Training Quiet Eye Improves Accuracy in the Basketball Free Throw

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University basketball players (Team A) received quiet eye (QE) training over two seasons of league play, compared to two control teams (Team B and Team C), who competed at the top of the same league but did not receive similar training. QE was defined as the player’s final fixation on the hoop or backboard prior to the shooting action. In Season 1, Team A improved significantly, Pre to Post, in experimental accuracy, QE duration, and relative shot timing but did not transfer these improvements to league play during the season. At the conclusion of Season 2, Team A improved their free throw shooting accuracy by 22.62% to 76.66%, more than Team A (66.18%) or B (74.05%). The results highlight the importance of training a sustained duration of QE on a single location on the hoop prior to the execution of the shooting action. Theoretical and applied implications of training QE are discussed, and recommendations are made for future research and training.

The purpose of this study was to determine if training quiet eye (QE; Vickers, 1996a, 1996b, 1996c) would improve the free throw shooting accuracy (FTM%) of university basketball players over two seasons of league competition. The ability to shoot free throws is critical in the game of basketball, with many contests decided by performance in this one skill. Free throw accuracy in the National Basketball Association in the 1999/2000 season averaged 75.08% (National Basketball Association Statistics, 2000), while that of the Women’s National Basketball Association averaged 73.09% (Women’s National Basketball Association Statistics, 2000). Individual statistics from both leagues ranged from the low 40s to high 90s. Although the free throw is taken without any direct interference from opponents and relatively near to the hoop, such a wide range in FTM accuracy at the highest level of play is perplexing. A closer look at these statistics also shows that some players record very high levels of accuracy when shooting from the floor (or field shooting), indicating they have mastered the technical requirements

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of shooting under conditions of pressure from opponents, but have very low accuracy in the free throw. These discrepancies suggest that problems in shooting the free throw may lie in areas additional to, or complementary to, the mechanics of the skill. In this study we concentrated on one dimension, that of training QE, which targets the visuo-temporal control of the gaze relative to the final shooting action.

**Quiet Eye**

QE is an objective measure of the location, onset, offset, and duration of the gaze recorded while the participant performs a motor skill (Vickers, 1996a, 1996b; Vickers & Adolphe, 1997). During QE, fixation or tracking is maintained on a specific location or object in space. Onset of QE occurs in advance of movement time (MT), and offset occurs when the gaze deviates off the fixated or tracked location. QE offset may occur before, during, or after MT. QE has been shown to be a characteristic of higher levels of skill and accuracy in basketball (Vickers, 1996a, 1996b, 1996c), darts (Vickers, Rodrigues & Edworthy, 2000), billiards (Frehlich, 1997; Frehlich, Singer, & Williams, 1999), rifle shooting (Janelle, Hillman, Apparies, et al., 2000; Janelle, Hillman & Hatfield, 2000; Vickers, Williams, Rodrigues, Hillis & Coyne, 1999), and the volleyball serve reception and pass (Adolphe, Vickers & LaPlante, 1997; Vickers & Adolphe, 1997). In each of these skills, it has been found that the highly skilled performer maintains a longer duration of fixation or tracking on a critical location than those with lower skill.

Movement time (MT) plays a critical role in the definition of QE and is defined as that portion of an action that is “common to all performers.” In basketball, as in many other skills, performers have unique preparatory actions that vary greatly from individual to individual. For example, in the free throw, some participants do not have a down phase (Vickers, 1996a); in table tennis, some do not have a backswing (Rodrigues, 2000). Despite considerable variability in these initial behaviors, all have a final MT. QE was therefore defined as the participant’s final fixation on the hoop or backboard prior to the extension of the arms/hands/ball into the shot. As such, QE was the performers last acquisition of target information before the shooting movement was initiated.

**Visual Control in Near and Far Aiming Skills**

It is customary for coaches and teachers in basketball to tell their players to hold their gaze on the hoop as they shoot (Knudson, 1993; Wissel, 1994). This advice is given because intuitively, one would think there is a direct link between the ability to maintain fixation on the hoop and aiming accuracy. Extensive research in aiming to near targets has also reinforced this thinking, as the target in near aiming skills is fixated as the final movement of the hand is made to the target (Abrams, 1994; Abrams, Meyer & Kornblum, 1990). Since most research on aiming has concentrated on near aiming skills where the target is within arm’s reach, it is not surprising that performers have been advised to maintain fixation on the target in all types of aiming skills, whether the target is near, far, or some combination of these distances.

