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The Effectiveness of the Shotloc Training Tool on Basketball Free Throw Performance and Technique

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Abstract

Background: Shooting technique in young players is dependent on the correct positioning of the hand on the ball during release. The ShotLoc was designed to produce the optimal hand position on the ball for shooting accuracy and correct release. **Purpose:** The purpose of this study was to determine the effectiveness of the ShotLoc shooting device in improving the shooting technique of young elite basketball players. **Method:** Eighty male and female adolescent basketball players recruited from an Elite Player Development Program were videotaped shooting three free throws and then scored on the number of free throw shots made out of thirty. A number of kinematic shooting variables were measured from the video tape. All participants participated in four 20 minute shooting practice sessions on a once per week basis; the experimental group wore the ShotLoc training tool for all of these practices while the control group practiced normally. All players were then videotaped and scored on the number of free throw shots again. **Results:** Statistical analysis of free throw percentage showed a 6.6% increase in those participants who were trained with the ShotLoc, while the control group experienced a .6% decrease in shooting percentage. None of the kinematic variables were found to be significantly different between groups, except wrist flexion that increased in the control group following the intervention. **Conclusion:** the ShotLoc shooting aid could improve free throw shooting percentage following practice using the device.

Keywords: Motion Analysis, Kinematics, Basketball Shooting

1. Introduction

Consistency and accuracy are key to successful shooting in basketball, including both foul shots as well as shots from the field. In order to achieve this consistency there should be limited variability in the kinematic parameters in an athlete's shooting technique (Hudson, 1985a). Coaches and basketball players are always searching for a technique or a device that will improve shooting from the field or the free throw line. The foul shot itself is particularly important to game success in that it can comprise up to twenty to thirty percent of a team's total points in a game (Meyer & Litzenburger, 1974). The successful foul shot depends on consistency in height, angle and velocity of release as well as sub-maximal impulse generation. In particular hand and wrist kinematics and kinetics have considerable impact on the trajectory of the ball (Tan, 1981; Tran & Silverberg, 2008). Statistical analysis of the XXV European Basketball Championships showed that the percentage of successful foul shots (FT%) had the highest correlation with other types of successful shots indicating that foul shot accuracy is highly correlated with general shooting accuracy (Tsarouchas, Kalamaras, Giavroglou, & Prassas, 1988). A training tool for shooting improvement called the ShotLoc has recently been developed that may help players to improve their foul shots, as well as their shooting from the field (Hoops Innovations Ltd, 2010). It consists of a modified glove constructed of form fitting foam that fits over the fingers and assists in maintaining correct positioning of the hand on the ball. Manufacturer suggested details (Hoops Innovations Ltd, 2010) of the training effects from using the ShotLoc are noted below, the position of the ShotLoc on the hand is shown in Figure 1. The training effects of the ShotLoc are stated to be as follows: lock fingers in the shooting position-palm flat, fingers spread, keep the basketball off the palm of the hand for proper positioning, ensure that your hand is held open at the release point of the shot, guide yourself to proper follow through technique, develop fine fingertip control and ball placement, reinforce proper dribble technique and floor control (Hoops Innovations Ltd, 2010).

Correct positioning of the hand on the ball is critical to the optimal release of the ball from the fingertips to ensure the ball moves in a straight pathway following release. The shooting hand should be positioned directly behind the ball with the third digit at ball center, fingers spread with the palm of the hand not in contact with the ball (Booher, 1990).

The pads of the fingertips and the base of the hand should lightly cradle, but not grip the ball. In order that the ball is released with a perfect backspin and moves in a straight line to the net the third digit should be the last to leave the ball from its centered position (Haskell, 1985). In some cases the ball may leave from the second and third digits simultaneously (Booher, 1990), in which case they should split the center of the ball on the posterior aspect to help ensure optimal trajectory and backspin. The follow through should be complete with the wrist reaching the end range of flexion, palm facing the floor, and shoulder at close to 140 degrees of flexion (Alexander & Way, 2009). The use of external aids to improve skill technique is dependent on the design and effectiveness of the device. If the device does improve key aspects of technique, then it may be worthwhile for use with developing athletes.

The ShotLoc is not the only training tool available for purchase that is designed to help improve shooting performance by improving hand and finger position on the basketball. Examples of other aids with similar outcome goals include the Naypalm (Jump USA, 2010b), the J-Glove (JumpUSA, 2010a) and the Shooters Fork (Morley Athletic, 2009). The Naypalm (Jump USA, 2010b) is a fitted band that wraps around the shooter's hand and provides feedback to the shooter when the ball is too close to the center of the palm. The J-Glove (JumpUSA, 2010a) is a modified 3-fingered glove that ensures the wrist and fingers are held in a proper shooting position, with slight flexion at the MCP joints and the shooting hand in proper alignment for a straight release and follow through. The Shooters Fork (Morley Athletic, 2009) is a silicon gel type wedge that sits in between the index and middle fingers and is designed to spread the fingers of the shooting hand. During the conduct of the present study no scientific research describing the effectiveness of the aforementioned shooting aids was located. The purpose of the present study was to examine the effects of using the ShotLoc shooting aid during practice on shooting performance and shooting technique of elite young basketball players. It was hypothesized that the use of the ShotLoc would improve shooting technique and free throw shooting percentages.

