The effectiveness of the ShotLoc training tool on basketball free throw performance and technique

A BIOMECHANICAL ANALYSIS

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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 there should be limited variability in the kinematic parameters in an athlete’s shooting technique. 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 & Litzenberger, 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 kinetics have considerable impact on the trajectory of the ball. Statistical analysis of the XXV European Basketball Championships showed that 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, 1990). 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 stated details of the training effects of using the ShotLoc are noted in Figure 1. The purpose of the present study is

- Lock fingers in the correct 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 towards proper follow-through technique
- Develop fine fingertip control and ball placement
- Reinforce proper dribble technique and floor control
to examine the effects of using the ShotLoc on shooting performance and shooting
technique of elite young basketball players. The ShotLoc is not the only training tool
available for sale that is designed to improve shooting performance. Examples of other
aids with similar outcome goals include the Naypalm (JumpUSA, 2010b), the J-Glove
(JumpUSA, 2010a) and the Shooters Fork (Morley Athletic, 2009), see Appendix A. The
Naypalm is a fitted band that wraps around the shooters hand just proximal to the
metacarpophalangeal (MCP) joints. It provides a feedback to the shooter when the ball
is too close to the centre of the palm of the hand as the softly spined material is pressed
into the palm. The J-Glove is modified 3-fingered glove that ensures the wrist and
fingers are held in a proper shooting position, with slight flexion at the MCP joints. The
hand and wrist component of the glove hold the shooting hand in proper alignment for a
straight release and follow through. The Shooters Fork is a silicon gel type wedge that
sits in between the index and middle fingers, attached to each by a loop. This tool is
designed to spread the fingers of the shooting hand. At the time of the present study no
scientific research into the effectiveness of the aforementioned shooting aids was
available.

The foul shot being a closed environment skill requires one consistent pattern of optimal
release conditions with minimal variability. In a closed environments skill there are no
extraneous environmental variables for the athlete to react or adjust to, so the outcome
is entirely based on individual skill and performance. There are many possible
successful combinations of release angle, velocity and force though players who
develop a consistency in technique will achieve greater accuracy over time. A study of
intra-individual variability in NCAA Division I male players showed that of missed foul
shots 32.8% were too far left and 19.5% were too far right, indicating that a total of 52.3% of missed foul shots were due to force production outside of the sagittal plane (Stankovic, Simonovic, & Herodek, 2006) (assuming proper setup with shooting side of the body in line with the basket (Alexander, 2002)). The overhand push style shot is the most commonly used technique; it is a one handed shot with the non-shooting hand acting in a supportive and directive role, it should not impart any forces onto the ball (Tan, 1981). One of the most important features of a properly executed foul shot is the presence of a positive backspin which helps with “capture” after a bounce off of either the rim or backboard (Okubo & Hubbard, 2006). The authors are referring to how likely the ball is, following contact with the rim or backboard, to bounce in such a way that the ball goes into the net. Backspin is imparted to the ball by flexion of the wrist through release with the trajectory and direction of spin controlled by the fingertips as they leave the ball (Brancazio, 1981). The ideal backspin occurs at 3Hz achieving approximately three revolutions during its flight to the basket (Tran & Silverberg, 2008).

The shooting hand should be positioned directly behind the ball with the third digit at ball centre, 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 move 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 (Booher, 1990) in which case they should split the centre 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.

The non shooting hand should rest in a similar position as the shooting hand with fingers spread and centre of the palm not in contact with the ball. The thumb of the guide hand should rest approximately one inch above that of the shooting hand creating the shape of a ‘T’ (Haskell, 1985). The non shooting hand acts as a guide only, if any forces are imparted onto the ball added rotation or altered trajectory could occur outside of the sagittal plane resulting in less than optimal release conditions and possibly negatively affecting the outcome of the shot.

METHODS

Description of Study

Male and female adolescent basketball players recruited from Basketball Manitoba’s Elite Player Development Provincial Team Program were videotaped shooting two to three free throws and scored on the number of shots made out of thirty. Three cameras were used to collect the data, one anterior view, one sagittal view and one posterior view. Training teams were categorized according to competitive standards by sex and age. The study group consisted of six elite teams scheduled to represent Manitoba in upcoming National Championships. The teams were: under-17 boys, under-17 girls, under-15 boys, under-15 girls, under-14 boys and under-14 girls. Subjects were randomly assigned to control and experimental groups within their training teams. All subjects participated in three to four shooting practice sessions; the experimental group wore the ShotLoc training tool for all practices. Subjects 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 one time per week following the regular training schedules of the teams involved. A final testing session was conducted repeating both videotaping and free throw scoring procedures. The pre and post practice film was analyzed using Dartfish film analysis software to determine whether the experimental group showed improvement compared to the control group in free throw technique.

A full skill analysis for each athlete was completed using Dartfish, a feedback CD containing the analysis was provided to each athlete following a review session with one of the researchers. Coaches were also provided with the film for their review.

Subjects

Eighty male and female adolescent basketball players recruited from Basketball Manitoba’s Elite Player Development Provincial Team Program were recruited for this study. Following the training period a total of seventy subjects completed the study, 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 summarized in Table 1. The athletes for this study were recruited with the support and permission of Basketball Manitoba (Appendix B). All subjects were minors (under 18 years of age) at the time of data collection and as such informed consent (Appendix C) was obtained for all subjects included in this study. Ethics approval was obtained from
the Education/Nursing Research Ethics Board at the University of Manitoba (Appendix D).

Table 1 Subjects categorized by age and sex

<table>
<thead>
<tr>
<th>AGE CATEGORY</th>
<th>#GIRLS</th>
<th>#BOYS</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>U14</td>
<td>11</td>
<td>12</td>
<td>23</td>
</tr>
<tr>
<td>U15</td>
<td>10</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>U17</td>
<td>12</td>
<td>11</td>
<td>23</td>
</tr>
<tr>
<td>TOTAL</td>
<td>33</td>
<td>34</td>
<td>70</td>
</tr>
</tbody>
</table>

Test Protocol

Each team was filmed during scheduled training sessions. A general introduction of the purpose and procedures of the study was given at the beginning of each session. Subjects were scored on number of successful free throws out of thirty trials followed by commencement of filming. The thirty shots were completed 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 in the middle of the thirty shots; the shooting test was scored by a research assistant. Percentage of successful free throws for each player was calculated using Microsoft Excel software. Each subject was briefly removed from their regular practice session as administered by their coach to complete filming procedures. Subjects 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, 2008). Male athletes used size 7 and females used size 6 basketballs for all testing and practice procedures in accordance with competitive standards. Filmed shots were completed at a pace determined by the athlete, similar to a game situation.

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. One GL2 camera was set up for a sagittal view placed at the sideline directly in line with the free throw line. The HV10A was placed at the midline of the basket on the end line for an anterior view of the subject.

**Biomechanical Skill Analysis**

Biomechanical analysis for this study focused on measured variables that may be affected by use of the ShotLoc training tool. The best trial for each subject was used for biomechanical analysis. Four key positions were identified for each subject at which the measurement variables would be recorded; the position of maximum knee flexion, the first frame where 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 2. All measured angles were determined using the angle measurement tool in Dartfish. Variables of interest were taken as relative angles using the 180 degree scale in anatomical position. Any difference in body segment angle from anatomical position is designated as the joint angle. 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 Variables measured for each subject during the free throw