Research on aiming to far targets, such as that found in basketball, shows that a different type of visuo-motor control is used. The gaze behaviors of expert basketball (FTM% above 75%) and near-expert (below 56%) basketball players
were recorded while they performed free throw shots to a regulation basket. It was found that the experts fixated the target earlier in the preparation of the shot and sustained fixation on the hoop prior to MT. During sustained fixation, QE was maintained on a single location on the hoop for a duration of almost one second, and this occurred before the shot was initiated. In contrast, the near-experts had a later onset of QE, a shorter duration, and fixation was maintained on the hoop as the shot was taken. Surprisingly, the experts did not maintain QE on the hoop during the final 300 to 400 ms of the shooting action. Instead, their eyes and head moved freely as their hands moved through the visual field to complete the shot.

The Pre-Shot Routine

The pre-shot routine is a set of repetitive behaviors performed prior to the final execution of a skill that is designed to improve concentration and performance. Feltz and Landers (1983), in a meta-analysis of mental training studies in a range of skills, found that training the cognitive elements of the skill at the same time as the physical components are practiced leads to greater improvements in performance than either alone. Effect sizes for three studies reported in the free throw that permitted extensive physical and mental practice, were .91, 1.6, and 2.6, supporting the notion that the most effective preshot training regime is one that permits higher levels of both mental and physical practice to occur.

Preshot routines in the free throw normally include an initial phase during which the end performance is visualized, followed by the skill being performed under conditions that simulate game conditions. Preshot routines have been described by Amberry (1996), who holds the world record for consecutive free throws (2,750). The preshot routine helps the shooter feel prepared and confident before the release of the ball and helps avoid external distractions and negative thoughts as the shot is taken. The preshot routine is viewed as a mind clearing process, which leads to a muscle synergy stage that in turn leads to a quick fluid shooting action, one that is efficient and economical. Despite the reported efficacy of these methods, none provide objective information about how the visual system contributes to accuracy in the free throw and more specifically, how vision is coordinated with the mechanics of shooting. Training QE, therefore, differs from other preshot routines as the performer is taught how to control the gaze relative to the mechanics of shooting.

QE Analysis and Training Method

The QE analysis and training methods used in the current study were adapted from those used in a study in volleyball (Adolphe, Vickers & LaPlante; Vickers & Adolphe). Team Canada male athletes were trained to improve their tracking on the ball during the serve reception and pass, followed by a three-year follow-up of their passing accuracy compared to top international players. QE was defined as that portion of pursuit tracking that occurred on the ball prior to the first step taken to receive the ball. Five phases were followed in the study. First, the player’s gaze was recorded in a pretest, while they received the ball and passed to the setter area in a game-like setting. The athlete’s QE onset, offset, and duration were determined during successful and unsuccessful passes to the setter area. As the QE of the highly skilled receivers differed significantly from that of the lower skilled (Vickers & Adolphe), this information was used for training purposes.
A QE training program was developed in which the athletes received feedback of their pursuit tracking, relative to an expert prototype (a member of the team with international pass reception statistics in the top ten). During the feedback session, the athletes were shown how to control their gaze in a manner similar to the expert prototype. On-court training sessions followed during regular practices, during which they performed drills designed to optimize their QE tracking. Six weeks after training, each athlete underwent a posttest, where their gaze was recorded as in the pretest. Transfer effects were assessed over three seasons, using passing data supplied by the International Volleyball Federation. The results showed significant pre-post improvements in QE tracking onset (earlier), QE tracking duration (longer), and number of step corrections (fewer). Over three seasons of international competition, it was found that those who had received QE training were significantly more accurate in passing than an equal number of international receivers (see Adolphe, Vickers, & LaPlante, 1997).

A similar process was followed in the current study, leading to the following expectations. In Season 1, QE training was expected to lead to significant pre-post improvements in Team A’s QE onset, QE duration, and QE location. This, in turn, was expected to contribute to Team A being significantly more accurate in free throw accuracy in both the experimental and league setting (Game FTM %). Transfer effects were assessed over two seasons of play (Season 1, Season 2), in which Team A’s FTM% in games was compared to two control teams (Team B and Team C). It was expected that Team A would be significantly more accurate than Team B or C over the two seasons.

**Method**

**Participants**

Participants were members of three women’s basketball teams, who played in the Canada West League of the Canadian Inter-University Athletic Association (CIAU). Only Team A participated in the pre-post test and underwent QE training. Teams B and C were selected at the conclusion of Season 2, based on their finishing in the final four of the national CIAU finals in each season. Table 1 summarizes the characteristics of the three teams and shows the number of league games played and number of players per team, the percent carry-over of players, and the number of players on Team A receiving QE training in each season. In Season 1, 11 athletes on Team A contributed to the league FTM statistics, but only eight were available to take both the pre- and posttest due to injury (2) or playing only one semester. In Season 2, six new players joined Team A and received modified QE training, meaning their gaze was not recorded but they did learn the 3-Step QE routine during regular practices. Ethics approval was received from the University of Calgary Ethics Board prior to testing.