2. Methods

2.1 Participants

Eighty male and female adolescent basketball players recruited from Basketball Manitoba's Elite Player Development Provincial Team Program were selected for this study. Following the training period a total of seventy participants were available to complete the final testing session. These seventy participants were included in the final analysis and examined for change over the training period. Thirty three females and thirty seven males were divided separately into competitive age categories; under seventeen (U17), under fifteen (U15), and under fourteen (U14), as reported in Table 2. The athletes for this study were recruited with the support and permission of Basketball Manitoba and the coaches of each individual team. All participants were minors (under 18 years of age) at the time of data collection and as such informed consent was obtained from parents/guardians for all participants included in this study. Ethics approval was obtained from the Education/Nursing Research Ethics Board of the University of Manitoba.

2.2 Study Outline

Eighty male and female adolescent basketball were videotaped shooting two to three free throws and scored on the number of shots made out of thirty (Button, MacLeod, Sanders, & Coleman, 2003). Each group of boys and girls formed a team that represented Manitoba in the national age group championships. No specific age, height or weight data was collected from the participants to ensure anonymity and personal privacy of the individual participants. Individual players who did not wish to participate in the study were given the opportunity to decline participation. Shooting technique training sessions were conducted by the investigators at the beginning of each team's regularly scheduled practices and lasted from 20-30 minutes. During that time coaches were encouraged to also work with the athletes as they would during a normal shooting practice. The participants recruited for this study were of elite developmental caliber as they were selected to be members of provincial teams; their motor skills, coordination and free throw ability were somewhat advanced when compared with other athletes of similar age.

2.3 Testing Procedures

The free throw test consisted of each player shooting 30 free throws with a partner rebounding; this test was administered both at the beginning and the end of the training period. The shooting test was scored by a research assistant, who recorded the number of shots made by each player out of the total of 30 shots. The shots were scored as they would be scored in a game, with a single point awarded for a made shot and no points recorded for a missed shot. Each player shot 15 consecutive shots, and then switched places with their partner so they had a short rest between 15 shot sessions. Testing normally occurred at the beginning of practice, after the players had undergone a brief warm-up.

Three cameras were used to collect the video shooting data, one anterior view, one sagittal view and one posterior view. Participants were randomly assigned a tracking number as they entered the gym; even numbered participants were assigned to the control group and odd numbered participants to the experimental groups. All participants participated in four weekly shooting practice sessions; the experimental group wore the ShotLoc training tool for all practices. The ShotLoc training tool consists of a foam band with four holes for digits 2-5 that sits just distal to the metacarpo - phalangeal joints, or at the base of the fingers (Figure 1). The device spreads the fingers comfortably and lifts the centre of the palm away from the ball. Two ShotLoc prototypes were used by the participants, one constructed of white foam was slightly softer and more form fitting and the other constructed of black foam that was more rigid and resisted becoming fitted to the hand. The participants self selected which ShotLoc they would use for the training sessions. It was found during the study that the black, more rigidly constructed ShotLocs were more likely to break, usually splitting at either the first or last finger hole.

Figure 1. The ShotLoc in position on the shooting hand

Participants participating in the study were regularly asked for feedback on how they felt wearing the ShotLoc and how they felt it may have affected their shooting performance. Participants were instructed to choose a ShotLoc size (small, medium or large) that felt snug but comfortable on the hand. Each practice session consisted of thirty shots two feet from the basket, thirty shots eight feet from the basket and thirty shots from the free throw line. Practice sessions occurred approximately once per week following the regular training schedules of the teams involved, for a period of four weeks. A final testing session was conducted repeating both videotaping and free throw scoring procedures. The pre and post practice film was analyzed using Dartfish (Dartfish, 2010) film analysis software to determine whether the experimental group showed improvement compared to the control group in free throw technique.

A full shooting analysis for each athlete was completed using Dartfish (Dartfish, 2010) to measure the shooting variables of interest (Table 1). A feedback CD containing the analysis was provided to each athlete following a review session with the primary researcher. Coaches were also provided with the analysis CD for their review.

