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The Impact of Spatial Occlusion Goggles on the Basketball Crossover Dribble

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Abstract

Spatial occlusion involves removing specific sources of visual information such as an object, limb or other information from the visuomotor workspace. In the sports context, limiting an athlete's visual system to sub-optimal conditions during complex motor skills such as the basketball dribble may be detrimental to performance. However, when normal visual conditions are returned performance may rise above its previous threshold, as athletes then rely less on visual information. In this study, we randomly assigned skilled basketball players into three groups; spatial occlusion (SPO), practice (PRA) and control (CON) and asked participants to execute a basketball crossover dribble task in a motion analysis laboratory. SPO and PRA groups underwent a pre-test, an acquisition phase, a post-test and retention test, while the CON group underwent no acquisition phase. During the acquisition phase, participants in the SPO group wore goggles that occluded vision of the limbs used during the basketball dribble., and the PRA group completed the same acquisition phase without occlusion goggles. Kinematic data during the crossover dribble task revealed a significant SPO group change in the height of the dribble at the third metacarpal ($p<0.05$) and significant improvements in the elbow angles ($p<0.05$) while neither the PRA or CON groups improved. The SPO group also showed a significant improvement in gaze fixations that was not experienced by the PRA or CON group. We conclude that spatial occlusion goggles applied in training may positively impact kinematic and gaze behavior of skilled basketball players' dribble performance.

Keywords: Spatial occlusion, Kinematics, Gaze behaviour, Basketball, Skill acquisition.

INTRODUCTION

Visuomotor coordination is the ability to use visual information, one of the most important sources of information gathered from the perceptual system, to generate appropriate motor skills [1]. Therefore, to accurately identify relevant visual information during the execution of complex motor skills, and the appropriate use of visual attention, is essential for both motor learning and motor performance [2].

Visual Occlusion is the process of limiting the vision of an object, limb or critical information source from the visuomotor workspace and is typically classified as temporal or spatial occlusion. Traditionally, temporal occlusion is the process of removing or masking visual information across different time periods [1]. Whereas, spatial occlusion involves removing specific sources of information from the visuomotor workspace such as a limb or racket [1]. Early research in visual occlusion used video-based simulation to identify differences in ability between skilled and less skilled athletes in racquet sports [3,4]. This approach continues to be a feature of more up to date occlusion research [5,6] using video-based temporal occlusion as a training intervention to assess and improve goalkeeper's ability to anticipate penalty kicks in football through a computerized response or verbally prediction of kick direction. Even though the approach continues to be a feature of the domain, questions regarding its effectiveness as a method of testing and training in real-world tasks remain. The primary concern relates to whether video simulation can effectively create a representative learning environment; especially with the method of response being computerized or verbalized [5,6]. If participants are not required to perform the movement response or complex motor task coupled with what they perceive, the learning may not be as beneficial.

A number of temporal occlusion studies have looked at addressing the gap in the literature to assess if 'visual occlusion through video simulation' and 'visual occlusion performed in an applied setting' are comparable [7-10]. Research in the domain of tennis [8,10] and more recently by Broadbent et al. [7] assessed the impact of video-based temporal occlusion in a laboratory and applied (on court) setting. Broadbent et al. [7] assessed the impact of video-based temporal occlusion practice structure, sequential and non-sequential, on participants' ability to return tennis strokes. Results demonstrated that video-based training had a positive impact on both the sequential and non-sequential group in the laboratory setting. The results of the field based transfer test also demonstrated positive improvements for the sequential and non-sequential group. Despite variations in video-based training interventions, similar findings were reported in previous research by Farrow et al. [8] and Williams et al. [10]. Although temporal occlusion has produced positive results in a laboratory and applied setting, it is important to question potential flaws in temporal occlusion as a concept. The primary concern with this approach is that typically the entire visual scene is removed milliseconds before, after or at the point of occlusion. Although this forces the visual system to process the scene in an intermittent manner resulting in a positive improvement once full visual conditions are returned, it does not guide the gaze toward any specific source of information.