**Collecting Vision-In-Action Data**

The Vision-in-Action (VIA) system (Vickers, 1996a) was used to simultaneously record the gaze, motor, and ocular behavior of the players as the free throws were performed. The VIA system was comprised of Applied Sciences Laboratories 501 eye tracker, an external camera, a time code generator, and two video mixers. Three video images were combined, as shown in Figure 1, enabling an analysis of
Table 1  Number of League Games and Number of Athletes on Team A, Team B, and Team C during Season 1 and Season 2

<table>
<thead>
<tr>
<th>Team</th>
<th>Team A</th>
<th>Team B</th>
<th>Team C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Season 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number League Games</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Total Athletes</td>
<td>11</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Athletes Pretest</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Athletes Posttest</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Athletes QE Trained</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Season 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>League Games</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Total Athletes</td>
<td>12</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>% Athlete Carry Over</td>
<td>50%</td>
<td>73%</td>
<td>92%</td>
</tr>
<tr>
<td>Athletes QE trained</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Note. Percent carryover of athletes in season 2 is shown as is the number of athletes on Team A receiving QE training.

* Three athletes were unable to complete the Posttest due to injury (2) or withdrawal from school.

the temporal control of the gaze relative to the movement of the arms/hand/ball during the shooting action. Image A was recorded by the eye camera on the tracker and shows the eye of the participant and origins of the corneal reflection eye data. Visible are the cross hairs denoting the center of the pupil and corneal reflection. Image B was recorded by the scene camera on the eye tracker and shows the hoop and backboard and location of the gaze, as indicated by the black cursor (accuracy of 1 degree of visual angle). Image C was recorded by an external camera placed in the sagittal plane to record the shooting action. A time code generator (D) recorded time in the three images at 30 Hz (33.33 ms).

The ASL 501 eye tracker is a monocular corneal reflection system that measures eye-line-of-gaze with respect to the helmet. The helmet has a 30-metre cord attached to the waist, interfaced to the main computer, thereby permitting the participant near normal mobility. Miniaturized optics (scene and eye camera), an illuminator, solid state sensor, relay lens, and visor are mounted on the helmet, which brings the total weight to 700 g. The ASL system measures the position of two features of the eye, the pupil and the corneal reflex. The corneal reflex is the reflection of a small, helmet-mounted light source from the surface of the cornea. By measuring both features, the system can accurately measure eye-line-of-gaze with respect to the helmet. The eye camera (mounted on top of the helmet) is directed at the eye via the reflective visor. It has appropriate magnification so that the camera “sees” approximately a one-inch square about the eye. The eye is illuminated by a near infrared light source that is beamed coaxially with the camera. The illuminator (which is invisible to the participant) retro-reflects from the retina, producing an image of a back lighted bright rather than dark pupil. The reflected image of the light source from the corneal surface appears as a very small spot that is even
Figure 1 — A frame of vision-in-action (VIA) data. Scene A shows the eye camera on the participant's eye as recorded by the eye camera on the tracker. The cross-hairs denote the corneal reflection and center of the pupil. Scene B presents the view from the scene camera on the eye tracker and shows the participant's gaze as indicated by the black cursor. Scene C was recorded by an external camera and shows the shooting movements of the participants. Time (D) was recorded at 30 Hz and synchronized in the three images.

brighter than the pupil image. The video image is processed by a computer to identify and determine the centers of the pupil and corneal reflex. By measuring the vertical and horizontal distance between the centers of the pupil and corneal reflex and correcting for second order effects, line of gaze with respect to the light source can be computed. Individual participant differences and the second order effects are then accounted for by using a short calibration procedure during which the participant fixates nine points in the scene.

In order to prevent mounting cameras in front of the participant's face, the optical path is bent by the visor that is coated to be reflective in the infrared and transmissive in the visible spectrum. The color scene camera is mounted under and in front of the visor and shows the reflected field of view in front of the participant. Thus, the scene camera appears to "see" the world from the same position as the participant's eyes and parallax problems are avoided. During set-up, the visor is oriented to pick up the optimal scene in front of the participant. A 40 degree vertical and 50 degree horizontal field of view is present when the head is fixed. However, since the participant is free to move the head, the scene changes with shifts in the participant's gaze. A square, transparent cursor (representing about one degree of visual angle) indicates the participants point of gaze in the scene and is superimposed on the video image to show the point of gaze. The system has an accuracy of ± 1 degree visual angle (the cursor width) and a precision of 0.5 degrees.