<table>
<thead>
<tr>
<th>Key Position</th>
<th>Variable Measured (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Knee Flexion</td>
<td>Wrist extension (degrees)</td>
</tr>
<tr>
<td></td>
<td>Elbow flexion (degrees)</td>
</tr>
<tr>
<td></td>
<td>Shoulder flexion (degrees)</td>
</tr>
<tr>
<td></td>
<td>Trunk flexion (degrees)</td>
</tr>
<tr>
<td>Hand Overhead</td>
<td>Finger abduction – 2nd to 4th digit (cm)</td>
</tr>
<tr>
<td></td>
<td>3rd digit to ball midline (cm)</td>
</tr>
<tr>
<td></td>
<td>Centre of palm on ball – (yes/no)</td>
</tr>
<tr>
<td>Release</td>
<td>Wrist extension (degrees)</td>
</tr>
<tr>
<td></td>
<td>Wrist deviation (degrees)</td>
</tr>
<tr>
<td></td>
<td>Elbow flexion (degrees)</td>
</tr>
<tr>
<td></td>
<td>Shoulder flexion (degrees)</td>
</tr>
<tr>
<td></td>
<td>Shoulder adduction (degrees)</td>
</tr>
<tr>
<td></td>
<td>Trunk flexion (degrees)</td>
</tr>
<tr>
<td></td>
<td>Finger abduction – 2nd to 4th digit (cm)</td>
</tr>
<tr>
<td></td>
<td>3rd digit to ball midline (cm)</td>
</tr>
<tr>
<td>Follow through</td>
<td>Wrist flexion (degrees)</td>
</tr>
<tr>
<td></td>
<td>Wrist deviation (degrees)</td>
</tr>
</tbody>
</table>

Table 3 Joint range of motion measured for each subject during the free throw

<table>
<thead>
<tr>
<th>Skill Phase</th>
<th>Joint Range of Motion Calculated (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force producing</td>
<td>Wrist flexion</td>
</tr>
<tr>
<td></td>
<td>Elbow flexion</td>
</tr>
<tr>
<td></td>
<td>Shoulder flexion</td>
</tr>
<tr>
<td></td>
<td>Trunk extension</td>
</tr>
<tr>
<td>Follow through</td>
<td>Wrist flexion</td>
</tr>
<tr>
<td></td>
<td>Wrist deviation</td>
</tr>
</tbody>
</table>

Measurement of wrist range of motion

Wrist flexion and extension were measured using 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 bone 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, 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. See Figure 2 for examples of wrist range of motion measurements.

Measurement of elbow range of motion
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, See Figure 3.

Measurement of shoulder range of motion
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; see Figure 4 for examples of shoulder range of motion measurement.

![Measurement of shoulder joint range of motion](image)

**Measurement of trunk range of motion**

Trunk flexion was measured in the sagittal plane and was 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. See Figure 5 for an example of trunk flexion measurement.
Measurement of shooting hand variables

Hand placement on the ball was determined using the distance tool in Dartfish. Ball diameter was used as a reference distance in the frame from which measurements were recorded. Female subjects used a size 6 basketball with diameter 23.25cm and males a size 7 basketball with diameter 24.34cm, regulation sizes according to the International Basketball Federation rules (FIBA, 2008). 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 time one and time two, 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 centerline in the frontal plane. If the digit was lateral to the centerline the value was recorded as positive, likewise if the digit was medial to ball
centerline the value was recorded as negative. The question of whether or not the
subjects palm was in contact with the ball was answered categorically on a yes or no
basis, and was determined using the anterior film view. See Figure 6 for examples of
hand measurements taken.

![Figure 5 Measurement of shooting hand position and placement](image)

**Statistical Analysis**

The variables listed in Table 2 were measured for each subject’s best shot captured on
film. 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 subjects 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. Microsoft Excel 2007 and
the XLSTAT add-in were used for all statistical analyses.
Paired t-tests were used to compare groups between their initial and final testing sessions. Twelve continuous variables were analyzed in this manner with significance level $p \leq 0.05$. Free throw percentage results were compared within six control and experimental groupings according to age and sex, see Table 4 for a complete summary. Due to the variances within the biomechanical data, results were pooled for all subjects into experimental and control groups in order to achieve the required subject numbers to determine significance. The Wilcoxon signed rank sum test 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 change 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 significance level $p \leq 0.05$.

**Table 4 Summary of groupings for statistical analysis of free throw percentages**

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>All subjects</td>
<td>70</td>
</tr>
<tr>
<td>Female subjects</td>
<td>33</td>
</tr>
<tr>
<td>Males subjects</td>
<td>37</td>
</tr>
<tr>
<td>Age 14 subjects</td>
<td>23</td>
</tr>
<tr>
<td>Age 15 subjects</td>
<td>24</td>
</tr>
<tr>
<td>Age 16 &amp; 17 subjects</td>
<td>23</td>
</tr>
</tbody>
</table>
RESULTS

The following section will report the means and standard deviations of all groups in the study for the initial and final testing sessions. The means of the measured variables are 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.

**Within groups across time**

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 pre/post manner allowed for paired tests for both continuous and categorical variables.

**Free throw percentage**

Free throw percentage was measured in both control and experimental groups before (test 1) and after (test 2) the free throw practice sessions. Analysis was completed for each of the groups presented in Table 4, free throw percentage means and standard deviations are presented along with the calculated $p$-value in Table 5.
Table 5 Means, standard deviations (SD) and t-test comparisons of the free throw percentages for control and experimental groupings (* indicates statistical significance $p \leq 0.05$)

<table>
<thead>
<tr>
<th>Group</th>
<th>Test 1</th>
<th>Test 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>All subjects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.677</td>
<td>0.169</td>
<td>0.668</td>
</tr>
<tr>
<td>Experimental</td>
<td>0.622</td>
<td>0.161</td>
<td>0.688</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.629</td>
<td>0.164</td>
<td>0.604</td>
</tr>
<tr>
<td>Experimental</td>
<td>0.565</td>
<td>0.142</td>
<td>0.633</td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.722</td>
<td>0.166</td>
<td>0.728</td>
</tr>
<tr>
<td>Experimental</td>
<td>0.670</td>
<td>0.163</td>
<td>0.733</td>
</tr>
<tr>
<td>14yrs old</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.525</td>
<td>0.088</td>
<td>0.508</td>
</tr>
<tr>
<td>Experimental</td>
<td>0.561</td>
<td>0.144</td>
<td>0.591</td>
</tr>
<tr>
<td>15yrs old</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.745</td>
<td>0.157</td>
<td>0.706</td>
</tr>
<tr>
<td>Experimental</td>
<td>0.613</td>
<td>0.187</td>
<td>0.700</td>
</tr>
<tr>
<td>16&amp;17yrs old</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.767</td>
<td>0.147</td>
<td>0.792</td>
</tr>
<tr>
<td>Experimental</td>
<td>0.694</td>
<td>0.123</td>
<td>0.770</td>
</tr>
</tbody>
</table>
Subjects 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 analysis of all groupings from Table 4. Analyzed together the experimental subjects that completed training with use of the ShotLoc training tool showed a statistically significant improvement in free throw percentage, going from 62.2% prior to training to 68.8% post ShotLoc training (Figure 7). Males trained with the ShotLoc showed an improvement from 67% pre-training to 73.3% post-training, see (Figure 8).
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%. Subjects 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 (Figure 9). Although not showing statistical significance control groupings of all subjects, females, 14 year-olds and 15 year-olds actually showed reduced post-training free throw scores.

Figure 8 Free throw percentage of 15 year-old subjects trained with the ShotLoc across time (*p≤0.05), N=24

Key Position: Hand Overhead

Variables describing hand positioning taken at the hand overhead key position were analyzed at test 1 and test 2 for each subject. Both variables were measured in centimeters. Means, standard deviations, and calculated p-value results are reported in Table 6 for all subjects in the control and experimental groups.
Table 6 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)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Test 1</th>
<th>Test 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Finger abduction (cm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>8.911</td>
<td>8.600</td>
<td>0.246</td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td>8.192</td>
<td>8.747</td>
<td>0.127</td>
</tr>
<tr>
<td><strong>Distance 3rd digit to ball midline (cm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>3.332</td>
<td>3.637</td>
<td>0.499</td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td>3.960</td>
<td>3.308</td>
<td>0.289</td>
</tr>
</tbody>
</table>

No statistically significant differences existed within groups at the hand overhead position; however the experimental group approaches significance improving mean finger abduction from 8.192cm prior to 8.747cm following training with the ShotLoc.