Table 1. Variables measured for each subject during the free throw

Key Position	**Variable Measured (units)**
Maximum Knee Flexion	Wrist extension (degrees)
	Elbow flexion (degrees)
	Shoulder flexion (degrees)
	Trunk flexion (degrees)
Hand Overhead	Finger abduction – 2nd to 4th digit (cm)
	3rd digit to ball midline (cm)
	Centre of palm on ball – (yes/no)
Release	Wrist extension (degrees)
	Wrist deviation (degrees)
	Elbow flexion (degrees)
	Shoulder flexion (degrees)
	Shoulder adduction (degrees)
	Trunk flexion (degrees)
	Finger abduction – 2nd to 4th digit (cm)
	3rd digit to ball midline (cm)
Follow through	Wrist flexion (degrees)
	Wrist deviation (degrees)
Joint range of motion measured for each subject during the free throw	**All measured in degrees**
Force producing	Wrist flexion
	Elbow flexion
	Shoulder flexion
	Trunk extension
Follow through	Wrist flexion
	Wrist deviation

2.4 Shooting Test Procedures

Each team was filmed during scheduled training sessions. A general introduction to the purpose and procedures of the study was given at the beginning of each session. Participants were scored on the number of successful free throws out of thirty trials followed by commencement of filming. The thirty shots were completed with the participants in pairs, with each athlete rebounding for their partner. Partner one completed fifteen shots while partner two retrieved rebounds before switching and allowing partner two to complete fifteen free throws while partner one retrieved rebounds. The procedure was repeated allowing each player a brief rest period during the thirty shots, while the shooting test was scored by a research assistant. The percentage of successful free throws for each player was calculated using Microsoft Excel software.

Each subject was briefly removed from their regular practice session being administered by their coach to complete filming procedures. Participants were asked to perform two or three free throws, from the free throw line as marked on the gym floor, all markings were in accordance with FIBA's Official Basketball Rules (FIBA, 2010). Male athletes used size 7 and females used size 6 basketballs for all testing and practice procedures in accordance with competitive standards. Filmed free throws were completed at a pace determined by the athlete, similar to a game situation. The numbers of shots attempted was determined by the success of the shots, so that if two filmed shots were scored a third shot was not filmed.

Athletes were filmed using three digital camcorders fixed to tripods; two Canon GL2 models and a Canon HV10A. One GL2 camera was placed at half court directly behind the shooting shoulder of the athlete for a posterior view. The HV10A camera was placed at the midline of the basket on the end line for a frontal plane view of the subject. The other GL2 camera was set up to film a sagittal view placed at the sideline directly in line with the free throw line. This camera was moved to either side of the free throw line depending on whether the shooter was right handed or left handed. Normally all of the right handed players were filmed first, followed by moving the sagittal camera to the other side of the free throw line and filming the left handed players from the left side of the player. All cameras filmed at a nominal filming rate of 30 fps; which was altered to 60 fields per second by Dartfish during the kinematic analysis.

2.5 Joint Position Analysis

Shooting analysis for this study focused on measured shooting variables that could be affected by use of the ShotLoc training tool. The best trial for each subject based on their shooting technique and movement smoothness was selected for biomechanical analysis. This was normally a shot that was scored, and one in which the player was balanced and smooth in delivery. In cases where no filmed shot was scored a shot that was most representative of the player's technique was selected. Four key positions that occurred during the shooting motion at which the measurement variables would be recorded were identified for each subject; the position of maximum knee flexion, the first frame in which the hand is visible above the shoulder/head from the posterior view, release, and maximum wrist flexion on follow through. A complete list of variables measured for each subject can be found in Table 1.

All measured angles were determined using the angle measurement tool in Dartfish (Dartfish, 2010). Variables of interest were taken as relative angles using the 180 degree scale in anatomical position, in which any difference in body segment angle from anatomical position is designated as the joint position. Joint ranges of motion were calculated for two phases of the skill; the force producing phase (from maximum knee flexion to release) and the follow through (from release to max wrist flexion). These values were calculated by finding the difference between joint positions at the indicated key positions using Microsoft Excel and are summarized in Table 3.

Table 2. Means, standard deviations (SD) and t-test comparisons of the free throw percentages for control and experimental groups (* indicates statistical significance p≤0.05)

		Test 1		Test 2		
Group		Mean	SD	Mean	SD	p-value
All participants N=70	Control	0.677	0.169	0.668	0.170	0.698
	Experimental	0.622	0.161	0.688	0.181	0.007*
Females N=33	Control	0.629	0.164	0.604	0.176	0.452
	Experimental	0.565	0.142	0.633	0.193	0.073
Males N=37	Control	0.722	0.166	0.728	0.143	0.880
	Experimental	0.670	0.163	0.733	0.161	0.050*
14yrs old N=23	Control	0.525	0.088	0.508	0.122	0.697
Females =11 Males = 12	Experimental	0.561	0.144	0.591	0.198	0.516

15yrs old N=24 Females = 10 Males = 14	Control	0.745	0.157	0.706	0.109	0.468
	Experimental	0.613	0.187	0.700	0.135	0.023*
16&17yrs old N=23 Females = 12 Males = 11	Control	0.767	0.147	0.792	0.132	0.476
	Experimental	0.694	0.123	0.770	0.180	0.103

Table 3. Means, standard deviations (SD) and t-test comparisons for the force producing ranges of motion for control and experimental groupings (*p≤0.05)