Pre-Post Protocol
The pretest of gaze and FTM occurred at the beginning of the Season 1, and the posttest occurred one week after national finals, a time span of six months. Pre-post
testing were similar and carried out at a regulation basket in the gymnasium where the participants practiced and played their games. The athletes first warmed up by taking free throws and then completed four blocks of 10 shots. The first block was performed without the eye tracker. Following this, the eye tracker was fitted and calibrated, and additional practice trials were taken to ensure comfort. The final three blocks of shots were then completed. In order to simulate conditions encountered in games, the participants stepped to the line, took two free throws, stepped off the line, and then back, in all blocks. Practice, calibration, and data collection took 45 minutes.

**Coding and Analysis of VIA Data**

The VIA data was coded in an editing suite equipped with frame by frame shuttle control and counter. The first ten hits and ten misses were coded for a total of twenty shots per participant. Five QE locations were defined, based on previous research (Vickers, 1996)—the front rim, back rim, left rim, right rim, backboard. QE occurred when the gaze was within one degree of visual angle of a location for a minimum duration of 99.9 ms (3 or more frames). QE onset occurred prior to MT and offset when the gaze deviated off the fixated location. Two phases of the shooting action were determined by the movement of the ball, as shown in Image C of Figure 1. The prep-down phase began with the frame showing the initial drop of the ball toward the floor, just prior to the final shot. The MT-Shot phase began with the first frame showing the ball moving upward into the shot to the basket. Offset of MT-Shot occurred during the first frame showing the ball off the fingertips.

**Protocol for Training Quiet Eye**

During Season 1, each athlete on Team A received video feedback of their QE, in a one-hour feedback session conducted in an editing suite with two monitors. During this session, they viewed their QE data relative to an expert free throw shooter, who exhibited control over QE similar to that found in previous research (Vickers, 1996a, b, c). During the feedback session, the participants were taught the 3-Step QE routine, consisting of the following steps:

1. **Take your stance at the line with your head up and direct your gaze to the hoop. Bounce the ball three times repeating the phrase slowly “nothing but net.”**

2. **Hold the ball in your shooting stance and maintain QE focus on a single location on the hoop for approximately 1.5 seconds. Keep you gaze stable on the one location, accompanied by the words “sight, focus.” You may fixate either the front, middle, or back rim. Regardless of the location fixated, maintain QE on only one location prior to beginning the final upward phase of the shot.** Note: this advice was given as previous research showed all three locations were effective (Vickers, 1996c).

3. **Shoot quickly using a quick, fluid action. The ball should move up through the center of your visual field, occluding the target. During this time, there is no need to maintain your gaze on the hoop as you shoot.**

After the video feedback session, the 3-Step QE routine was taught to all the players in an on-court session to all the players and then reinforced on an individual basis during practices throughout the season. In Season 2, all Team A participants, including the new players, were coached to follow the 3-Step QE routine.
using verbal instruction and the VIA tapes of the expert performers taken the previous season.

**Analysis of the Data**

Two steps were followed in the analysis of the data. First, in Season 1, pre-post differences were determined for Team A in experimental FTM\%, QE duration (ms), QE location (%), relative shot duration (%), and league FTM\%. Second, Team A's FTM\% in league games was compared to Team B and C during Season 1 and 2. Repeated measures ANOVA was used to analyze the data. Effect sizes were determined using procedures outlined in Thomas & Nelson (1996). Level of significance was set at $p < .05$.

**Results**

**Pre-Post FTM\%**

Free throw accuracy data were analyzed using a $2 \times 4$ (Test, Blocks) ANOVA, with repeated measures on the last factor. This analysis determined free throw accuracy, pre-post, across the four blocks of 10 shots. During the first block of shots, the eye tracker was not worn; therefore, the analysis also determined the extent to which the eye tracker affected accuracy. A significant difference was found for Test, $F(1, 21) = 10.67, p < .01$. $ES = .80$, a large effect. Pretest accuracy was 62.31\% ($SD = 16.65\%$) and posttest was 74.31\% ($SD = 12.86\%$). Figure 2 shows that Team A improved by 11.98\%, Pre to Post. There were no significant differences for Blocks, or interaction of Test $\times$ Blocks, indicating the eye tracker did not affect accuracy in either the pre or posttest.