Unlike temporal occlusion, spatial occlusion removes specific sources of information from the visual scene. However, there has been a limited volume of research implementing spatial occlusion to date, with the research that has done so utilizing it as a method of identifying information sources and control processes for sports performance [11-14]. Research conducted in ice hockey, explored the use of a customized spatial occlusion screen, designed to assess control strategies for rapid interceptive actions by goaltenders [11] while subsequent research investigating spatial occlusion focused on the sport of tennis. Ida et al, explored the use of a computer graphics animation polygon with human characters to depict the tennis serve and then applied three viewing conditions; no occlusion, racket-occlusion and body-occlusion [12]. The results demonstrated that an end-effector such as the tennis racket provides important information for the anticipation of a tennis serve. Similar results were experienced by Jalali et al., who examined a variation on the traditional methodology used to achieve spatial occlusion. This was achieved through classification-image techniques grounded in traditional psychophysics known as Gaussian windows. The technique is similar to the traditional approach to spatial occlusion. However, in the Gaussian window approach, the initial image is displayed in a fully occluded state before specific areas are revealed at random positions. This method was applied to the tennis serve and forehand stroke with results suggesting that successful trials were due to spatial (and temporal) windows provided significant information for participants to identify the landing position of the tennis ball [13].

Research that encompassed both temporal and spatial occlusion utilized a task design that incorporated both pre-release and ball flight information to assess one-handed catching behaviors of skilled participants [14]. Results from the spatial occlusion manipulation demonstrated no differences in catching performance despite significant changes experienced in total movement time and maximum velocity of the catching hand. The results also demonstrated that the spatial occlusion of larger body parts caused participants to use information available after ball release. Although spatial occlusion research has provided a platform for understanding how athletes use visual information to identify the outcomes of particular sports tasks such as the tennis serve there is a paucity of research investigating the capabilities of spatial occlusion as a training tool.

Research by Bennett et al., assessed one-handed catching under different visual conditions, which was achieved using a lightweight opaque Perspex screen attached to the side of a lightweight helmet [15]. The results demonstrated improvements in the number of catches made by participants who transferred from the spatial occlusion condition to full vision available. This is an important consideration in the application of spatial occlusion, as it suggests that occluding a person's limbs while they complete a complex motor skill can be beneficial to the performance of the skill once normal visual conditions are returned. Although the research of Bennett et al. [15] used an applied approach to spatial occlusion, it was only used to analyze its effects on catching in child participants. To the best of the author's knowledge, there is currently no research using spatial occlusion in an applied setting to improve complex motor skill for particular sports. This warrants the need for further research into the use of applied spatial occlusion such as spatial occlusion goggles (Figure 1). It is worth noting the change in use of the term spatial occlusion across this research timeline as it now encapsulates a more applied setting where the execution of a motor skill is interrupted via the removal of critical information. This evolution of visual occlusion research to bridge the gap from verbal responses to context-specific action is pertinent to the current study.

Figure 1: Visual Occlusion Goggles used by participants in the VO Group during the acquisition phase.

In a sport such as a basketball, the majority of kinematic research has focused on shooting, such as the success rate of the basketball free throw [16] or the biomechanical analysis of the jump shot [17]. Few researchers have examined the kinematics of the basketball dribble [18-20]. The coordination pattern of ball bouncing as a function of skill was investigated [18] with nine participants of varying skill levels from most-experienced to least-experienced at bouncing a basketball were selected. Black circular spots, half an inch in diameter, were painted on 11 lateral points of the participants' body to facilitate the digitization of these points for recording. Participants were required to bounce a basketball at a preferred rhythm while standing still for as long as possible. The most successful trials, assessed via the standard deviations of the horizontal placement of ball strikes on the floor, were selected for analysis. The digitized points on the body represented projections of the body parts on the camera and were measured in terms of linear positions over time in a vertical direction of that plane. Results of a pairwise correlation between linear displacements suggested that the coordination patterns of less-skilled participants were more variable than those of more skilled participants. Analysis of hand movement was also prominent in the research of Katsuhara et al., [19] who analyzed ball-hand contact time during rhythmic stationary ball bouncing, and in the research of Mohamed et al., [20] who analyzed hand kinematics of basketball bouncing from varying heights. Although previous research in basketball has looked at stationary bouncing, the kinematic analysis in the current research will predominantly analyze upper limb kinematics during the dribble due to its effects on basketball dribble performance.

Unlike traditional visual occlusion studies, in the current study, we used a novel approach to the spatial occlusion to examine the effects of spatial occlusion goggles on participants' ability to perform the basketball crossover dribble. This form of spatial occlusion removed the sight of the participants' limbs and lower body as well as the basketball while the participant performed a basketball crossover dribble. It was hypothesized that the use of spatial occlusion goggles would demonstrate an increase in the third metacarpal height of the spatial occlusion (SPO) group's basketball dribble in accordance with the instruction provided by the testers. It was also hypothesized that; the practice (PRA) group who merely practiced with no occlusion intervention and the control (CON) groups who did not have any intervention, would experience no change in kinematic behaviors. It was hypothesized that there would be a reduction in the number of fixation errors, gazes occurring in a downward direction, during the basketball dribble for those in the SPO group, whereas the PRA group was not expected to see a significant reduction in fixation error. The CON group was not expected to experience any change in fixation error. It was hypothesized that those who practiced with the spatial occlusion goggles would experience not only a practice effect but also a learning effect. It was expected that the PRA group may experience a practice effect, with the CON group not expected to experience any change.