		Test 1		Test 2		
Variable	Group	Mean	SD	Mean	SD	p-value
Wrist flexion ROM (deg)	Control	13.237	21.200	18.850	18.141	0.046*
	Experimental	25.725	25.458	22.376	20.340	0.221
Elbow extension ROM (deg)	Control	89.571	18.035	86.062	14.783	0.343
	Experimental	83.567	17.294	79.855	17.160	0.354
Shoulder flexion ROM (deg)	Control	55.677	22.488	56.295	22.528	0.858
	Experimental	53.793	27.231	51.070	24.163	0.284
Trunk extension ROM (deg)	Control	7.348	6.058	6.906	6.048	0.727
	Experimental	11.399	11.862	11.455	13.561	0.966

Wrist flexion and extension were measured from the sagittal view film by extending the line of the long axis of the forearm beginning at the elbow joint and passing through the centre of the wrist joint. The angle between this and the long axis of the third metacarpal in the sagittal plane was recorded as the angle of wrist flexion or extension.

Wrist deviation was measured from the long axis of the forearm and again through the third metacarpal, the angle recorded in the frontal plane from the posterior view film. Ulnar deviation was recorded as being positive and radial deviation recorded as negative for the purposes of statistical analysis.

Elbow range of motion was measured by extending the line of the long axis of the humerus; a line passing from the centre of the shoulder joint passing through the centre of the elbow joint. The angle between that and the long axis of the forearm as previously described was recorded as the amount of elbow flexion.

Shoulder range of motion was measured by identifying the long axis of the torso extending from the centre of the shoulder joint to the centre of the hip joint. The angle of shoulder flexion was created by this line and the long axis of the humerus in the sagittal plane. Shoulder adduction was measured from the posterior view film in an arm overhead position. Shoulder adduction angle was measured in the frontal plane as the angle created by the humerus and the absolute vertical axis. Trunk flexion was measured in the sagittal plane as the angle created by the long axis of the subject's body (as previously described) and the absolute vertical axis. Trunk extension was recorded as a negative value for the purposes of statistical analysis.

2.5.1 Measurement of shooting hand variables

Hand placement on the ball was determined using the distance tool in Dartfish (Dartfish, 2010). Ball diameter was used as a reference distance in the frame from which measurements were recorded. Female participants used a size 6 basketball with diameter 23.25 cm and males a size 7 basketball with diameter 24.34 cm, regulation sizes according to the International Basketball Federation rules (FIBA, 2010). Stability of the ball on the hand of the shooter is required for control and accuracy of shot; this depends on a player's fingers being well spread directly behind the ball. The amount of finger abduction was measured in centimeters as the distance between the second and fourth fingertips. Each subject was measured at the beginning and end of the practice sessions, a matched pairs analysis allows each subject to act as his/her control in finding a difference across time. Hand position on the ball was determined by taking measurement of the distance between the subject's third digit to ball center in the frontal plane. If the digit was lateral to the center the value was recorded as positive, likewise if the digit was medial to ball center the value was recorded as negative. The question of whether or not the participant's palm was in contact with the ball was answered categorically on a yes or no basis, and was determined by examining the anterior camera view.

2.6 Statistical Analysis

The variables listed in Table 1 were measured for each subject's most skilled shot captured on film. This shot was one that scored a point if possible, and one in which the shooter remained balanced and exhibited skilled technique. Variables utilized in the statistical analysis include; free throw percentage, force producing ranges of motion at the wrist, elbow, shoulder and trunk, follow through ranges of motion for wrist ulnar deviation and wrist flexion, hand positioning measurements at the hand overhead as well as release key positions and shoulder adduction at release. The shot that was utilized for analysis was determined according to the most optimal film views, shooting technique and outcome for that subject. Measurements for each variable were combined with the values for all participants within a group to produce an overall mean. Group means were then used to compare the variables within groups across time as well as across groups (Hassard, 1991). Microsoft Excel 2007 and the XLSTAT add-in were used for all statistical analyses. Free throw percentage was measured as number of successful attempts out of thirty in both control and experimental groups before (test 1) and after (test 2) the free throw practice sessions.

The means of the measured variables were compared across time and across groups. The intervention groups were trained during the four free throw practice sessions with the ShotLoc training tool; the control group completed the same training protocol without use of the ShotLoc.

Paired t-tests were used to test twelve continuous variables for differences in means within groups from test 1 to test 2 with a significance level $p \leq 0.05$. A Wilcoxon signed rank sum test was used to compare one categorical variable, the position of the palm of the hand on the ball. Evaluation of each subject in a pretest and posttest allowed for paired tests for both continuous and categorical variables. Free throw percentage results were compared within six control and experimental groupings according to age and sex.

Due to the variances within the biomechanical data, results were pooled for all participants into experimental and control groups in order to achieve the required subject numbers to determine significance. The Wilcoxon signed rank sum test (Hassard, 1991) was used to analyze one categorical variable, whether or not the centre of the palm was in contact with the ball during the force production phase of the free throw. Each subject was analyzed before and after practice sessions allowing for a paired data analysis looking for changes in performance between test 1 and test 2. Numerical values were assigned to each of the possible outcomes; zero denoting palm in contact and one denoting palm not in contact with the ball. The tests were conducted with a significance level of $p \leq 0.05$.