**Quiet Eye Duration**

QE duration (ms) data were analyzed using a $1 \times 1$ (Accuracy, Test) ANOVA, with repeated measures on the last pre-post factor. A significant difference was found for Test, $F(1, 75) = 8.13, p < .006$. $ES = .23$, a low effect. Figure 3 shows that QE duration increased from the pretest, 783 ms ($SD = 628.77$), to posttest, 981 ms ($SD = 448.88$). The interaction of Accuracy $\times$ Test was significant, $F(1, 75) = 4.82, p < .03$. Figure 4 shows that QE duration on hits increased from 706.07 ms

![Figure 2 — Pre-Post free throw accuracy (FTM\%) of Team A in Season 1.](image)
(SD = 548.09) on the pretest, to M = 1061.30 ms (SD = 419.85) on the posttest. QE on misses increased from 857.19 ms (SD = .697.59) during the pretest, to 903.33 ms (SD = 467.67) during the posttest.

**Relative Shot Duration**

Duration data of the final two phases of the shot (prep-down, MT-shot) were determined in milliseconds and converted to relative time (%). Relative time (%) was calculated by dividing the duration of each phase by the sum of both phases (Schmidt & Lee, 1999). A 2 × 2 (Phase, Test) ANOVA was used, with repeated measures on the last factor. A significant effect was found for Phase, F(1, 76) = 49.91, p < .0001. ES = 2.7, a very large effect. The interaction of Phase × Test was significant, F(1, 76) = 27.29, p < .0001. Figure 5 shows that during the prep-down phase, relative time increased from 63% (SD = .19) to 68% (SD = .20), while in the MT-shot phase, relative time decreased from 37% (SD = .19) to 32% (SD = .20).

**Quiet Eye Location**

Percent QE to five locations on the hoop or backboard was determined (front rim, back rim, left rim, right rim, backboard) during the pre and posttests. Pre to post changes in QE location were front rim (pre 40%, post 35%); back rim (pre 23%,
Figure 5 — Pre-post improvement in relative shot duration (%) of Team A in the Prep-Down and MT-Shot phases in Season 1.

post 57%; left rim (pre 3%, post 1%); right rim (pre 1%, post 2%); backboard (32%, 4%). None of these differences were significant. As is evident, the greatest change after training was in the allocation of a higher percent of QE to the back rim and lower to the backboard.

**Accuracy Over Two Seasons**

A $1 \times 1$ (Team $\times$ Season) ANOVA, with repeated measures on the last factor, was used to determine the FTM% accuracy of Team A, B, and C over Season 1 and 2. Source of data was the Canada West Universities Athletic Association Basketball Statistics (Collins, 1999, 2000). A total of 20 games per season, or 40 total, was included for each team. No significant main effects were found for Team, but there was a significant effect for Season, $F(1, 22) = 4.87$, $p < .04$, $ES = .07$, a low effect. The interaction of Team $\times$ Season neared significance, $F(2, 22) = 3.03$, $p < .07$. A priori comparison of means found that Team A improved significantly over the two seasons, $F(1) = 8.16$, $p < .006$. Effect size = .92, a large effect. In Season 2, Team A was significantly more accurate than Team C, it's nearest competitor in terms of FTM%, $F(1) = 3.81$, $p < .05$, $ES = .16$, a low effect. Figure 6 presents the interaction of Team $\times$ Season and shows that over the two seasons, Team A improved from 54.14% to 76.66% (+22.6%), Team B declined from 67.67% to 66.18% (-1.5%), and Team C improved from 61.36% to 74.05% (+12.6%).

**Free Throws Attempted (FTA) and Free Throws Practiced**

Other data pertinent to each team's free throw performance was derived from Collins (1999, 2000) and summarized in Table 2. During Season 1 and 2, the number of free throws attempted (FTA) per player per team ranged from 26–42. Individual FTA range was 1–106, a wide range, but similar across teams and seasons. The head coaches of each team remained the same in Seasons 1 and 2. Each coach was interviewed by e-mail at the end of the Season 2 and asked to estimate the number of free throws taken in practice per week per athlete. This number varied from 5 per athlete per practice for Team A, 26 for Team B, and 40 for Team C. The number of free throws taken by each athlete on their own ranged from 100 per week for Teams A and B, to 300 for Team C.
Figure 6 — Percent free throws made (FTM%) by Teams A, B, and C over Season 1 and Season 2 of league play.

Table 2 Free Throw Shooting Accuracy (FTM%) of Team A in Season 1, Pre-Post. FTM% of Teams A, B, and C During Season 1 and 2 in League Play (Game FTM%), as Well as Average Free Throws Attempted (FTA) Per Athlete and Range FTA Per Team.