MATERIALS AND METHOD

Participants

Fifteen skilled male basketball players (M=22.6 years, SD=3.9), with a minimum of 10 years playing experience playing at the highest level in Ireland, were recruited for this study. Each participant had a normal or corrected-to-normal vision and was right-hand dominant. Participants were randomly assigned to one of three groups: Spatial Occlusion (SPO), Practice (PRA) or Control (CON). The sample size was determined by accessible skilled population, data collection time (approximately 1.5 hours per participant) and participant availability [21] to commit to 6 contact sessions over the span of 8 days. Ethical approval was attained from the Cork Institute of Technology Research Ethics Committee. Participants were provided with a participant information sheet and had the protocol for each phase of the research explained to them before signing the participant consent form and beginning the research.

Materials and apparatus

An eight-camera (MX13+) Vicon motion analysis system was utilized for analysis in addition to a full body biomechanical model (Figure 2).

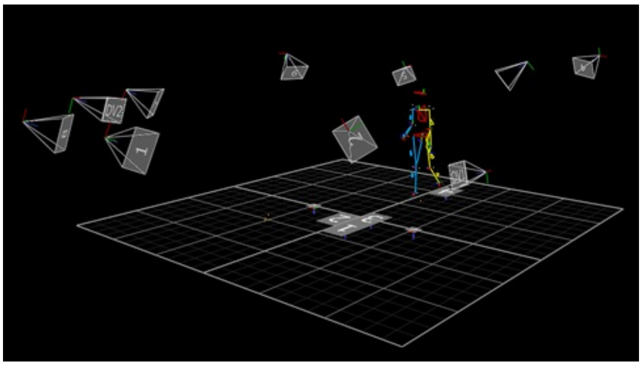

Figure 2: Motion Analysis Laboratory setting including 8 MX13+ motion cameras, 2 digital video cameras and a 3D representation of a participant.

Sixty-nine reflective markers were placed on anatomical landmarks covering the entire body (Figure 3), with each anatomical landmark palpated according to Van Sint Jan [22].

Figure 3: Skeletal image representing the 69 markers on the anatomical landmarks.

Vicon Nexus v1.8.5 software was utilized for motion capture and subsequent data analysis. The capture volume facilitated the recording of two full dribble sequences with 5 trials recorded to complete a single test. Data were also recorded using three standard video cameras with the first recording participants' eye movements, the second recording all movement in the coronal (frontal) plane and the third camera recording motion in the sagittal plane. Spatial occlusion goggles were used by the SPO group. A regulation competition basketball (Molten Official FIBA Approved GG7) inflated to the prescribed 8 psi was used for both the testing and acquisition phase.

Procedure

Participants were measured for height and body mass prior to the dribbling task. They were then instructed to complete a basketball crossover dribble sequence where each sequence began with the participant bouncing the ball with their dominant or non-dominant hand while moving forward. The initial bounce was followed by a second and third bounce where the ball was bounced across the participant's body and the same process was repeated on the opposite side (Figure 4). Participants were instructed to "stay tall and look straight ahead" for the duration of each dribble sequence. The purpose of this instruction was to establish a consistent basketball dribble style across participants and to facilitate analysis of eye movement. Trials were counter-balanced as the participant was instructed to start with their dominant or non-dominant hand every second trial. A total of 5 trials were completed during each testing phase which accounted for 10 dribble sequences, totaling 30 bounces of the basketball [20].

