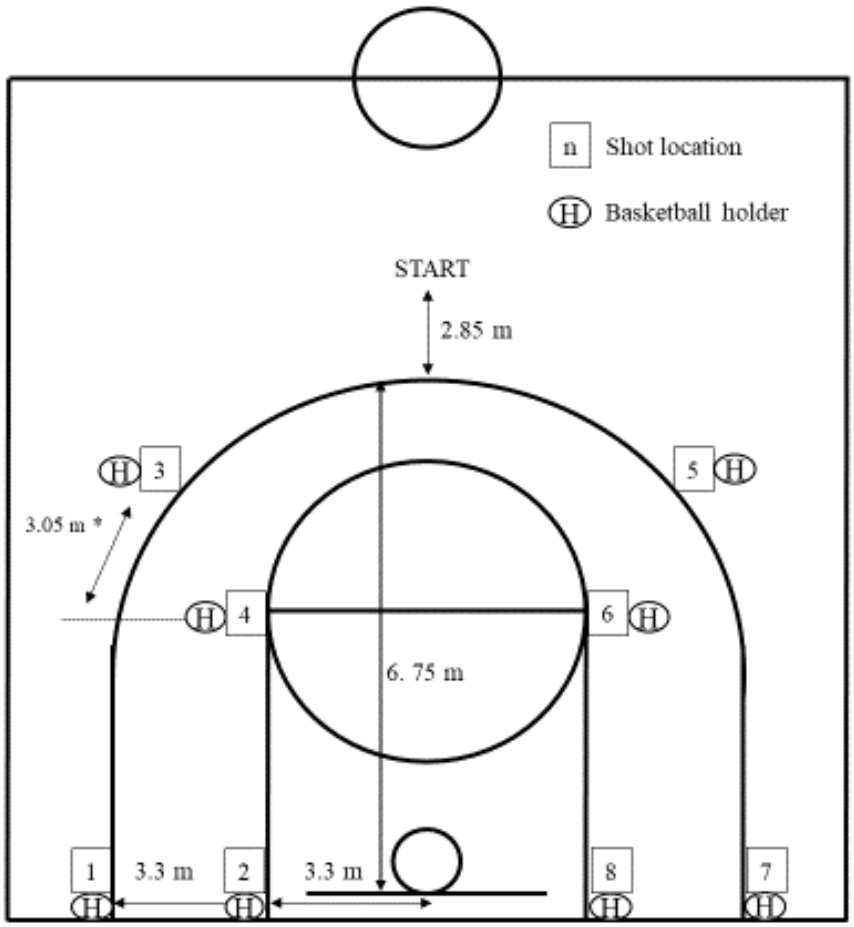

Figure 1. Layout of the Basketball Jump Shooting Accuracy Test.

*Distance between shot location three and extended free-throw line

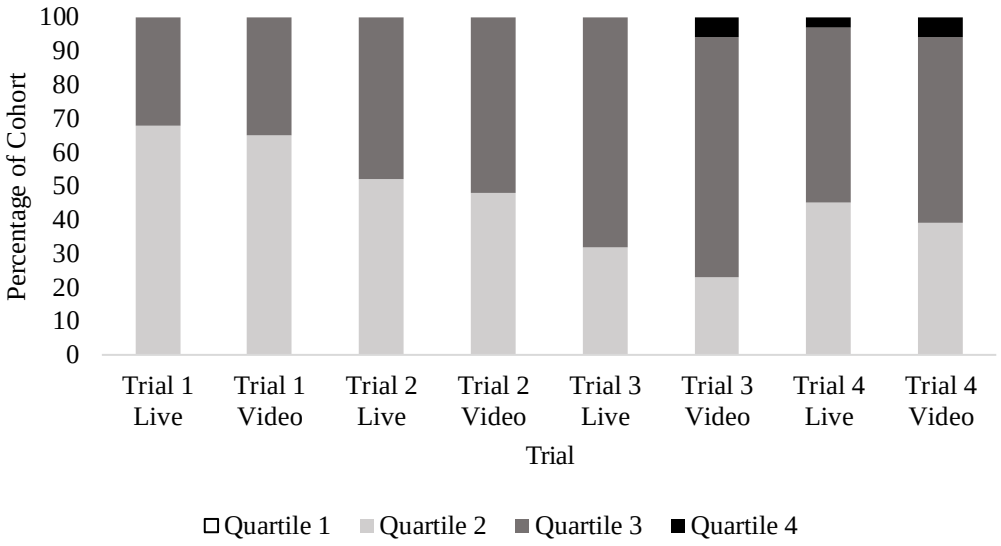

Figure 2. Intra-rater reliability BJSAT score by quartile for each trial of the BJSAT.

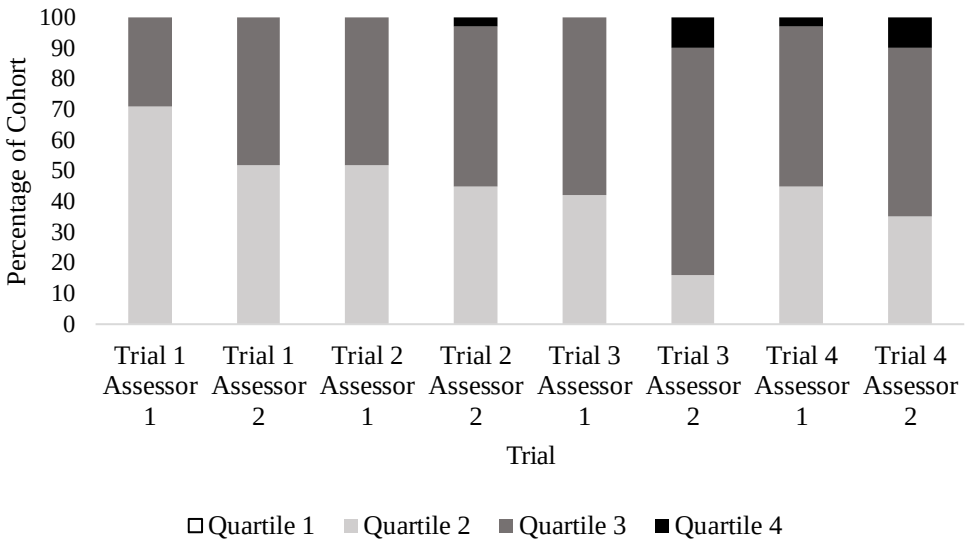

Figure 3. Inter-rater reliability BJSAT score by quartile for each trial of the BJSAT.