<table>
<thead>
<tr>
<th>Season</th>
<th>Team</th>
<th>Team A</th>
<th>Team B</th>
<th>Team C</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Pretest FTM</td>
<td>62.31%</td>
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<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Posttest FTM</td>
<td>74.31%</td>
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<td>n/a</td>
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<tr>
<td></td>
<td>Number League Games</td>
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<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>League Games FTM</td>
<td>54.14%</td>
<td>67.67%</td>
<td>61.36%</td>
</tr>
<tr>
<td></td>
<td>Average FTA/athlete</td>
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<td>36</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Range FTA</td>
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<td>20</td>
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<td></td>
<td>League Games FTM</td>
<td>76.66%</td>
<td>66.18%</td>
<td>74.05%</td>
</tr>
<tr>
<td></td>
<td>Average FTA/athlete</td>
<td>35</td>
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<td>42</td>
</tr>
<tr>
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<td>Range FTA</td>
<td>3-104</td>
<td>2-100</td>
<td>1-83</td>
</tr>
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</table>

Discussion

The purpose of this study was to determine if training QE over two consecutive seasons of league play would increase the FTM accuracy of Team A, compared to two control teams not receiving similar training. Team A received QE training, while Teams B and C served as controls and were selected, post-hoc, based on their finishing in the top four in national CIAU finals. In terms of the overall competitiveness of the teams in each season, Team B was the national champion in Season 1, Team C placed second, and Team A did not make it to the final eight
teams. In Season 2, Team C won the national championship, Team B was fourth and Team A was second. We therefore see that all three teams performed at a high level, defined by their standings in national championships.

Williams and Grant (1999, p. 198) state that “few studies have attempted to determine whether the pre to post-test improvement observed in clinical settings transfer to the sporting domain.” In this sense, the current study was unique in that it was situated within two competitive seasons of elite basketball, with the participants being athletes actively engaged in training and competition. In interpreting the results, the most important question to resolve is whether the improvements in Team A’s FTM% in both the experimental pre-post setting and in league play over two seasons was due to the QE training program or to other factors associated with coaching, training, and/or other reasons. We first highlight the strengths and weaknesses of the research, using four qualities outlined by Williams and Grant (1999) for conducting field research. They state that a competitive measure must be used, process measures of improvement must be determined, a control group included, and transfer effects determined to the real world of competition. We then identify other factors that may have accounted for the results, including practice procedures, carryover of players, and other factors. In the end, we provide a weight of evidence in support of QE training, concluding with a discussion of the theoretical significance of the work and recommendations for future research and training.

**Competitive Improvement**

In order to determine whether a valid improvement has been achieved as a result of training, Williams and Grant state that a competitive measure should be used, one provided by the sport itself and recognized as contributing to overall success and failure. FTM% was used, as recorded both in the experimental pre-post setting and also by the Canada West league, independent of the researchers. In Season 1, Team A increased its free throw accuracy in the experimental setting, pre to post, by 11.98% but did not show any improvement in games. Their FTM% in Season 1 was low, 54.14%, compared to 67.67% for Team B, and 61.34% for Team C. However, by the end of Season 2, Team A had improved their FTM% by 22.62%, an unusually large increase to 76.66%, while Team B declined—1.5% to 66.18%, and Team C improved by 12.6% to 74.05%. Team A ended Season 2 with a FTM that was 10.5% higher than Team B, 1.6% higher than Team C, 1.8% higher than the average for NBA, and 2.8% higher than the WNBA.

**Process Measures of Improvement**

Williams and Grant state that process measures of improvement are required, that is, measures of physiological, biomechanical, and/or psychological change that can be attributed to the training. Team A improved significantly after training in the duration of QE, which increased from 782 ms in the pretest to 981 ms in the post. The longest QE duration was observed on posttest hits (1,061 ms), indicating fixation was sustained longer prior to successful shots. These results agree with other studies of a similar nature (Adolphe et al., 1997; Frehlich et al., 1999; Janelle, Hillman, Aparies, et al., 2000; Vickers et al. 2000).

The relative timing of the shot also changed significantly, with 5% more time allocated to the prep-down phase and 5% less to the MT- shot. This was an unexpected finding, as there was no attempt made in training to change the timing of the shot beyond encouraging the athletes to shoot in a quick and fluid manner.
Instructions to shoot in this manner may have led to the faster MT-shot phase observed, but the change in the prep-down phase must have occurred as a result of allocating more time to QE, thus slowing the initial part of the action as a result of the sustained QE focus. This is an important finding, as it indicates a cognitive intervention precipitated a change in the mechanics of shooting. We therefore see that a number of process measures changed significantly, pre to post, following training. Team A exhibited a greater stability of QE, a longer duration of QE, and a change in the relative timing of the shot that lead to more time allocated to the preparation phase and less to the shooting action.