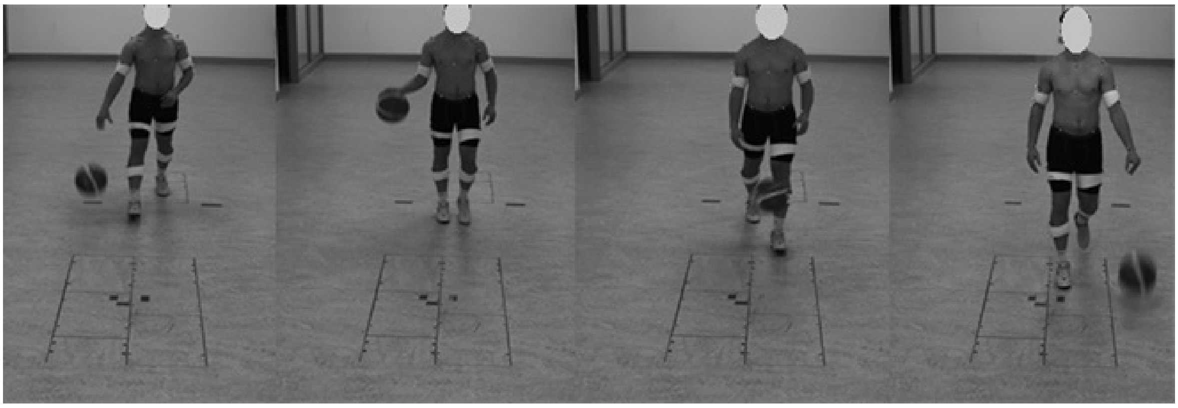

Figure 4: Images illustrating the dribble sequence with the dominant hand.

A validated upper limb biomechanical model was utilized to produce accurate and valid kinematic data for analysis [23]. The model identified the movement of the shoulder complex by accurately locating the glenohumeral joint center through marker placement [24]. The elbow joint center was defined as the midpoint of the lateral and medial epicondyle of the elbow and the wrist joint center was located at the midpoint of the radial and ulnar styloid of the wrist. All segment coordinate systems were defined with axes orientations defined by the International Society of Biomechanics (ISB) [25]. Other markers fixed to a four-marker panel were secured to the upper arms, thighs and lower legs with a non-adhesive wrap to display the positioning of the corresponding bone (e.g. the upper arm represented the femur). A further 4 markers were placed on a headband around the athlete's head in order to represent the orientation of the participants' head.

Testing protocol

The testing protocol consisted of a pre-test, an acquisition phase, a post-test and a 2-day retention test. Two familiarization trials were conducted before the data collection process commenced. Pre-, post- and retention tests were performed adopting an identical protocol. The acquisition phase of the testing protocol was completed over four consecutive days. The SPO group (n=5; M=22.4 years, SD=3.1) wore occlusion goggles for the duration of the four-day acquisition phase. The PRA group (n=5; Mean age=22.6 years, SD=1.1) completed the acquisition phase without the visual occlusion equipment. The CON group (n=5; Mean age=21.8 years, SD=1.4) did not complete any acquisition phase. Participants completed a total of 400 dribble sequences during the acquisition phase. A dribble sequence in the acquisition phase was identical to the dribble sequence completed during testing. Each day comprised of 100 dribble sequences, segregated into 10 blocks of 10 dribble sequences. Each block was counter-balanced with the participants beginning with their dominant or non-dominant hand every second sequence.

DATA ANALYSIS

Kinematics

Each dribble sequence consisted of 3 bounces of the basketball, ensuring 6 bounces available for analysis per trial. However, the third dribble in each sequence was removed from analysis due to the last dribble in the sequence being across the body, thus changing the mechanics of the movement. Therefore, 4 bounces were selected for analysis per trial. Vertical position of the third metacarpal was documented at four critical positions of the basketball dribble; (i) Peak Height of the Dominant hand (PHDH), (ii) Minimum Height of the Dominant hand (MHDH), (iii) Peak Height of the non-dominant hand (PHNH) and (iv) Minimum Height of the non-dominant hand (MHNH). Mean vertical height was then calculated across trials for the pre-test, post-test and retention test for each critical position. The third metacarpal plays a pivotal role in the control of the basketball during the dribble and has been used as a marker for measurement when analyzing the dribble [18,20]. The reason for this is that the fingers push the ball towards the floor as opposed to a slapping effect from the palm of the hand. The height of the dribble also has an impact on the control of the basketball and amplitude of the third metacarpal [20]. The mean linear change in height from pre-test to post-test, pre-test to retention test and post-test to retention test was analyzed to assess potential changes in dribble behavior. Additional data were analyzed in order to gain additional insight into the standard deviation of the third metacarpal to assess the stability of any potential change in dribble height. The standard deviation of the elbow angles (degrees) at the 4 critical points PHDH, MHDH, PHNH, and MHNH was also documented. The purpose of using standard deviation as a unit of measurement was due to inter-participant differences in dribble behavior heights/limb length differences in the cohort.

A 3 group × 3 test ANOVA was conducted to analyze the impact of the acquisition phase on participants' kinematic output. The alpha level required for significance for all tests was set at $p<0.05$ with the confidence interval level set at 95%. Partial squared was used to assess effect size.