**Key Position: Release**

At the key position of ball release three continuous variables were measured for each subject prior to and following four weeks of training. Means, standard deviations and t-test results for these variables are reported in Table 7. None of the measured biomechanical variables at the position of ball release changed with statistical significance in either the control or experimental groups across time.
Table 7 Means, standard deviations (SD) and t-test comparisons of measured variables at the release position for control and experimental groupings (*p≤0.05)

| Variable                        | Group     | Test 1 |    | Test 2 |    | 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 |

**Key Skill Phase: Force Production**

For the purposes of this study the force producing phase of the free throw was marked from the position of maximum knee flexion to the position of release. 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. Means, standard deviations and t-test comparisons for the force producing variables can be found in Table 8.
Table 8 Means, standard deviations (SD) and t-test comparisons for the force producing ranges of motion for control and experimental groupings (*p≤0.05)

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

Control subjects 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, see Figure 10. Neither the control or experimental groups showed a difference from test 1 to test 2 in any of force producing elbow, shoulder nor trunk ranges of motion.
Figure 9 Force producing wrist ROM of control subjects trained with the ShotLoc across time (*p≤0.05), N=35

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 9. Subjects 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, see Figure 11.

Table 9 Number of subjects in each group with no contact between the palm of the hand and the ball for control and experimental groupings, Wilcoxon test results (*p≤0.05)

<table>
<thead>
<tr>
<th>Group</th>
<th># of subjects with palm off the ball</th>
<th>Test 1</th>
<th>Test 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control n=35</td>
<td></td>
<td>16</td>
<td>18</td>
<td>0.484</td>
</tr>
<tr>
<td>Experimental n=35</td>
<td></td>
<td>20</td>
<td>28</td>
<td>0.013*</td>
</tr>
</tbody>
</table>
Figure 10 Number of experimental subjects with contact between the palm of the hand and the ball across time (*p≤0.05), N=35

Key Skill Phase: Follow through

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. Paired t-tests were utilized to assess differences within the control and experimental groups across time; at test 1 and test 2. No differences were found within groups at a significance level p≤0.05, see Table 10.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable</th>
<th>Test 1</th>
<th>SD</th>
<th>Test 2</th>
<th>SD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist flexion ROM (deg)</td>
<td>Control</td>
<td>75.001</td>
<td>26.521</td>
<td>71.618</td>
<td>21.542</td>
<td>0.477</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>72.182</td>
<td>23.371</td>
<td>71.909</td>
<td>20.339</td>
<td>0.934</td>
</tr>
<tr>
<td>Wrist ulnar deviation ROM (deg)</td>
<td>Control</td>
<td>19.450</td>
<td>16.911</td>
<td>18.598</td>
<td>13.078</td>
<td>0.768</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>13.425</td>
<td>10.119</td>
<td>17.139</td>
<td>11.486</td>
<td>0.069</td>
</tr>
</tbody>
</table>

Table 10 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)
**Between groups across time**

Twelve continuous variables measured for each subject at test 1 and test 2 were compared across control and experimental groups using a two-way repeated measures analysis of variance. The outcome of interest was the presence of an interaction between group and time and would suggest that the groups actually differed from one another, see Table 11. Free throw percentage showed an interaction of main effects with a p-value of 0.048. Using a Newman-Keul’s post hoc test it was determined that the control and experimental group were significantly different at test 1 but not at test 2, see Figure 12. Force producing range of motion showed an interaction with a p-value of 0.037, there was a significant difference between groups at test 1 but not at test 2.

![Figure 11 The interaction between group and time for successful free throw percentage (*p≤0.05)](image)

Whether or not subjects hand palm 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, see Figure 13. Subjects in the experimental group showed a significant reduction in ball contact with the palm of the hand.
Table 11 Means, standard deviations and p values of the all continuous variables for both control and experimental groups at Test 1 and Test 2 (*p ≤ 0.05)(Exp = experimental, HO = hand overhead, FP = force producing, R = release, FT = follow through)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control Group Test 1</th>
<th>Control Group Test 2</th>
<th>Exp. Group Test 1</th>
<th>Exp. Group Test 2</th>
<th>f-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=35</td>
<td>N=35</td>
<td>N=35</td>
<td>N=35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free throw %</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.677 (0.169)</td>
<td>0.668 (0.170)</td>
<td>0.622 (0.161)</td>
<td>0.688 (0.181)</td>
<td>3.973</td>
<td>0.048*</td>
</tr>
<tr>
<td>HO: Finger abduction (cm)</td>
<td>8.91 (1.54)</td>
<td>8.60 (1.51)</td>
<td>8.19 (2.07)</td>
<td>8.75 (1.21)</td>
<td>1.660</td>
<td>0.179</td>
</tr>
<tr>
<td>HO: Distance 3rd digit to ball midline (cm)</td>
<td>3.33 (2.92)</td>
<td>3.64 (2.69)</td>
<td>3.96 (3.04)</td>
<td>3.31 (3.08)</td>
<td>0.633</td>
<td>0.595</td>
</tr>
<tr>
<td>FP: Wrist flexion ROM (deg)</td>
<td>13.24 (21.20)</td>
<td>18.85 (19.79)</td>
<td>25.73 (25.46)</td>
<td>22.38 (20.34)</td>
<td>2.903</td>
<td>0.037*</td>
</tr>
<tr>
<td>FP: Elbow extension ROM (deg)</td>
<td>89.57 (18.03)</td>
<td>86.06 (16.46)</td>
<td>83.57 (17.29)</td>
<td>79.85 (17.16)</td>
<td>1.980</td>
<td>0.120</td>
</tr>
<tr>
<td>FP: Shoulder flexion ROM (deg)</td>
<td>55.68 (22.49)</td>
<td>56.30 (22.35)</td>
<td>53.79 (27.23)</td>
<td>57.07 (24.16)</td>
<td>0.360</td>
<td>0.782</td>
</tr>
<tr>
<td>FP: Trunk extension ROM (deg)</td>
<td>7.35 (6.06)</td>
<td>6.91 (6.01)</td>
<td>11.40 (11.86)</td>
<td>11.46 (13.56)</td>
<td>1.307</td>
<td>0.275</td>
</tr>
<tr>
<td>R: Finger abduction (cm)</td>
<td>7.89 (1.45)</td>
<td>8.17 (1.61)</td>
<td>7.63 (1.64)</td>
<td>7.52 (1.74)</td>
<td>0.996</td>
<td>0.397</td>
</tr>
<tr>
<td>R: Distance 3rd digit to ball midline (cm)</td>
<td>0.83 (1.64)</td>
<td>1.17 (1.78)</td>
<td>1.40 (2.25)</td>
<td>2.06 (2.33)</td>
<td>2.413</td>
<td>0.064</td>
</tr>
<tr>
<td>R: Shoulder adduction (deg)</td>
<td>11.51 (8.75)</td>
<td>11.98 (9.40)</td>
<td>9.69 (10.65)</td>
<td>11.63 (10.60)</td>
<td>0.630</td>
<td>0.597</td>
</tr>
<tr>
<td>FT: Wrist flexion ROM (deg)</td>
<td>75.00 (26.52)</td>
<td>71.62 (24.05)</td>
<td>72.18 (23.37)</td>
<td>71.91 (20.34)</td>
<td>0.257</td>
<td>0.856</td>
</tr>
<tr>
<td>FT: Wrist ulnar deviation ROM (deg)</td>
<td>19.45 (16.91)</td>
<td>18.60 (15.01)</td>
<td>13.42 (10.12)</td>
<td>17.14 (11.49)</td>
<td>1.479</td>
<td>0.223</td>
</tr>
</tbody>
</table>
**Figure 12** The interaction between group and time for palm contact with the ball during force production (*p≤0.05)

**Figure 13** The interaction between group and time for force producing range of motion at the wrist (*p≤0.05)
SUMMARY OF STATISTICALLY SIGNIFICANT FINDINGS

Within the control group between test 1 and test 2

1. Force producing range of motion at the wrist increased from 13.24 degrees to 18.85 degrees.

Within the experimental group between test 1 and test 2

1. Free throw percentage for all subjects increased from 62.2% to 68.8%.
2. Free throw percentage for male subjects increased from 67.0% to 73.3%.
3. Free throw percentage for fifteen year-old subjects increased from 61.3% to 70.0%
4. Percentage of subjects with contact between the palm of the hand and the ball during force production reduced from 42.9% to 20.0%.