Transfer Effects

Effective field studies require a measure of transfer effects, that is, did the changes observed in training also affect competitive performance. A weakness of the current study (and perhaps field studies in general) is in being unable to conclude that the athletes transferred the improvements found in training to games. The current study does not provide evidence that changes in QE duration and relative shot duration, detected in the pre-post tests, were carried forward to games. Research conducted during competition would be necessary to establish this. Changes in relative timing would be easy to detect during games using external cameras; however, eye trackers are not small enough nor portable enough to be worn during competition. League rules also do not permit equipment of this type to be worn. The inevitability of this occurring, however, is high as eye trackers improve yearly in terms of size, portability, and cost.

Control Group Comparison

Measures of change, whether process or competitive, need to be compared to a control group. Two control teams were selected, based on their being in the top four in national finals. As summarized above, Team A achieved a higher average FTM in league competition than either Team B and C in Season 2. Team A’s improvement over the two seasons relative to Teams B and C neared significance (p < .07). Perhaps as important, Team A recorded a higher average FTM than the NBA and WNBA, standards of accuracy recognized internationally. No process measures were taken of Team A and B; therefore, it was not possible to report if Team A and B had similar or different QE duration and/or relative shot timing than Team A.

Other Factors

Within each season, a number of other factors may have affected the results, which additionally must be considered. All three teams maintained the same coaches over the two seasons, therefore the training environments were relatively similar from Season 1 to Season 2. E-mail post-hoc interviews with each of the coaches revealed that there was a difference in how each team practiced the free throw. The players on Team C practiced the most free throws per week, both in practice and on their own (40/300), followed by Team B (24/100), and Team A with the least (5/100). Therefore, the sheer number of free throws taken per week differed for each team.

Whitehead, Butz, Kozar, and Vaughn (1996) compared the free throw shooting technique and performance of skilled players during practice and games. They found that free throw shooters are inconsistent in how they train in practices and
then perform in games, taking longer to prepare the free throw in games as opposed to practices. Their study revealed that those who had developed one system of timing for practices, and another for games, tended to be less accurate during games. Shooting a large number of free throws in practice can be tedious, and therefore, players may rush this part of training and use a timing system in games that they have practiced very little. We have seen that the 3-Step QE routine required a more deliberate pace of shooting, with more time devoted to QE in the prep-down phase and less time to the MT-shot phase. You may also recall that Team A practiced the fewest free throws during practice. Further discussion with the head coach revealed that implementing the 3-step QE routine did create a practice habit that was more similar to games. Rather than practicing a large quantity of shots, Team A concentrated on taking fewer shots in a manner similar to competition. Following the 3-step QE routine in both practice and games may, therefore, have facilitated the development of a single timing system that transferred more readily to competition.

Did the carry-over of players from one season to another affect the accuracy of Team A? Team A had the lowest carry-over of athletes from Season 1 to Season 2, 50%, as compared to 72% for Control A and 92% for Control Team B. Of the six new players who joined Team A in Season 2, only one made the starting line-up. Together, all six contributed 21% of all free throws made or attempted, 12% by the one starting player. Was it possible that the increase in FTM was due to the addition of these new players? Game accuracy of the new players in Season 2 was high, 80.5% (range 43.8–100%), compared to 72.7% for the starting six. The high accuracy of the new athletes was surprising, leading to additional interviews to determine if they were exceptional shooters before arriving on the team or if the QE training they had received was responsible for their better performance. They reported that there was nothing in their previous history to account for their better performance. One summarized the comments of all in stating that the QE routine allowed her to step to the line, block everything out, focus, and shoot in a relaxed manner. We therefore see that Team A had a nucleus of six experienced players who accounted for 79% of the free throws taken and made in Season 2, yet it was clear that the new players did affect the overall accuracy of Team A from Season 1 to Season 2. These results suggest that using the 3-step QE routine was especially effective with the new players, allowing them to go into games and shoot very well, even though they had little court time.

Verbal interviews were conducted with the Team A participants over the two seasons in order to determine their reception of QE training and the extent to which they were able to transfer QE training to games. Overall, they appeared to be less concerned about incorporating QE control within their free throw routine, as compared to changing their shot mechanics. This might have been due to the uniqueness of QE and the perception that this was a new skill, one that could be added to established habits. The positive reception of QE training might also have been influenced by the objective nature of QE and the fact that the participants were able to see their own QE control and that of experts on the VIA tapes. In terms of the player's ability to transfer QE to games, the process of incorporating QE appeared to vary from individual to individual. All indicated they tried to implement QE, but sometimes in the pressure of games, they forgot, rushed the shot, and/or did not use QE appropriately.
Theoretical Considerations

The results lead to the question of what is most important in improving accuracy—QE location, QE duration, QE onset, or QE offset. Of these four variables, it would appear that, in the free throw, it is the timing of QE relative to the final shooting action that is most important. QE onset occurred about one second prior to the initiation of the final MT. QE remained stable on one location during this time, which was either the front or back of the hoop. During the shooting action, which was quicker after training, QE was not maintained on the hoop, and the shot was taken without regard for maintaining the gaze on the hoop.