Gaze behaviour

Gaze behavior data were recorded using a video camera which was zoomed in to focus on the eyes of the participants. Each recording was then assessed using Dartfish version 7 software. Recordings were analyzed using a frame by frame approach to accurately identify changes in fixations. Fixations were classed as a change in eye movement which lasted for 100 ms or longer [26]. The purpose of recording gaze behavior was to initially identify if wearing spatial occlusion goggles impacted how often participants looked down at their hands or the basketball while completing the basketball crossover dribble. Gaze behavior data were also recorded to complement the biomechanical data collected. The purpose for this was to ensure that those who completed the acquisition phase with the spatial occlusion goggles and experienced positive changes in kinematics did not do so as a result of looking down during the post and retention tests. Therefore, any fixation in a downward motion towards the basketball or upper limbs was classed as a fixation error.

RESULTS

Kinematics

A One-Way ANOVA was conducted for between-group differences in order to assess for differences in skill level at pre-test. The was no significant difference between groups for PHDH, $F(2,12)=0.662$, $p=0.533$. The lack of a significant difference between groups was consistent across each critical point; MHDH, $F(2,12)=1.817$, $p=0.204$, PHNH, $F(2,12)=0.545$, $p=0.593$ and MHNH, $F(2,12)=1.876$, $p=0.194$.

Mean vertical heights for the third metacarpal across each testing phase are illustrated in Figure 5a-5d. A mixed between-within subjects' ANOVA was conducted to assess the impact of the spatial occlusion goggles on third metacarpal height and movement during the basketball dribble. There was a significant interaction for PHDH Kinematics × Group, $F(4, 22)=4.88$, $p=0.006$, $=0.47$. Post-hoc analysis revealed that the SPO group had a significant increase ($p<0.05$) in PHDH pre-test (M=1129.00 mm, SD=81.83 mm) to post-test (M=1254.50 mm, SD=83.97 mm) as well as a significant increase ($p<0.05$) in PHDH and from pre-test to retention test (M=1263.20 mm, SD=99.8 mm). Despite the increase in PHDH from post-test to retention test no significant change was found ($p>0.05$). No significant changes in PHDH were found for the PRA or CON group ($p>0.05$).