Between groups and between test 1 and test 2

1. Free throw percentage in the experimental group at test 1 (62.2%) was lower than that of the control group at test 1 (67.7%)
2. Experimental subjects (20%) had less contact between the palm of the hand and the ball during force production than control subjects (48.6%) at test 2.
3. Force producing range of motion at the wrist was higher in the control group than in the experimental group at test 1 (12.49 degrees)
DISCUSSION

**Basketball Shooting: Extension and release of the shot**

**Extension**

The force producing movements are the movements of the body parts that produce upward and forward force to project the ball to the basket, that include leg and trunk extension as well as straightening of the shooting arm. During the force producing movements the ball is held in front of the body with the right shooting hand directly behind the ball, and the left hand to the side and underneath the ball. The fingers are well spread and the ball sits on the base of the fingers and the pads of the fingers, not directly on the palm. The force producing movements for the shot begin when the trunk reaches the vertical position and the ball is held just above shoulder level. At this point the knees are in maximal flexion and the vertical velocity of the ball is zero. From this position the first true force producing movements are the extension of the knees and hips and the elevation of the ball by shoulder flexion. The timing of the movements is that the knees and hips are extended initially; followed by shoulder flexion, then elbow extension and wrist flexion. One error sometimes seen during the force producing movements for the shot is excessive shoulder girdle elevation in which the shoulders are brought upwards closer to the ears. This position of excessive tension in the trapezius can lead to high levels of shoulder and neck tension, and may interfere with smooth shoulder flexion during the shot. Another error sometimes seen during the trunk extension phase is trunk hyperextension occurring in the lower back. This appears as excessive lumbar lordosis, or increased curvature of the lumbar spine. This position can lead to lower back strain from too much tightness in the spinal extensors.
Figure 14 Ideal shooting stance with the shooter facing the basket, feet slightly staggered in the forward backward direction, and excellent range of knee flexion and trunk flexion.

Ideal shooting stance should have the shooter facing the basket directly, with the ball over the shooting side, or directly above the right foot for a right handed shooter. The toes should be facing the basket, the hips and shoulders should be square to the basket. Knees and hips should be flexed, and trunk should be flexed forward between 40° and 50° to the vertical (Figure 14). Feet should be staggered slightly in the forward backward direction, with the feet shoulder width apart in the sideways direction.
Figure 15 Knees and hips are extending as trunk approaches vertical and shoulder is flexing upwards. Elbow and wrist angles are constant as they have not yet begun to make their contributions. Note shooting hand is directly underneath the ball and non shooting hand is supporting the lower left side of the ball.

Figure 16 Player is facing too far to the left for a right handed shooter. Player should be facing directly forward with the toes pointing to the basket. Ball should be over the shooting side and not the non shooting (left) side.
Figure 17 Player has extended the trunk and the knees are extending while the ball remains stationary above the forehead. Shoulder flexion angle is moved to above horizontal and elbow flexion remains optimal; this is an excellent shot because the elbow remains flexed as the knees are extended and shoulder flexion begins.

**Shooting Arm Movements**

As the knees are extending, the shooting shoulder is flexed (the upper arm is raised upward) to the horizontal position so that the upper arm is almost parallel with the floor (Figure 17). As the upper arm is raised to the horizontal the elbow flexion is increased to close to 130 degrees of flexion. Much of the power for the shot comes from extension of the elbow and the flexion of the wrist at release (Hartley and Fulton 1971). The elbow must be kept directly under the ball during the shot, so that all the forces are directed toward the basket (Figure 18). The elbow should be kept as close to the body as possible during the shot (Haskell 1985). The elbow position checklist suggests that the elbow should be directly under the ball (Figure 18), pointed toward the basket and over the front foot prior to the upward movement of the ball (Haskell 1985).
Figure 18 Player on the right has good position of the elbow with the elbow directly underneath the ball. Player on the left has elbows extending too far out to the sides of the body, decreasing potential lift on the ball.

The wrist also should be positioned into extreme hyperextension as the ball is raised above the head to maximize the range of flexion that can occur during the shot. The wrist range of motion during the free throw shot has been reported to be 54 degrees (Vaughn 1993). From this position with the ball at forehead level, the upper arm is raised to a more vertical position by means of shoulder flexion. This shoulder flexion movement is one of the most important for the shot, as it produces much of the upward force for the elevation of the ball, as well as helping to cock the elbow and wrist to increase their range of motion. The average shoulder flexion range of motion has been reported to be 82 degrees for elite players (Vaughn 1993). The shoulder flexion movement is followed by the extension of the elbow joint, which is also an important force producing movement in the skill.

**Timing of Arm Movements**

One key to a skilled shot is for the player to hold the position of the elbow in flexion (bent) while the shoulder is flexing at the beginning of the arm movement. The average
elbow flexion range of motion for the free throw has been reported to be 80 degrees for Division I male players (Vaughn 1993). Some players make the mistake of lining up their nose with the target and not lining up the shooting shoulder with the target. The ball must be kept lined up with the shoulder, and not with the midline of the body (Meyer and Litzenburger 1974). The release point should be directly in front of the shooting side of the body, in front of the right shoulder and hip, and the body should be squarely facing the basket and not turned to the side (Figure 16).

The sequence of the upper body joint movements should be: trunk extension, shoulder flexion, and then elbow extension and wrist flexion together. A common error in shooting is to perform elbow extension and shoulder flexion at the same time, so there is a lesser contribution from elbow extension in the shot as its contribution is combined with the shoulder flexion instead of adding to the velocity of the hand. As the ball is being brought upward with both hands, it will pass directly in front of the shooter’s eyes and the shot will actually be aimed with the eyes under the ball.

**Position of Hands on the Ball**

The ball should rest on the pads of the fingers and the heads of the metacarpals (base of the fingers) as it is being raised upwards. The fingers should be spread comfortably on the ball with the fingers pointing straight forward or upward (Booher 1990). The back of the shooting hand faces the body initially, and the non shooting hand is on the side of the ball. The fingers should remain pointing forward throughout the shot, with the fingers extended toward the basket (Figure 19). The fingers should be flexed only slightly at the base of the fingers; rather the fingers and palm should act as one unit.
moving only at the wrist. The ball should not rest on the palm of the hand as ball control comes from the fingers and thumb. The ball is held in the shooting hand with the hand behind the ball and the middle finger splitting the ball in half. It has been suggested by some that the index finger splits the ball in half (Haskell 1985), but this is not commonly seen in skilled players. Most skilled players line up the middle finger with the middle of the ball.

![Figure 19](image1.png)

*Figure 19 Note the middle finger of the shooting hand is lined up with the middle of the ball, which is correct*

The non shooting hand is used as a support on the side of the ball as it is raised from waist level to a position above the head. This non shooting hand is held underneath the ball with the fingers along the side of the ball. A common error is the hold the non shooting hand too far on top of the ball (Figure 20), which brings the non shooting shoulder too far forward as the ball is raised for the shot. If the non shooting hand remains underneath the ball it allows the shoulder to rotate back as the shooting shoulder is brought upward and forward for the shot. Shoulder girdle rotation is an important aspect of lining up the shooting side of the body with the basket.
Figure 20 Player has non shooting hand too far on top of the ball. This has brought the non shooting shoulder too far forward. Ball leaves middle finger last, palm facing basket and fingers extended towards basket.

Figure 21 Good position of the fingers on ball, well spread with no palm contact, but fingers pointing left. Hand is too far to the right side of the ball, should be directly under the middle of the ball. The elbow is not directly under the ball, forearm is angled so elbow outside of ball. Non shooting hand on left has incorrectly rotated to face the basket.
Wrist Flexion and Backspin

The wrist is held in hyperextension (fingers pulled back towards the face) during most of the elbow extension (Figure 22); the ball is then released during forceful wrist flexion from a hyperextended position. The ball moves up along the fingers to the fingertips during release, with the index or middle finger being the last to leave the ball (Haskell 1985). Other authors have suggested that the ball leaves from both the index finger and middle finger of the shooting hand (Booher 1990). All good basketball shots should be released with a forward flick of the wrist (wrist flexion) to produce backspin on the ball. Backspin is produced by an eccentric or off center force, a force that does not pass directly through the CG of the ball. In this case, the force is applied to the outside of the ball by pulling the fingers underneath the ball during release--this produces backspin on the ball as well as assisting the forward-upward trajectory of the ball.