3. Results

Analysis of the free throw test data was completed for each of the groups and free throw percentage means and standard deviations are presented along with the calculated p-value in Table 3.

Table 3. Means, standard deviations (SD) and t-test comparisons of the free throw percentages for control and experimental groups (* indicates statistical significance p≤0.05)

		Test 1		Test 2		
Group		Mean	SD	Mean	SD	p-value
All participants N=70	Control	0.677	0.169	0.668	0.170	0.698
	Experimental	0.622	0.161	0.688	0.181	0.007*
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Males N=37	Control	0.722	0.166	0.728	0.143	0.880
	Experimental	0.670	0.163	0.733	0.161	0.050*
14yrs old N=23	Control	0.525	0.088	0.508	0.122	0.697
Females =11 Males = 12	Experimental	0.561	0.144	0.591	0.198	0.516
15yrs old N=24	Control	0.745	0.157	0.706	0.109	0.468

Females = 10 Males = 14	Experimental	0.613	0.187	0.700	0.135	0.023*
16&17yrs old N=23	Control	0.767	0.147	0.792	0.132	0.476
Females = 12 Males = 11	Experimental	0.694	0.123	0.770	0.180	0.103

Participants in the control group did not show a statistically significant improvement in percentage of successful free throws from testing session one to testing session two in all groups from Table 2. Analyzed together the experimental participants that completed training with use of the ShotLoc training tool showed a statistically significant improvement in free throw percentage, improving from 62.2% prior to training to 68.8% post ShotLoc training. Males trained with the ShotLoc showed an improvement from 67% pre-training to 73.3% post-training.
Females in the experimental group showed improvements approaching statistical significance with a test 1 score mean of 56.5% and test 2 score mean of 63.3%. Participants in the 15 year-old experimental group also showed statistically significant improvement in successful free throw percentage beginning at 61.3% pre-training to 70.0% post-training. The control groups of all participants, females, 14 year-olds and 15 year-olds actually showed decreased post-training free throw scores, although the differences were not statistically significant (Table 2).

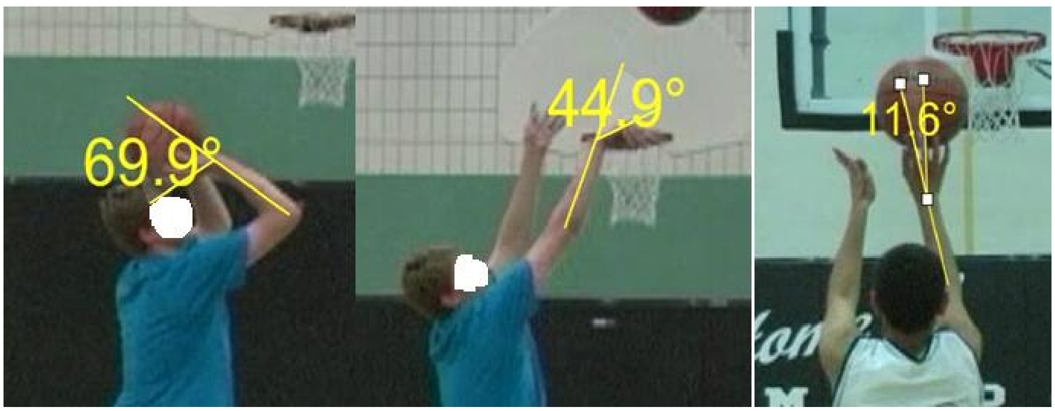

Figure 2. Measurement of wrist joint angles.

Range of motion (ROM) at the wrist, elbow, shoulder and trunk were measured and analyzed using paired t-tests with significance level p≤0.05 (Figure 2, 3, 4). Means, standard deviations and t-test comparisons for the force producing variables can be found in Table 3. Control participants showed a significant increase of 5.61 degrees in wrist flexion range of motion during the force producing phase of the free throw during the time between test 1 and test 2. Neither the control nor the experimental groups showed a difference from test 1 to test 2 in any of force producing elbow, shoulder or trunk ranges of motion.

Figure 3. Measurement of elbow joint angle

Variables describing hand positioning taken at the hand overhead key position were analyzed at test 1 and test 2 for each subject. These variables included finger abduction and finger placement on the ball, and both were measured in centimeters. Means, standard deviations, and calculated p-value results are reported in Table 4. No statistically significant differences existed within groups at the hand overhead position; however the experimental group approached significance by improving mean finger abduction from 8.192cm prior to 8.747cm following training with the ShotLoc.