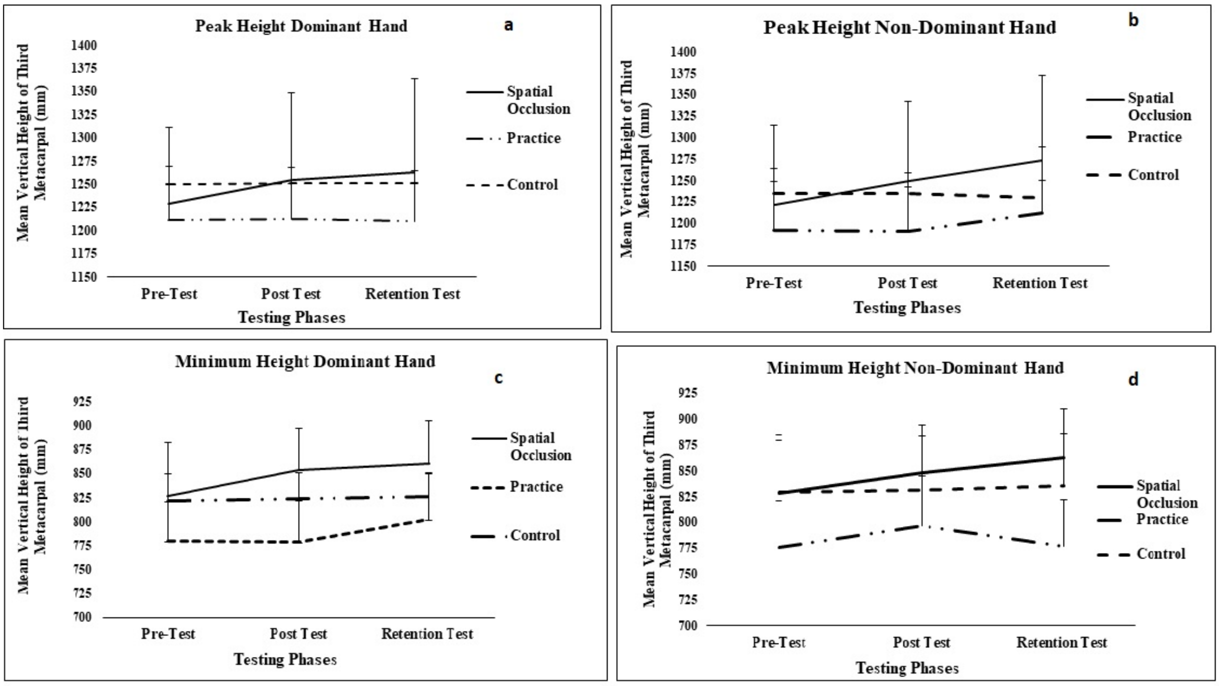

Figure 5: a: Mean vertical height of the third metacarpal in mm for the peak height on the dominant side; b: Mean vertical height of the third metacarpal in mm for the Peak Height on the non-dominant side; c: Mean vertical height of the third metacarpal in mm for the minimum height on the dominant side; d: Mean vertical height of the third metacarpal in mm for the minimum height on the non-dominant side.

A significant interaction effect was also recorded for the PHNH Kinematics × Group F (4, 22)=6.73, p=0.001, =0.55. Findings from the PHNH demonstrated a significant increase in height (p<0.05) from pre-test (M=1221.40 mm, SD=93.41 mm) to post-test (M=1249.00 mm, SD=92.91 m). A significant increase in height (p<0.05) was found from pre-test to retention test (M=1274.00 mm, SD=98.22 m). There was no significant different experienced from post to retention test (p>0.05). The PRA and CON groups showed no significant change across any test (p>0.05).

Minimum height of the third metacarpal was also analyzed due to the important role it plays in control of the basketball. There was a significant interaction effect for MHDH Kinematics × Group, F (4, 22)=5.21, p=0.004, =0.486 with Post-hoc analysis displaying significant increases in height for the SPO group (p<0.05). The significant change occurred from pre-test (M=827.00 mm, SD=55.86 mm) to post-test (M=854.00 mm, SD=42.82 mm) with no significant increase being experienced from pre-test to retention test (p=0.072). There was no significant change for the PRA or CON group (p>0.05). There was also a significant interaction effect for the MHNH, F (4, 22)=5.071, p=0.005, =0.48. However post-hoc analysis indicates that the significant change occurred from pre-test to retention test with no significant change occurring from pre-test to post-test (p>0.05). Additional analysis focused on the standard deviation of movement at the third metacarpal. However, no significant interaction effect between standard deviation × group occurred for any of the four critical points of the third metacarpal movements, F (4, 22)=1.67, p=0.19, =0.23.

There was a significant interaction between group and top elbow angles, F (4, 22)=4.03, p=0.013, 0.42. Post-Hoc analysis demonstrated that the SPO group had significant improvements in the top elbow angles from pre- to post-test and from post- to retention test (p<0.05) for both the dominant and non-dominant side. Significant changes experienced at the elbow angles reinforce the significant change that occurred at the third metacarpal during the basketball dribble. There was a significant interaction between group and bottom elbow angles, F (4, 22)=3.49, p=0.024, =0.39. The significant improvement was experienced by the SPO group at the bottom of the elbow angles on the dominant side from pre- to post-test (p<0.05). The non-dominant side of the bottom of the elbow angles had a significant change from pre- to post-test and from post- to retention test (p<0.05). Results illustrated that there was no significant change in elbow angles on the dominant or non-dominant side for the PRA group or the CON group (Figure 6a-6d).