This combination of visual and motor control characteristics has been called location-suppression (Vickers, 1996a). During the location phase, a specific target location is fixated for about one second prior to the final aiming movement. During this time, it is hypothesized that the neural networks underlying the aiming movement are organized during a period of sustained focus and concentration. Janelle, Hillman, Apparies, et al. (2000) and Janelle, Hillman, and Hatfield (2000) found that changes in neural firing do occur during aiming skills that require sustained QE on the target. They found an increased specificity in relevant neural pathways during successful rifle shots using a combination of eye movement techniques similar to that used in this study and simultaneous electroencephalograph (EEG) recordings.

During the suppression phase, which follows immediately after QE and coincides with the aiming action, vision is suppressed in order to prevent information entering the system that could perturb the aiming commands set during the location phase. In the free throw, the suppression phase was characterized by the ball moving into the visual field and occluding the hoop. During this time, the gaze was not maintained on the target. The duration of the MT-shot phase was significantly reduced after training QE, leading to the possibility that a faster shooting action may reduce the time during which external stimuli could affect the preprogrammed action. A similar result has been found in the dart throw, where the hand also occludes the target during the final throwing action (Vickers et al., 2000). In other skills, however, such as rifle shooting (Janelle, Hillman, Apparies, et al., 2000; Janelle, Hillman, & Hatfield, 2000) and billiards (Freihlich, 1997), research shows the target is not occluded by the hand. The gaze remains on the target location as MT occurs. The difference in these results indicates that there is much about the suppression phase that is yet to be defined.

Neural Networks and Degrees of Freedom

In this final section, we speculate about what might have happened from a neuro-motor perspective when QE was trained. When the participants selected a single location on the hoop and exhibited a long duration of QE prior to the movement of the hands into the shot, they may have optimized the use of three neural networks of visual attention, as described by Posner and Raichle (1994). These networks, called the posterior orienting, anterior executive, and vigilance networks, together possess specific characteristics that may be critical in planning and executing a complex shot like the free throw. The posterior orienting network is responsible for the control of the gaze in space. This network, which is located in the parietal region, functions to direct the gaze to specific locations of interest and importance
in a task. This network is also responsible for preventing the disengagement of the gaze to other locations. In this study, the participants may have used the posterior network to select and hold the gaze stable on a single location on the hoop, rather than let the gaze wander or drift to other locations as the shot was taken. The second network, the executive anterior network, is responsible for bringing into consciousness critical aspects of what is being fixated. The anterior network interprets what is seen and imposes higher-order understandings on a task. The executive network may have been responsible for facilitating the athlete's understanding and development of a new timing system that enhanced accuracy. This network may also have facilitated the development of a more fluid shooting action, one in which vision has a reduced role. Posner and Raichle explain that the third, vigilance network is responsible for coordinating the posterior and anterior networks and preventing unwanted or distracting information from gaining access to either during periods of sustained focus. In the free throw, the vigilance network may be responsible for the sustained concentration one sees over two or three shots, especially when taken during the pressure filled close game.

In conclusion, training QE led Team A to a more economical visuo-motor routine, as indicated by a longer duration of QE, a more stable QE on one location, a slower prep-down phase, and faster Shot-MT. These changes in visuo-motor control, in turn, appeared to contribute to Team A's increase in FTM accuracy. Bernstein (1967) has described the acquisition of skill as a process of reducing the degrees of freedom to lower and more manageable levels. In traditional forms of coaching, players are taught to hold the gaze on the hoop during the shooting action. If the gaze is held on the hoop at this time, then the athlete has to exercise hypothetical control over at least three degrees of freedom—the head, the gaze, and the hands/ball as the shot is taken. Instructions of this nature may increase the degrees of freedom to levels that are simply unmanageable. When QE is trained, fixation is maintained on the hoop prior to the shot, leaving only one degree of freedom to be controlled as the shot is performed, that of the hands/ball. Therefore, instead of trying to control three degrees of freedom during the critical aiming action, training QE simplifies the skill, leading to an economy in thought and action and higher levels of accuracy.

References


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