Figure 22 Good position of wrist hyperextension that is maintained as elbow is extending
Backspin has two major roles in a basketball shot--it stabilizes the flight of the ball in the air, and it produces a softer rebound on contact with the backboard which may produce a score (Adrian and House 1987). Any time a ball has spin on it, it carries a small layer of air around with it as it travels to the target--this layer of air stabilizes the flight of the ball by equalizing the air pressure on the ball from all directions. Any turbulence encountered by the ball en route to the basket will not affect its flight because the boundary layer of air protects it from this turbulence. The rotation on the ball should be three to three and a half times on the way to the basket (Haskell 1985) or a rate of rotation of 3 Hz, or three revs per second (Tran and Silverberg 2008). The ball should rotate around a left right axis parallel to the backboard, and it should have counterclockwise spin or backspin for a right handed shooter. Less rotation or sideways rotation will not stabilize ball flight and the ball may wobble en route to the basket.

As the wrist is being flexed, the lower arm is also pronating during release of the ball to impart more backspin to the ball in order to stabilize the flight. Pronation is recommended because it will help ensure that the spin is occurring around the left-right axis only, and no side-spin is imparted to the ball. If the lower arm moves into supination (hand facing the midline of the shooter), then there is often sidespin imparted to the ball that may produce erratic flight or an off center rebound. If the wrist and hand movements are started before the elbow extends, the ball will not receive proper backspin and will have no spin or spin around the incorrect axis, which will cause the ball to float like a knuckleball (Hartley and Fulton 1971).
Release of Shot

The critical instant in shooting is the instant of ball release, since following release nothing the shooter can do will affect the flight of the ball. At release the trunk and legs should be fully extended, indicating that these joints have made a full contribution to the flight of the ball (Figure 23). In a skilled shot the trunk is in full extension, the hips and knees are fully extended, and the ankles are fully plantarflexed (toes pointing to the ground). Some players will leave the floor during release of the ball, indicating a forceful push off from the floor. If the player leaves the ground during release of the shot, the feet should land in the same spot as the takeoff. A common error in shooting is to float slightly backwards or forwards at release, leading to a landing behind or in front of the point of takeoff. The trunk should be vertical and not leaning forward or backward during the release and follow through of the shot (Penrose and Blanksby 1976).

The shooting shoulder should be in 140-150 degrees of flexion, a position in which the shooting arm is almost pointing vertically to the ceiling (Figure 23). A good coaching cue is a near vertical shooting arm as the ball is released, to ensure optimal vertical velocity is imparted to the ball. The elbow should be approaching full extension at release, to ensure that this joint has made a full contribution to the flight of the ball. It has been reported that a full range of elbow movement is related to greater success in the free throw of club level basketball players (Stankovic, Simonovic et al. 2006). However, there will be slight flexion in the shooting elbow, as the ball is released at peak angular velocity of the elbow, and this occurs in mid range and not at full extension. The wrist should be in mid flexion at release, a position halfway between full extension and full
flexion to ensure that the hand is moving at maximum wrist angular velocity as the ball is being released. If the ball is released too early or too late, the velocity of the ball will not be optimum as the wrist and elbow joints will be speeding up or slowing down rather than being at peak velocity. Wrist flexion provides the final thrust for release of the ball and helps determine both the velocity and angle of projection of the ball (Hess 1980; Martin 1981).

The non shooting hand should drop off the ball just prior to the instant of release (Hartley and Fulton 1971; Penrose and Blanksby 1976), so that the shooter can retain control over the ball as long as possible (Figure 25). A study of jump shooters revealed that top players removed the non shooting hand from the ball significantly later than did the average group (Penrose and Blanksby 1976). As the wrist is flexing for release, the non shooting hand will drop off to the side of the ball with the palm facing the ball. It is important that the non shooting hand remain in position facing the ball during release, so that it does not impart any unwanted sidespin to the ball from lower arm supination (hand facing backwards) or pronation (hand facing forward) during release. A common error in shooting is to rotate the non shooting hand to face forward or backward as it comes off the ball, to the possible detriment of the shot by imparting unwanted off center forces to the ball at release.

The ball should be released as high as possible, since the higher the ball is released the less time it is in the air to the basket and the less time it has to move off target. Release height is related to height of the player, amount of trunk extension, shoulder flexion and elbow extension at release, and whether the shooter leaves the ground during release (Figure 23). Also, less time in the air is related to a lower velocity
at release, so joint range of motion is smaller and release time is decreased. Elite shooters have been found to have a higher release point and less trunk inclination than less skilled shooters (Hudson 1982; Hudson 1985).

![Image of basketball player shooting](image)

**Figure 23** Good release position of the ball with ball released from as high as possible. Ball is released at point of maximum velocity of elbow and wrist. Excellent wrist flexion on follow through. Body is erect and not leaning forward or back.
Figure 24 Elbow extension is nearing completion while wrist remains in extension through release; shoulder flexion has reached completion of the range of motion, trunk has rotated to the left to line up shooting arm with the basket so number on his back is visible. Ball is rolling off the fingertips during release as elbow continues to extend and wrist is flexing. Fingers are moving forward under the ball to produce backspin.

Arch of the Shot

After the ball leaves the shooter’s hand it becomes a projectile that has a parabolic pathway to the basket. The ball can reach the basket with a high arch or a lower arch, with the higher arch giving the greatest chance for the ball to go into the basket. As most coaches have by now determined, the most effective arc for a successful shot is one which is as high as possible—the closer to 90 degrees the angle of approach of the ball to the hoop, the greater the probability of making the score. Brancazio, 1984 has suggested that a good technique for coaches to use in evaluating the arc of the shot of their players is to stand near the sideline, and watch the flight of the ball. If the arc of the ball is at least at the height of the top of the backboard, the arc is sufficient. If the arc does not reach the top of the board, the shot is probably too flat to be consistent. However, the amount of arc on a shot is also related to the strength of the player, and some players may not have sufficient strength to attain a high arc from past 15 feet from
the basket. A higher arched shot requires more strength to generate the vertical velocity required for the attainment of a greater peak height.

The optimal vertical velocity for a basketball free throw is between 6.0 and 6.3 m/sec, depending on the height of release; with an angle of release of 50-55 degrees (Brancazio 1981). The theoretical angle and speed of release was determined experimentally to be 60 degrees and 7.3 m/s, but these values have not been measured directly from skilled players (Hamilton and Reinschmidt 1997). A computer model of the ideal free throw for a player 6 feet 6 inches tall is 52° from the horizontal (Tran and Silverberg 2008); most shooters shoot with a lower angle of release than the optimal. In the two groups of elite university players in the current study, over 80% of the players shot at an angle of between 45- 50 degrees. A higher vertical velocity would require significantly more muscle force, which would necessitate a larger range of motion from the legs and shooting arm and would differ markedly from the shot technique used in a game.

Figure 25 Controlled and balanced follow through with correct alignment of shoulder, hip and knee, good range of shoulder flexion, elbow extension and wrist flexion. Shooting arm is aligned with the shooting shoulder; trunk is rotated away from the shooting arm to line up with hoop.
Muscle Relaxation

The release of the basketball must be accompanied by relaxation in the muscles of the shooting arm, with no excessive tension in the shooting arm or wrist and hand. Only the muscles required to project the basketball should be contracted; and all other arm and shoulder muscles should be loose and relaxed so as not to interfere with the action from the hand and wrist (Alexander 1988). The active muscles should include the shoulder flexors, the elbow extensors, the finger extensors and the wrist flexors; the remainder of the shooting arm muscles should be relaxed. Skilled players are able to relax completely the muscles opposite those needed for the shot being performed, so that no unnecessary tension interferes. A loose wrist and fingers and relaxed shoulder and elbow joints following release of the ball are indicators that the shooting arm is relaxed (Alexander 1988).