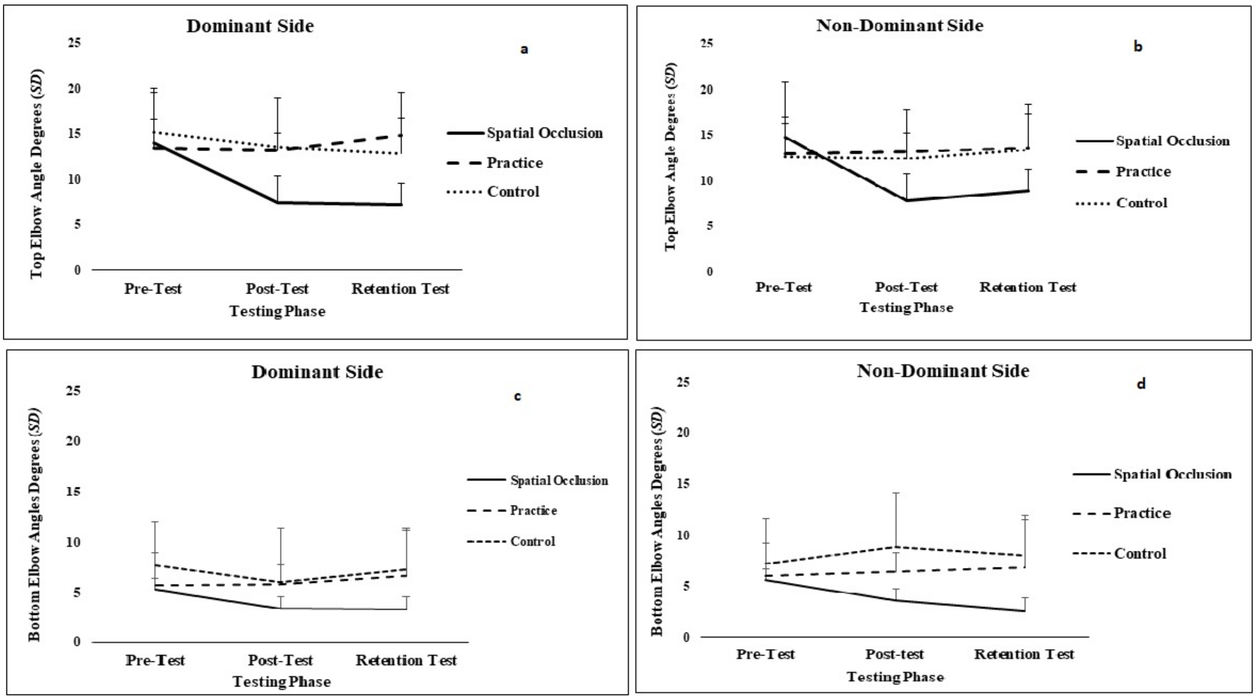

Figure 6: a: Mean outcome scores for dominant elbow angles (SD) at the top of the basketball dribble; b: Mean outcome scores for the non-dominant elbow angles (SD) at the top of the basketball dribble; c: Mean outcome scores for dominant elbow angles (SD) at the bottom of the basketball dribble; d: Mean outcome scores for the non-dominant elbow angles (SD) at the bottom of the basketball dribble.

Gaze behaviour

Participants' gaze behavior was analyzed using a 3 group × 3 test ANOVA to assess the impact of the spatial occlusion acquisition phase. There was a significant interaction between group and fixations, $F (6, 20)=4.53$, $p=.005$, $=0.58$. Post-hoc analysis revealed a significant decrease in fixation error for the SPO group from pre- to post-test and from post- to retention test ($p<0.05$). There was no significant change in fixation error for the PRA or CON groups ($p>0.05$).

DISCUSSION AND CONCLUSION

Visual Occlusion research originated from the need to assess differences in gaze behavior between skilled and less skilled athletes [3,4]. The research has since evolved, utilizing temporal occlusion as a method of training through video-based studies in a laboratory setting [5,6], as well as in an applied setting [7-10]. Unlike temporal occlusion, spatial occlusion research has predominantly been used to assess how participants use visual information [11-15]. Due to the lack of training based spatial occlusion studies, the aim of the current research was to assess the impact that training with spatial occlusion goggle would have on the basketball crossover dribble.

The vertical height of the third metacarpal was an important measure in the current study as a means of evaluating ball control during the execution of the skill, with the instruction provided to participants at the beginning of the testing period being of equal importance when interpreting the results. Participants were instructed to stay tall and look straight ahead for the duration of the dribble, this instruction was provided to participants in order to establish a standardized basketball crossover dribble style. It was hypothesized that the SPO group would experience an increase in height of the third metacarpal following the acquisition phase across all four critical points. Findings demonstrated that the SPO group experienced a significant increase in height at PHDH, PHNH, and MHDH from pre-test to post-test with a significant increase in height from pre-test to retention test for the MHNH. This result suggests that participants in the SPO group were significantly better at following the instruction of staying tall while performing the basketball crossover dribble without needing to lower their hand to maintain control over the basketball while dribbling. These results are comparable to those demonstrated by Bennett et al., [15] who examined the use of a spatial occlusion tool on one-handed catching and found that when participants transferred from a spatial occlusion visual condition to normal visual conditions, more successful catches were recorded. An important factor to consider when comparing these findings to the current study is that improvements in performance were experienced subsequent to the visual system being placed in detrimental viewing conditions through the spatial occlusion. This finding promotes the training of complex motor skills under restricted visual conditions, such as spatial occlusion, as an increase in performance may be experienced when full viewing conditions are returned.