Table 4. Means, standard deviations (SD) and t-test comparisons of the shooting hand variables at the hand overhead position for control and experimental groupings (*p≤0.05)

		Test 1		Test 2		
Variable	Group	Mean	SD	Mean	SD	p-value
Finger abduction (cm)	Control	8.911	1.537	8.600	1.401	0.246
	Experimental	8.192	2.072	8.747	1.215	0.127
Distance 3rd digit to ball midline (cm)	Control	3.332	2.922	3.637	2.469	0.499
	Experimental	3.960	3.038	3.308	3.078	0.289

At the key position of ball release three continuous variables were measured for each subject prior to and following four weeks of training, these included finger abduction, finger position on the ball and shoulder adduction. Means, standard deviations and t-test results for these variables are reported in Table 5. None of the measured biomechanical variables at the position of ball release were significantly different in either the control or experimental groups across time.

Figure 4. Measurement of shoulder joint angles

Table 5. Means, standard deviations (SD) and t-test comparisons of measured variables at the release position for control and experimental groupings (*p≤0.05)

		Test 1		**Test 2**		
Variable	Group	Mean	SD	Mean	SD	p-value
Finger abduction (cm)	Control	7.890	1.451	8.172	1.761	0.424
	Experimental	7.627	1.638	7.517	1.740	0.761
Distance 3rd digit to ball midline (cm)	Control	0.832	1.635	1.174	1.929	0.298
	Experimental	1.401	2.248	2.057	2.334	0.087
Shoulder adduction (deg)	Control	11.515	8.755	11.978	10.118	0.789
	Experimental	9.690	10.654	11.635	10.603	0.172

Wrist flexion and ulnar deviation ranges of motion were measured for each subject at test 1 and test 2 during the follow through phase of the skill (Figure 2). Paired t-tests were utilized to assess differences within the control and experimental groups across time. No differences were found within groups at a significance level p≤0.05, see Table 6.

Table 6. Means, standard deviations (SD) and t-test comparisons for the follow through ranges of motion for control and experimental groupings across time (*p≤0.05)

		Test 1		Test 2		
Variable	Group	Mean	SD	Mean	SD	p-value
Wrist flexion ROM (deg)	Control	75.001	26.521	71.618	21.542	0.477
	Experimental	72.182	23.371	71.909	20.339	0.934
Wrist ulnar deviation ROM (deg)	Control	19.450	16.911	18.598	13.078	0.768
	Experimental	13.425	10.119	17.139	11.486	0.069

Each subject was evaluated at test 1 and test 2 for ball contact with the centre of the palm. This categorical variable was measured during the force producing phase of the free throw and analyzed in a paired design Wilcoxon signed rank sum test with significance level 0.05, see Table 7. Participants trained with the ShotLoc during the practice sessions showed significant improvement in reduction of ball contact with the palm of the shooting hand from test 1 to test 2.

Table 7. ANOVA comparison of all the continuous variables for both control and experimental groups at Test 1 and Test 2 . Exp = experimental, HO = hand overhead, FP = force producing, R = release, FT = follow through)

	Control Group Test 1	Control Group Test 2	Exp. Group Test 1	Exp. Group Test 2	f-value	p-value
Variable	N=35 Mean (SD)	N=35 Mean (SD)	N=35 Mean (SD)	N=35 Mean (SD)		
Free throw %	0.677 (0.169)	0.668 (0.170)	0.622* (0.161)	0.688* (0.181)	3.973	0.048*
HO: Finger abduction (cm)	8.91 (1.54)	8.60 (1.51)	8.19 (2.07)	8.75 (1.21)	1.660	0.179
HO: Distance 3rd digit to ball midline (cm)	3.33 (2.92)	3.64 (2.69)	3.96 (3.04)	3.31 (3.08)	0.633	0.595
FP: Wrist flexion ROM (deg)	13.24* (21.20)	18.85* (19.79)	25.73 (25.46)	22.38 (20.34)	2.903	0.037*
FP: Elbow extension ROM(deg)	89.57 (18.03)	86.06 (16.46)	83.57 (17.29)	79.85 (17.16)	1.980	0.120
FP: Shoulder flexion ROM (deg)	55.68 (22.49)	56.30 (22.35)	53.79 (27.23)	57.07 (24.16)	0.360	0.782
FP: Trunk extension ROM (deg)	7.35 (6.06)	6.91 (6.01)	11.40 (11.86)	11.46 (13.56)	1.307	0.275
R: Finger abduction (cm)	7.89 (1.45)	8.17 (1.61)	7.63 (1.64)	7.52 (1.74)	0.996	0.397
R: Distance 3rd digit to ball midline (cm)	0.83 (1.64)	1.17 (1.78)	1.40 (2.25)	2.06 (2.33)	2.413	0.064
R: Shoulder adduction (deg)	11.51 (8.75)	11.98 (9.40)	9.69 (10.65)	11.63 (10.60)	0.630	0.597
FT: Wrist flexion ROM (deg)	75.00 (26.52)	71.62 (24.05)	72.18 (23.37)	71.91 (20.34)	0.257	0.856
FT: Wrist ulnar deviation ROM (deg)	19.45 (16.91)	18.60 (15.01)	13.42 (10.12)	17.14 (11.49)	1.479	0.223

*Means are significantly different from each other at p<.05

Whether or not the participant's palm was in contact with the ball was analyzed between groups using a Mann-Whitney U test. The analysis showed no difference between groups at test 1 but a significant difference between groups at test 2 with a p-value of 0.013. Participants in the experimental group showed a significant reduction in ball contact with the palm of the hand.