It has been reported that unsuccessful shots were associated with a longer muscle activation period, as measured using electromyography, suggesting that muscle tension should be minimal during release for success in shooting (Miller 1999). Shots requiring the least amount of energy to be expended at release are the easiest to control and have the greatest probability of success (Huston and Grau 2003). The player in Figure 23 shows a very relaxed shooting arm and hand, related to his effective shooting technique. In mechanically correct shots, the wrist, forearm, upper arm, and right side of the body will be in a straight line and perpendicular to the floor (Hartley and Fulton 1971; Ball 1989). All the resultant forces should be only in a straight line to the basket, so that the wrist and hand will not have to compensate for improper placement of the
elbow. A common error made by many shooters is having the elbow pointing out to the side (excessive shoulder horizontal abduction) rather than in a straight line with the wrist and hand (Hartley and Fulton 1971).

Figure 26 Full extension of the shooting arm at release; ball is lined up with the shoulder, hip and knee of the shooting side; non shooting lower arm is incorrectly rotated forward (pronated) as it comes off the ball.

In the player in Figure 26, the shooting arm may be experiencing excessive tension in the wrist and finger flexor muscles - the arm does not appear to be relaxed following release as fingers are extended and abducted and wrist is locked. The arm in the follow through should appear as it does in Figure 23, with the shoulder fully flexed, the elbow extended, the wrist fully flexed and fingers relaxed and slightly flexed at the knuckles (metacarpophalangeal joint). This position is often called the “goose-neck” pose, due to the fully extended arm (neck) and flexed hand; and is often used by coaches to check for the correct form in the follow through.
Release Height

One key to effective free throw shooting is that the body remains erect and vertical during release of the ball (Penrose and Blanksby 1976). This will ensure optimal vertical velocity is imparted to the ball at release, and will be conducive to a higher release point. The higher the ball is released, the less time it is in the air before reaching the basket and the less time for off line velocity to act. Since most male players release the ball from a higher point than most females, the optimal release velocity is less for most males (6.0 m/s) than for most females (6.35 m/s) (Satern 1993). The higher peak height of release will give the ball a greater angle of approach to the basket, a larger diameter of hoop to fall through, and a greater chance of scoring (Hay 1993). The closer the release height to the height of the basket, the smaller the projection angle needed and also the less the velocity of release needed (Kreighbaum and Barthels 1996). Height of release has been found to be important to the success of the shot, as (Hudson 1983) has noted that successful shots are significantly related to a height ratio calculated by comparing the standing height of the shooter to the height of the shooter’s release. The higher the release height, the better the shot. Studies have reported that shots of highly skilled players are released higher than those of less skilled players; and a higher release is related to greater flexion at the shoulder which is desirable (Hudson 1982). Successful shots were released an average of 4 cm higher than those that were unsuccessful (Hudson 1982). Higher release height is attained by greater shoulder flexion and elbow extension at release (Yates and Holt 1983). This position gives the shooter a higher release point and a more vertical angle of ball projection.
Figure 27 Ball has left the hand but shoulder flexion, elbow extension and wrist flexion remain incomplete at release. Trunk should be vertical at release rather than leaning forward, knees should be fully extended at release.

Follow Through

The final phase of the shot is the follow through, in which all the joints continue to move through to the end of their full range of motion following release of the ball. In the skilled follow through, the legs are fully extended and the ankles are plantarflexed (toes pointing to the floor). The trunk is vertical and the shooting hip is lined up vertically with the knee and ankle, as well as with the joints of the shooting arm. The shooting shoulder is in at least 140-150 degrees of shoulder flexion - the closer the upper arm is to the vertical the better the shot because the greater the vertical forces applied to the ball. This movement of the joints to the end point of their range of motion will ensure that the joints do not stop moving prior to release of the ball, which would decrease the release velocity of the ball. The trunk should be rotated away from the shooting hand, to line up the shooting shoulder and arm more directly with the hoop. This trunk rotation
should occur during the release of the ball from the hand, as it is facilitated by the dropping off of the non shooting hand from the ball.

After the ball has left the hand the elbow should reach full extension, the wrist should be fully flexed, the lower arm should be in pronation and the fingers should be pointing slightly to the outside, indicating that pronation has occurred during the shot. The elbow extension and wrist flexion are responsible for application of upward force and spin to the ball at release, which will help to stabilize the flight of the ball on the way to the basket.

Figure 28 Shooting arm has crossed the midline following release of the shot, and is now pointing to the left. Shooting arm should remain pointed toward the basket. Hand is pointed too far toward the right indicating too much pronation has occurred.
Common Errors in Free Throw Shooting

1. **Poor Alignment** - Many shooters fail to line up the shooting side hip, knee, shoulder and elbow with a line through the ball to the basket. If any of these joints is out of alignment the shot is more likely to be released off line and miss the basket.

2. **Lack of Backspin** - players often apply sidespin to the ball at release; or else apply no spin at release. Both of these errors will affect the flight of the ball and may cause it to go off line en route to the basket; or to rebound off the backboard too hard or sideways and not drop into the hoop.

3. **Low arc on the shot** - players who do not have sufficient shoulder flexion, elbow extension or trunk extension during release often release the ball too flat; a high arc is required to ensure the ball has the maximum area of the basket to utilize on entry.

4. **Relaxation of the shooting arm** - the shooting arm should be completely relaxed during the shot, with only the active mover muscles contracted and all others loose and relaxed. Too much tension in the non-mover muscles of the shooting arm will interfere with the smooth release of the ball and shorten the follow through.

5. **Full follow through after release** - players should finish in the full goose neck position of the shooting hand with the arm pointing to the ceiling and the hand pointing directly to the basket.

6. **Interference from non shooting hand** - If the non shooting hand is pronated or supinated at release it may move the ball out of alignment with the hoop, or apply unwanted spin to the ball.
7. **Ball shot too hard**- When a player is excited or tired they may release the ball with too much horizontal speed and it will bounce off the back of the rim and miss the basket.

8. **Too much tension in shooting arm**- shooting arm should be in full shoulder flexion, elbow extension and wrist flexion at release of the ball. If muscles are tense it may decrease the range of motion of these joints and interfere with the shot. Contraction of the trapezius may also interfere with shoulder movements.

9. **Taking off at an angle**- Player taking off or landing at an angle to the floor- either forward or backward- will produce an off center jump and apply non-vertical forces to the ball. Takeoff and landing should occur from the same footprints.

**Off balance at Release**- Player is either leaning forward, backwards or sideways during the release of the ball, which will produce an off center force on the ball at release. This may also cause the player to be off balance as they leave the floor.

The purpose of this study was to determine the effectiveness of the ShotLoc shooting tool of free throw performance and technique. Controlled and consistent shooting technique is key to free throw performance and free throws can be the deciding difference between a team’s winning or losing a basketball game. Many other basketball shooting and training tools are available for purchase but none with scientific research on the biomechanical and performance outcomes of using these aids.

For analysis the free throw was divided into several key positions and skill phases including the position of maximum knee flexion, force producing range of motion, the position of hand overhead, the position of release and the range of motion in the follow through. 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 limb with a goal of looking for the effects of use of the ShotLoc shooting tool on the shooting hand. The subjects were tested initially by scoring free throw percentage and filming two to three trials of the free throw. Subjects were filmed from the anterior, sagittal and posterior aspects to ensure that all biomechanical variables could be measured. Subjects completed an average of four training sessions having been randomly assigned to either the control or experimental groups. Subjects 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. The ShotLoc training tool consisting of a foam band with four holes for digits 2-5 sits just distal to the metacarpophalangeal joints. It spreads the fingers comfortably and lifts the centre of the palm away from the ball. Two prototypes were used by the subjects, one constructed of white foam was slightly softer and more form fitting and the other constructed of black foam that was more rigid and resilient against becoming fitted to the hand. It was found during the study that the black more rigidly constructed ShotLocs were more likely to break, usually at either the first or last finger hole. Subjects participating in the study were always asked for feedback on how they felt wearing the ShotLoc and how they felt it may have affected their shooting performance. 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
subjects 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. It was suggested to those athletes that found the constriction uncomfortable to try a larger size. Most athletes found the ShotLoc very comfortable to wear during shooting practice sessions. Generally they
found that it held the hand in a comfortable open position, prevented the ball from contacting the palm and aided in release and follow through form. The design of the ShotLoc is such that it forces the fingers into a widespread but comfortable position. This in effect distributes the forces imparted by the wrist equally across the ball by forcing the athlete to use all fingers to control the ball. The hand is put into a more optimal position for release allowing the ball to leave from the third or second and third digits. Subjects were commonly observed to hold the fingers close together during force production and release, but especially during the follow through phase of the skill (Figure 29). Adduction of the fingers at any point during the shot can produce off-centre forces and impart unwanted side-spin or trajectory to the ball. When using the ShotLoc the fingers are held in this ideal position throughout the entire shot ensuring no unwanted forces are produced, athletes finish the shot with perfectly spread fingers with the palm of the hand flat (see Figure 30 & 31). The resultant increase in free throw percentage found in subjects who had trained with the ShotLoc may be the result of this increased ball-control, as accuracy and consistency improved within the experimental group.