It was also hypothesized that there would be no change in kinematic behavior for the PRA or CON groups. Kinematic analysis of changes at elbow angles on the dominant and non-dominant side also revealed a significant change for the SPO group with no change being experienced by the PRA or CON groups confirming this hypothesis. The change experienced at the elbow substantiates the significant change at the third metacarpal and demonstrates the collective change in kinematic behavior. These findings reflect similar patterns of improvement in results obtained from studies where positive changes in the movement were experienced as a result of temporal occlusion [7-10]. Broadbent et al., [7] and [10] reported improvements in response accuracy (response relevant to tennis shot destination) for groups exposed to video-based occlusion as part of a training program. Farrow et al., [8] also presented results consistent with the current research where the use of visual occlusion paradigms as a training tool improved prediction performance (correct prediction of stroke direction) in both skilled and novice tennis players. The basketball dribble, like the return stroke in tennis, is a complex motor task. It includes a flick motion of the wrist as the basketball is released, therefore the significant improvement experienced at the elbow as well as the third metacarpal provides a more comprehensive understanding of the results in the current research. These results support the work of Muller and Abernethy [9] who suggested that using both the video simulation approach to visual occlusion and using temporal occlusion spectacles in an applied setting as tools to train anticipation in cricket batsman improved foot movement which spatially positioned the body for an interception. It was also suggested that when the task was performed with movement the quality of bat-ball contacts increased.

Despite the similarities in results presented between results of the current research and other research in the domain [7-10], as a consequence of the use of visual occlusion, it is important to note the disparities. The current research used a novel approach to spatial occlusion as a training tool. The spatial occlusion goggles removed the lower grade of the visual field and were responsible for removing the sight of the limbs and basketball during the complex motor task. This is significantly different to how visual occlusion was applied in the research by Farrow et al., [8], Muller and Abernethy [9] and Williams et al. [10].

The results obtained regarding upper limb movement from the motion analysis lab in the current study suggest that implementing an acquisition phase with spatial occlusion goggles has a positive effect on the kinematics of the crossover dribble. Although there was an increase in dribble height for the SPO group, combined with a significant change in elbow angles, there was no significant change evident for the standard deviation of the third metacarpal which suggests that there was no change in variability of the basketball dribble. It is vitally important to note that no change in variability, does not mean a reduction in variability of the basketball dribble. These results are not consistent with those presented by Broderick and Newell [18] who suggest that coordination patterns of less skilled players were more variable. However, it is imperative to note that the skill gap between participants in the current research was minimal whereas the skill gap between participants in the study by Broderick and Newell [18] was vast with participants ranging from 4 to 22 years of age. This indicates that although the research of Broderick and Newell [18] and the current research both assess the kinematic behavior of the basketball dribble or ball bouncing it would be ill-advised to directly compare both studies.

There were no opponents or teammates included in the current experimental design due to the task being performed in a motion analysis lab. Despite this, it was hypothesized that there would be a significant decrease in fixation error for the spatial occlusion group. The results from the analysis of fixations demonstrated that the SPO group significantly decreased in fixation errors. Integrating the results of gaze behavior with those of the kinematic analysis suggests that the SPO group were not only able to maintain their gaze outward but significantly decrease fixation errors while improving the kinematic qualities of the basketball dribble post-acquisition phase. There were no significant changes for the PRA or CON groups across any variable or test. The use of a customized spatial occlusion screen identified ice hockey goaltenders' use of predictive control strategy for rapid interception [11]. Although the current research did not explore the use of applied spatial occlusion for anticipation, limiting the vision of the limbs and ball while executing the basketball crossover dribble with the athletes' gaze directed outward had a positive effect on the skill when full visual conditions were resumed.

The current study examined the use of spatial occlusion goggles as a training tool to improve the basketball dribble. One of the reasons for this approach was to examine spatial occlusion in a different way, as traditional research in visual occlusion used video simulation to assess expert performance versus intermediate or novice performance [3,4]. The results of the post- and retention tests for the spatial occlusion group demonstrated not only a practice effect but also a learning effect, as was hypothesized by the authors of the current research; a key consideration in motor learning. The presence of a learning effect for the spatial occlusion group suggests potential positive benefits of practicing with spatial occlusion goggles in the basketball dribble.

Further research is required in the application of spatial occlusion goggles in order to broaden our understanding of the goggles' capabilities as a training tool. Different applications of spatial occlusion goggles should be investigated in different sporting contexts such as anticipation or interceptive actions. In summary, this experiment has demonstrated that skilled participants who practice with the spatial occlusion goggles demonstrated significant improvements in their ability to perform the basketball dribble while concurrently reducing fixation errors. This suggests that incorporating the spatial occlusion goggles as a tool into a training program for basketball players may have a positive impact on their dribbling ability.

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