4. Discussion

Free throw performance was analyzed by the calculation of percentage of successful shots out of a trial of thirty as well as assessment of biomechanical variables at different stages of the shot. For the purposes of this study the biomechanical variables measured were limited to those of the trunk and upper limbs with a goal of determining the effects of use of the ShotLoc shooting tool on the shooting hand. The participants were tested initially by scoring free throw percentage and filming three trials of the free throw. Participants were filmed from the anterior, sagittal and posterior aspects to ensure that all key biomechanical variables could be measured. Participants completed an average of four training sessions having been randomly assigned to either the control or experimental groups. Participants assigned to the experimental group completed all training sessions with the ShotLoc training tool. Training sessions consisted of thirty shots 2 feet from the basket, thirty shots 8 feet from the basket and thirty shots from the free throw line. Those participants in the ShotLoc group were asked regularly how they felt about the device. Most participants thought it helped keep their shooting hand in a better position on the ball and helped to keep their palm off the ball. Some participants found the ShotLoc to be uncomfortable on their hand and that it interfered with their control of the ball. Some suggested that it made dribbling more difficult as less of the hand was in contact with the ball. The contact of the ShotLoc with the ball was felt to be less secure than the bare hand by some players when dribbling with the ShotLoc.

There were two types of ShotLocs used in this study, the softer white model and a harder, more rigid black model. Participants frequently reported that the softer white ShotLocs were more comfortable to wear, noting that they were softer and more readily conformed to the shape of the hand. Though participants were instructed to choose a size (S/M/L) that they found most comfortable it was sometimes reported that with extended use the fingers felt constricted. This could be attributed to the increased blood flow through the fingers and hands that would naturally occur during activity or sport participation, causing swelling of the hand and increased pressure from the ShotLoc. It was suggested to those athletes that found the finger constriction uncomfortable to try a larger size.

Most athletes found the ShotLoc moderately comfortable to wear during shooting practice sessions. Generally they found that it held the hand in a comfortable and relaxed open position, prevented the ball from contacting the palm and aided in maintaining correct form in release and follow through. The design of the ShotLoc is such that it forces the fingers into a spread but comfortable position. This in effect distributes the forces imparted by the wrist more equally across the ball by making the athlete use all fingers to control the ball. The hand is put into a more optimal position for release allowing the ball to leave the hand from the third or second and third digits. Participants were commonly observed to incorrectly hold the fingers close together during force production and release, but especially during the follow through phase of the skill.

Adduction of the fingers (moving fingers together) at any point during the shot can produce off-centre forces and impart unwanted side spin that could alter the trajectory of the ball. When using the ShotLoc the fingers are held in this more ideal abducted position throughout the entire shot ensuring fewer unwanted forces are produced. Athletes should finish the shot with perfectly spread fingers and with the palm of the hand flat. The resultant increase in free throw percentage found in participants who had trained with the ShotLoc may be the result of this increased ball-control, as accuracy and consistency improved within the experimental group.

The ShotLoc prevents the ball from contacting the centre of the palm of the hand and thus places the ball in the correct position on the fingertips. The result of using the fingertips rather than the palm of the hand is greater ball control during both shooting and dribbling. Ball control is key to success in either of these activities but especially so for an accurate and consistent free throw. A significant reduction in palm-to-ball contact was found in athletes that had been trained using the ShotLoc. As a result of many hours of practice and development of advanced skills these athletes already have very well developed motor patterns. Shooting mechanics in these athletes were very well established including less than ideal technique in some cases. Athletes may in fact have developed compensatory movements to account for these technical faults.

A common fault noted in a number of the players was lining up the ball over the non shooting side of the body, and not over the shooting side. This fault necessitated the ball being moved over toward the shooting side while it was moved upward into shooting position, which may produce a lack of consistency in ball positioning for the shot. Another common fault was the hand position on the ball being too far over on the right side of the ball, instead of being directly under the middle of the ball. This position introduced a tendency to shoot the ball to the left side of the basket. This tendency was also reported in a study of NCAA male basketball players that revealed 32.8% of missed free throws were off-line to the left, and 19.5% were off to the right (Vaughn, 1993). A number of the players in this study allowed the shooting elbow, and also the non shooting elbow, to extend too far out to the side (shoulder abduction), producing a sideways component to the forces being applied to the ball. Another common fault was to allow the hand to point either medially or laterally during the follow through, allowing for some sideways forces to be applied to the ball at release.

Statistical analysis of free throw percentage in this study showed a 6.6% increase in those participants who were trained with the ShotLoc during the training period (Table 2). This finding was an important result, as it suggests that practice with the ShotLoc training device can actually improve the ability to score free throws. It is likely that the ShotLoc produces alterations in technique that can improve hand position on the ball and shooting accuracy. There was no corresponding difference found in the shooting percentage of the Control group that did not practice with the ShotLoc.