Figure 31 The ShotLoc holds the fingers and palm in an ideal position throughout the follow through phase of the free throw
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 (Figure 32).

![No contact between the ball and palm of the hand following training with the ShotLoc](image)

Subjects were recruited from Basketball Manitoba’s Elite Player Development Provincial Team Program. The program divides players by sex and age into categories of seventeen years and under, fifteen years and under and fourteen years and under. Individual players who did not wish to participate in the study were given the opportunity to decline participation. Training sessions were conducted at the beginning of each team’s regularly scheduled practices and lasted from 20-30 minutes. During that time coaches were encouraged to work with the athletes as they would during a normal shooting practice. The level of coach participation was varied, some coaches became quite involved during the training sessions and some chose to allow athletes to
complete the shooting practice without any interactions. Subjects were not coached differently based on their participation in either the experimental or control groups. The subjects recruited for this study were of elite developmental caliber; their motor skills, coordination and free throw ability were no doubt advanced when compared with other athletes of similar age. Having many hours of practice and advanced skills these athletes already have very well developed motor patterns. Shooting mechanics in these athletes will be very well established including less than ideal technique. Athletes may in fact have developed compensatory movements to account for these technical faults.

Very commonly athletes develop a habit of what has been termed ‘piano fingers’ during the preparatory phase of the skill, where their fingers are flexed and extended, abducted and adducted during setup for the shot in an attempt to achieve a perfect grip. This can occur in both the shooting and non shooting hand. Some players may use this technique as part of their preparation as a method of relaxation, ridding the fingers and hands of tension for the shot. If the athlete though cannot settle his/her grip and continues the ‘piano fingers’ too long it may have adverse effects on the shot. It was noted in one subject that had this problem that when she wore the ShotLoc for shooting practice the motion in the fingers was prevented. She was able to settle into her grip earlier and the consistency and control of her shot improved immediately. The subject’s non shooting hand displayed the same ‘piano finger’ technique and so as a trial she was fitted with an additional ShotLoc on the non shooting hand. Again, motion of the fingers was prevented and further improvement in shooting technique and consistency was noted by both the researcher and coach. Use of the ShotLoc may assist athletes in finding a comfortable and effective grip on the ball by reducing their ability to shift
around prior to release and this may contribute to the development of the consistency required of a good free throw shooter.

Statistical analysis of free throw percentage in this study showed a 6.6% increase in those subjects who were trained with the ShotLoc during the training period. Measured against the control group a significant difference existed between groups at test 1 but not at test 2. Though not statistically significant the control subjects actually had a decline free throw percentage across time of 0.9%, indicating that there was no change in free throw performance in the control group.

When statistically analyzed separately by sex, male subjects in the experimental group showed a significant improvement over time whereas female subjects did not. It is difficult to speculate the possible causes for these observations. Male subjects when compared to females of the same age possess a higher skill level and better free throw performance. It would be logical to assume that female subjects would benefit more from the use of a shooting aid such as the ShotLoc, clearly though this is not the case.

One possible explanation for this is that the reasons for missed free throws are different for males vs. females. Young female basketball players frequently lack the strength to execute the free throw with perfectly ideal technique. As was observed in the fourteen and fifteen year old subjects females will adopt a technique closer to a two handed overhand throw in order to achieve the force required to make the shot. Use of the ShotLoc cannot make up for the strength deficits demonstrated by the young female subjects and this could be a reason that no improvement was seen in these subjects.

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 subjects 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 subjects were not tested wearing the
ShotLoc re-learning of hand position on the ball must have occurred.
When analyzed by age the fifteen year old experimental subjects showed a significant
improvement in free throw performance, a result not observed within the other age
groups. Again it is difficult to pinpoint the exact cause for these results however similar
reasoning can be applied. The ShotLoc theoretically will be most effective on 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 within the
shooting hand the ShotLoc would have minimal effect on performance. Fourteen year
old subjects 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. As previously discussed the timing of the shot is
imperative to successful shooting. Correction of timing faults occurring throughout the
shooter’s entire force producing skill phase are beyond the capabilities of the ShotLoc
shooting tool. If then the younger subjects involved in this study were suffering from
inconsistent timing during the shot the ShotLoc would have no effect on performance.
Subjects belonging to the sixteen and seventeen year old experimental group entered
into the study with very highly developed skills and already fairly good free throw
performance and technique. In such subjects correction of established motor patterns, if required, could be expected to be more difficult than in a younger less experienced subject.

Subjects 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 subjects 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 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.

Analysis of the mechanical aspects of the free throws within groups across time and between groups across time mostly 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. This could have resulted from anomalous data or human error during either the recording or data analysis stages.

Due to the repetitive nature of basketball shooting practice established motor patterns are difficult at best to alter or change. Introduction of the ShotLoc training tool at this
stage in development may be less than ideal in that it will be very difficult to change the
established motor patterns. Four 20-30 minute training sessions wearing the ShotLoc
may not be sufficient to induce any noticeable changes in the athlete’s throwing
technique. Increasing the number of exposures to the ShotLoc may result in more
noticeable differences in technique across time. It may be of interest to repeat this type
of study using subjects with less skill as it could be expected that they might benefit
from the biomechanical guidance provided by the ShotLoc. Introducing the ShotLoc to
athletes early in their athletic development could be useful in developing good
mechanics during shooting; use of the tool in this manner could prevent poor habits
from becoming established motor patterns. When used in a corrective manner the
ShotLoc can provide athletes with a valuable external cue for a more correct hand-to-
ball position. Much repetition with the ShotLoc would be required for the athlete to re-
learn a more correct shooting motor-pattern.

The results presented in this study are very positive towards the effectiveness of the
ShotLoc on free throw performance. Subjects who wore the ShotLoc for the described
training period significantly improved their free throw percentages. It is hypothesized
than an even greater difference would be observed in younger less experienced/skilled
players. The results of this study conclude that the ShotLoc is a valuable training tool for
teaching correct hand positioning and encouraging proper hand to ball contact during
the basketball free throw.
REFERENCES


FIBA. (2008). Official basketball rules No. 1


Haskell, D. M. (1985). When shooting free throws, a player's body and mind must work as one if the shot is to be successful. Athletic Journal, 66(1), 30-31: 54.


A. The Naypalm (JumpUSA, 2010b)

B. The J-Glove (JumpUSA, 2010a)
C. Shooters Fork (Morley Athletic, 2009)
April 16, 2010

Ethics Board
Dr. Marion Alexander
Faculty of Kinesiology and Recreation Management
University of Manitoba
Winnipeg, MB R3T 2N2

To whom it may concern,

Basketball Manitoba has reviewed the research proposal on the ShotLoc presented to us by Dr. Marion Alexander. The study time, consisting of four 15 minute filmed sessions with our players shooting free throws is perfectly acceptable to us. We would encourage our Basketball Manitoba players to participate in this study. The feedback provided by this study will help further educate our athletes on their shooting technique and is a welcomed opportunity to our program.

Signed consent forms have been provided and will be required of all participants for participation in the study.