In fact the control group was found to decline .9% in free throw percentage across time (Table 2), although this difference was not found to be statistically significant.

Analysis of the mechanical aspects of the free throws within groups across time and between groups across time generally did not show significant changes in either the experimental or control groups. Only the control group was found to have an increased range of motion at the wrist during the force production phase of the free throw following the four week training period. This finding is difficult to explain given no additional changes in mechanical technique within the control group or the experimental group. The two groups differed at the time of test 1 but not at test 2, though there is no apparent stimulus for the control group to have changed this aspect of free throw technique over time.

The range of motion at the wrist in this study was measured through the force producing phase; defined as the total angular displacement of the wrist from the key point of maximum knee flexion to release of the shot. It was measured as a separate variable during the follow through phase of the skill. Wrist flexion in elite basketball players as reported by Vaughn (1993) was 54 degrees, significantly higher than those measured in this study for the force producing phase of the skill only. It is possible that the measurement of wrist range of motion in these two studies were not measured from the same time markers (maximum knee flexion), this would make the results of the two studies unable to be compared. Another difference exists in the age and skill level of the participants studied. The participants in this study were at a developmental stage and significantly younger than NCAA players in Vaughn's 1993 study. The results of Vaughn's study of NCAA Division I basketball players may indicate that more skilled athletes use a greater amount of wrist flexion during the free throw

When statistically analyzed separately by sex, male participants in the experimental group showed a significant improvement over time whereas female participants did not show a statistically significant improvement. Males improved from 67% to 73.3 % after training with the ShotLoc (Table 2). The females also improved after using the ShotLoc, from 56.5% to 63.3%, but the improvement was just below the significance level (Table 2). It is difficult to speculate on the possible causes for these findings. Male participants when compared to females of the same age possess a higher skill level (better shooting technique) and higher scoring free throw performance. It would be logical to assume that female participants would benefit more from the use of a shooting aid such as the ShotLoc to improve hand position and finger alignment, although this was not the case in this study.

One possible explanation for this finding is that the reasons for missed free throws may be different for males vs. females. Male basketball players often shoot the ball too hard and it bounces off the back of the rim instead of dropping directly into the net. Young female basketball players frequently lack the strength to execute the free throw with perfectly ideal technique, and the ball is more likely to bounce off the front or hit the side of the rim. As was observed in some of the fourteen and fifteen year old females, participants will often adopt a technique closer to a two handed shot in order to achieve the force required to make the shot. Use of the ShotLoc cannot overcome the strength deficits demonstrated by the young female participants and this could be a reason that limited improvement was seen in these participants (Button et al., 2003).

When analyzed by age the fifteen year old experimental participants showed a significant improvement in free throw performance, a result not observed within the other age groups. Again it is difficult to determine the exact cause for these results however similar reasoning can be applied. The ShotLoc theoretically will be most effective when used by those athletes whose free throw performance in negatively affected by poor mechanics in the shooting hand and wrist. If an athlete's deficit in free throw technique is not related to the shooting hand the ShotLoc would have minimal effect on performance. Fourteen year old participants in this study, though advanced for their age demonstrated the greatest variability in technique. This would indicate that they are still developing the consistency in shooting technique that is required of a successful shooter. Variability in mechanical aspects of the fourteen year old shots existed in the hand, but also very notably in the timing of the force producing extension.

Participants were evaluated for whether or not the centre of the palm was in contact with the ball during the force production phase of the free throw. Each subject was categorized as yes or no, the results of this study show that participants who were trained with the ShotLoc were less likely to have palm to ball contact following training. There was no significant change in the control group across time. A Mann-Whitney test (Hassard, 1991) showed that a difference existed at test 2 but not test 1 suggesting that the ShotLoc was effective in training athletes to control the ball, not with the palm of the hand but with the pads of the fingers. Of the thirteen measured variables for each subject only ball contact with the palm of the hand changed significantly over time, those trained with the ShotLoc had reduced palm to ball contact across time. This result indicates that those participants trained with the ShotLoc were more likely to control the ball with the fingertips rather than the palm of the hand. Handling of the ball with the fingertips rather than the palm of the hand could increase control over ball trajectory. As participants were not tested wearing the ShotLoc, re-learning of hand position on the ball must have occurred.

5. Conclusions

The results presented in this study suggest that the ShotLoc is a useful training aid to increase free throw shooting effectiveness of young shooters. Participants who wore the ShotLoc for the four session training period significantly improved their mean free throw percentages, although individual differences in performance did occur. It is suggested here that an even greater difference would be observed in younger, less experienced/skilled players who do not yet have their shooting skills developed. The results of this study suggest that the ShotLoc is a valuable training tool for teaching correct hand positioning on the ball and encouraging proper hand to ball contact during the basketball free throw.

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