Adam Wedlake
Executive Director
Basketball Manitoba

Dan Becker
Technical Director
High Performance Coach
Basketball Manitoba
Guidelines for Informed Consent

Parental Consent Form (Subjects under 18 years)

Research Project Title: An examination of the effectiveness of the ShotLoc shooting device on free throw shooting technique of developing basketball players.

Researcher(s): Marion J.L. Alexander, Professor, Faculty of Kinesiology and Recreation Management

Sponsor (if applicable): Hoops Innovation Ltd.

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Outline of the Study:

The purpose of this study is to examine the basketball free throw shooting techniques of the participants in Provincial Junior Basketball Programs sponsored by the Manitoba Basketball Association. A number of young basketball (both male and female) players who are members of six provincial teams will be asked to use the ShotLoc during 4 fifteen minute practice sessions for free throw shooting (SL group). The young basketball players will be members of Manitoba boys and girls Provincial Basketball teams in the following three categories: Under 17 or Juvenile players, Under 15 or Midget players and Under 14 or Developmental players. The study will consist of a pretest of free throw shooting and video filming of shooting; followed by four 15 minute shooting practice sessions; followed by a posttest of free throw shooting and video filming.

The data will be collected over 4 weeks during the May-July training period while the teams are preparing for their National championships.

Methodology:
The players will be filmed during free throw shooting while attending a Provincial Basketball Practice session, using filming equipment from the Biomechanics Laboratory in the Faculty of Kinesiology and Recreation Management. All Provincial basketball practices are organized and administered by the coaches recruited to administer the programs who will instruct the athletes regarding the shooting techniques to perform. Prior to filming each athlete, the filming procedures will be explained to each group of athletes. Each player will be asked to perform the free throw shooting as normally performed in a game situation, and the techniques will be filmed. Parents must provide informed consent for the athlete’s participation in the study prior to filming. All filming procedures will be organized and administered by the principal investigator, Dr. Marion Alexander, who will be assisted by qualified graduate students. In addition to the filming of the technique, the score will be recorded for the number of shots made out of a total of 30 free throws.

Two or three video cameras will normally be used to film the athletes: one placed at the side of the athlete, and one placed to the rear of the athlete at a safe distance from the players, and one at a diagonal angle to the participant if required. The video cameras will be started together to ensure that they start and stop at the same instant. The cameras will capture the face of the subjects in some views, but the film will only be viewed by the researchers, the athlete and the coach. Faces can be blacked out if film is used to illustrate specific technique variables to coaches. The investigators will instruct the athlete regarding which shooting skills are to be performed while the cameras are filming.

Following the initial filming procedures and the free throw test, all subjects will be given four 15 minute shooting practice sessions. The experimental group will be asked to practice while using the ShotLoc to enhance technique. All subjects will then be filmed again while shooting free throws, as well the score out of 30 free throws will be determined. When filming is completed, the films will be analyzed by the principal investigator and the graduate students working on the project. The most skilled two shots for each player will be analyzed in detail. This detailed analysis will consist of measurement of the key positions and angles of the player’s shooting arm and trunk. The angles to be compared will be measured at four key shooting positions: during the position of maximum knee flexion, when the ball is at eye level, at maximum elbow extension, and at release of the ball. The following angles will be measured at each position: finger flexion angle, finger abduction angle, thumb angle relative to the palm, wrist flexion and adduction angles, elbow flexion and release angles, elbow valgus angle, alignment of the wrist, elbow, shoulder and shooting hip, shoulder angle and trunk angle. The angles at the hips and knees will not be measured in this study.

An overall evaluation of the technique free throw shooting for each athlete will be provided to the coaches in an oral session with the coaches and the athletes, as well as on a prepared CD for coaches and athletes. The CD will contain the selected video clips that best represent the skill performance of each of the athletes. It is possible that some of the technique descriptions developed from this analysis may eventually be published in a technical journal in basketball. If so, the identity of the person shooting will be blacked out.

**Risks/Benefits:**

There is no additional risk involved in this study, as the athlete will perform the skills as they would normally perform them in a practice situation. The shooting glove will not interfere in any way with the technique or performance of the shot. The cameras will be out of the way, and will not
interfere with your performance of the skills. The film will be kept confidential, and will only be used for
the purposes of this study and to assist the athlete in their shooting technique.

A possible benefit to participation in the study is in improvement of shooting technique. It is possible
that the improved hand position on the ball and improved finger alignment produced by the ShotLoc
will increase shooting skill and accuracy.

Confidentiality:

The film will be viewed only by the researchers involved in the study, the coaches, and
by the athletes filmed in the study. The amount of data and skill analysis information available
to the athletes will be determined by the coaches. The data derived from the film will be
available to the coaches and athletes in order to help to improve performance. The video films
and all of the research data will be kept in a locked cabinet in the Biomechanics laboratory, and
will not be used for any other purpose than the current study. No one will have access to the
films or data except the principal investigator and the research assistants. After the project is
completed the films and the data will not be used again.

Signature of Parents or Guardians:

Your signature on this form indicates that you have understood to your satisfaction the
information regarding participation of your child in the research project and agree to
their participation as a subject. In no way does this waive your legal rights nor release
the researchers, sponsors, or involved institutions from their legal and professional
responsibilities. Your child is free to withdraw from the study at any time, and /or refrain
from answering any questions they prefer to omit, without prejudice or consequence.
Call M. Alexander to withdraw. Your child’s continued participation should be as
informed as your initial consent, so you should feel free to ask for clarification or new
information throughout your child’s participation.

Principal Researcher: Marion J.L. Alexander, Professor, Faculty of Kinesiology and
Recreation Management, University of Manitoba, Ph 474 8642

This research has been approved by the Education/Nursing Research Ethics Board. If
you have any concerns or complaints about this project you may contact any of the
above-named persons or the Human Ethics Secretariat at 474-7122. A copy of this
consent form has been given to you to keep for your records and reference.

If you are an athlete under the age of 18 years, signed consent must be provided by your
parent or guardian in order for you to participate in this project. Please have your parent
or guardian sign in the appropriate space below.

Researcher and/or Delegate’s Signature

Date
Parent and/or guardian’s signature (if under 18 years)       Date
_________________________________________________________________

I would like to request a copy of the findings of this study. ___yes ____no

Name: ________________________________________________

Address: ________________________________________________

Additional Information for parents, guardians and athletes:

• Athletes will be provided with a CD that contains only their own shooting video films and analysis. The athlete will be able to keep the individual CD to study their performance.

• The identity of athletes will be made available only to the coaches and the athletes, since coaches are also attempting to improve shooting skill. Each subject will be given an identification number in our analysis, and shooting data will be stored only by identification number.

• Coaches will not be involved in review or detailed analysis of films for the study. Coaches will be present when the films are viewed by the athletes involved and may offer technique opinions or suggestions at that time.

• Parents or athletes can request a summary of the findings of the shot analysis, and of the study as a whole by signing above and providing their name and address.

• The findings of the study will be provided to Hoop Innovations Inc, who have developed the ShotLoc device. They may use the findings in their product advertisements, if the findings appear to be positive. There will be no individual subject identities disclosed to the company.

• There may be a basketball shooting technique article written from our laboratory based on the findings of this study. It may appear on the web in a site such as the Manitoba Basketball or Basketball Canada web site, or in a Basketball Technical Journal. No subject identities will be disclosed in such a publication.
APPROVAL CERTIFICATE

April 16, 2010

Hoops Innovation

TO: Marion Alexander
Principal Investigator

FROM: Lorna Guse, Chair
Education/Nursing Research Ethics Board (ENREB)

Re: Protocol #E2010:041
"Effects of ShotLoc on Free Throw Shooting"

Please be advised that your above-referenced protocol has received human ethics approval by the Education/Nursing Research Ethics Board, which is organized and operates according to the Tri-Council Policy Statement. This approval is valid for one year only.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- If you have funds pending human ethics approval, the auditor requires that you submit a copy of this Approval Certificate to Eveline Sorella in the Office of Research Services, (e-mail eveline.sorella@umanitoba.ca or fax 251-0325), including the Sponsor name, before your account can be opened.

- If you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.


Bringing Research to Life