A PILOT STUDY OF ELBOW-SHOULDER COORDINATION PATTERNS DURING 3-POINT SHOTS IN PLAYERS OF DIFFERENT SKILL LEVELS

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The purpose of this study was to determine shoulder and elbow coordination between different skill levels in basketball players during 3-point shots. Digital video data were collected while five players performed 3-point shots. Video data were processed with Theia3D software, and shoulder and elbow joint angles were calculated in Visual3D. Vector coding analysis was used to calculate shoulder-elbow coupling angles. The mean coupling angles and frequency counts showed anti-phase coordination with elbow dominancy during ball release phase was consistent among all players. The results highlighted that high-skilled players may adopt more efficient shoulder and elbow coordination patterns to enhance their 3-point shots by taking relatively longer duration to adjust shoulder dominant in-phase coordination during shot preparation.

KEYWORDS: sports, biomechanics, basketball, vector coding, circular statistics

INTRODUCTION: Basketball players have 2-point or 3-point shot opportunities during games. In recent years, offensive strategies have changed shot selection from mid-range 2-point shots to more 3-point shots since average points per shot attempt are greater with 3-pointer (Fichman & O'Brien, 2019). Scoring with the 3-point shots is more efficient and the ability to make greater numbers of 3-pointer are now an important strategy for teams to score more points and win more games.
A three-point field goal needs to be performed from beyond the three-point arc. The greater distance of 3-pointers compared to shots closer to the basket naturally demands that players propel the ball a longer distance and thus requires efficient delivery and greater impulse along the kinematic chain (Miller & Bartlett, 1996; Robins et al., 2006). Numerous studies showed that basketball players use different upper limb kinematic characteristics when shooting a ball from long distance (Cabarkapa et al., 2021; Miller & Bartlett, 1996; Okazaki et al., 2015; Robins et al., 2006). For example, players showed greater center of mass (COM) horizontal and vertical velocity, greater elbow range of motion, greater shoulder, elbow, and wrist angular velocity during 3-point shots than 2-point shots.
Skill level is also known to influence shooting biomechanics (Cabarkapa et al., 2021; Okazaki et al., 2015). Previous findings indicated kinematic differences between skilled vs. unskilled players during shooting movement (Button et al., 2003; Cabarkapa et al., 2021; Chiang & Liu, 2006). High-skilled players showed greater elbow and shoulder flexion (Cabarkapa et al., 2021), and greater wrist range of motion (Button et al., 2003). Moreover high-skilled player can organize more flexible and independent upper joints movement than less skilled players (Chiang & Liu, 2006).
However, how high-skilled and less-skilled players coordinate and control their joints during 3-point shooting is still unclear. Vector coding calculates coupling angle which represents relative motion between two joints or segments and can thus provide insights about 1) frequency counts of the coordination patterns and 2) time-series coordination patterns classification between different groups of players or within individual players (Needham et al., 2020). Therefore, this study aimed to use vector coding analysis to investigate shoulder and elbow coordination during 3-point shots in players with different skilled levels.

METHODS: Five male basketball players (age: 19.2±0.8; height: 1.97±0.1; mass: 93.4±8.1; shooting hand: 2 left, 3 right) participated in this pilot study. Players performed nine to 11 3-point shots at the top of the arc (6.75 m) while 2D video data were recorded with eight Sony RX0 II video cameras (Sony Corporation; Minato, Japan; 120 Hz). The video data were processed with Theia3D (Theia Markerless, Inc., Kingston, Ontario) software. A cutoff frequency of 6Hz filter was used to smooth the pose from the inverse kinematics and C3D files were exported for further analysis with Visual3D Professional (C-Motion, Inc., Germantown, MD, USA). Relative sagittal plane shoulder and elbow joint angles were calculated during the 3-point shot. The shooting motion was defined from when the center of mass reached the lowest height to the last frame in which the basketball kept contact with the player's fingers. The beginning of ball release phase was defined when elbow extension begins while the shoulder kept flexing. Movement prior to the release phase was defined as the shot preparatory phase (Okazaki et al., 2015). While some trials were discarded due to technical problems, at least 3 successful made shots (5.8±2.3) were used and time normalized to 101 points (0-100%) with cubic spline interpolation. Data processing and vector coding analysis (Needham et al., 2020) were performed in a custom Python 3.9.7 (Enthought, Inc., Austin, TX, USA) code. The coupling angle between the shoulder and elbow joint angles was quantified. The coupling angles from all shots were averaged across via circular statistics. The players were divided into three groups based on their 3-Point Field Goal Percentage (3P%) statistics in the current 2022-2023 NCAA season (≥30%: high; 20 to <30%: mid; 10 to <20% low). Three players were included in the high skilled group and two were classified into the remaining two groups. The mean coupling angles were classified into four different coordination patterns (i.e., IPPD: in-phase proximal dominancy, IPDD: in-phase distal dominancy, APPD: anti-phase proximal dominancy, APDD: anti-phase distal dominancy); In-phase coordination (represents when angular motion of two joints rotates in the same direction), anti-phase coordination (represents when two joints rotate in the opposite direction), and proximal or distal joint dominance (defined on when rotational change of one joint is greater than the other). Individual player's coupling angles were analyzed to examine coordination patterns throughout the shooting motion. Additionally, frequency counts were used by dividing the coupling angles into specific coordination pattern bins to illustrate distribution of coordination pattern classification and predominant coordination tendency across the shooting motion.

RESULTS: Shoulder joint angles ranged from ~10° to 140° while elbow joint angles ranged from ~30° to 140° (Figure 1[a]). Frequency of the coordination patterns of the three high-skilled and one mid-skilled player showed in-phase with shoulder dominancy (IPPD) and anti-phase with elbow dominancy (APDD), whereas the low-skilled player showed noticeably greater anti-phase with shoulder dominancy (APPD) and anti-phase with elbow dominancy (APDD) while shooting 3-pointers (Figure 1[c]). For shoulder and elbow coupling angles (Figure 1[b]), mean coupling angles showed similar coordination patterns (anti-phase with elbow dominancy, ~270° to 315°) during ball release phase for all five players, whereas various coordination patterns were noted during the shot preparation phase. Specifically, mean shoulder-elbow coordination angles of top 2 players showed in-phase with shoulder dominancy (IPPD: 3.6° to <45°) and in-phase with elbow dominancy (IPDD: 45.1 to 53.3°) during the shot preparation phase (~60%), but the frequency of IPPD was greater than IPDD. The other high skilled player showed only in-phase shoulder dominancy (IPPD: 3.7° to 30.9°) throughout the shot preparation phase, which accounted for 58%. The mid-skilled player showed a combination of coordination pattern similar to the top two skilled players, which was in-phase with shoulder dominancy (IPPD: 0.2-44.8°) followed by in-phase with elbow dominancy (IPDD: 45.8° to 51.8°) during shot preparation, but the mid-skilled player showed shorter shot preparation duration (~40%) compared to the high-skilled group. Lastly, the low-skilled player showed distinctive shoulder-elbow coordination pattern. As the shot preparation commenced, the beginning included a small percentage of in-phase with shoulder dominancy (IPPD: 1.6°-13.8°), the majority of time was spent (40%) at anti-phase with shoulder dominancy (APPD: 317.3°-358.8°)

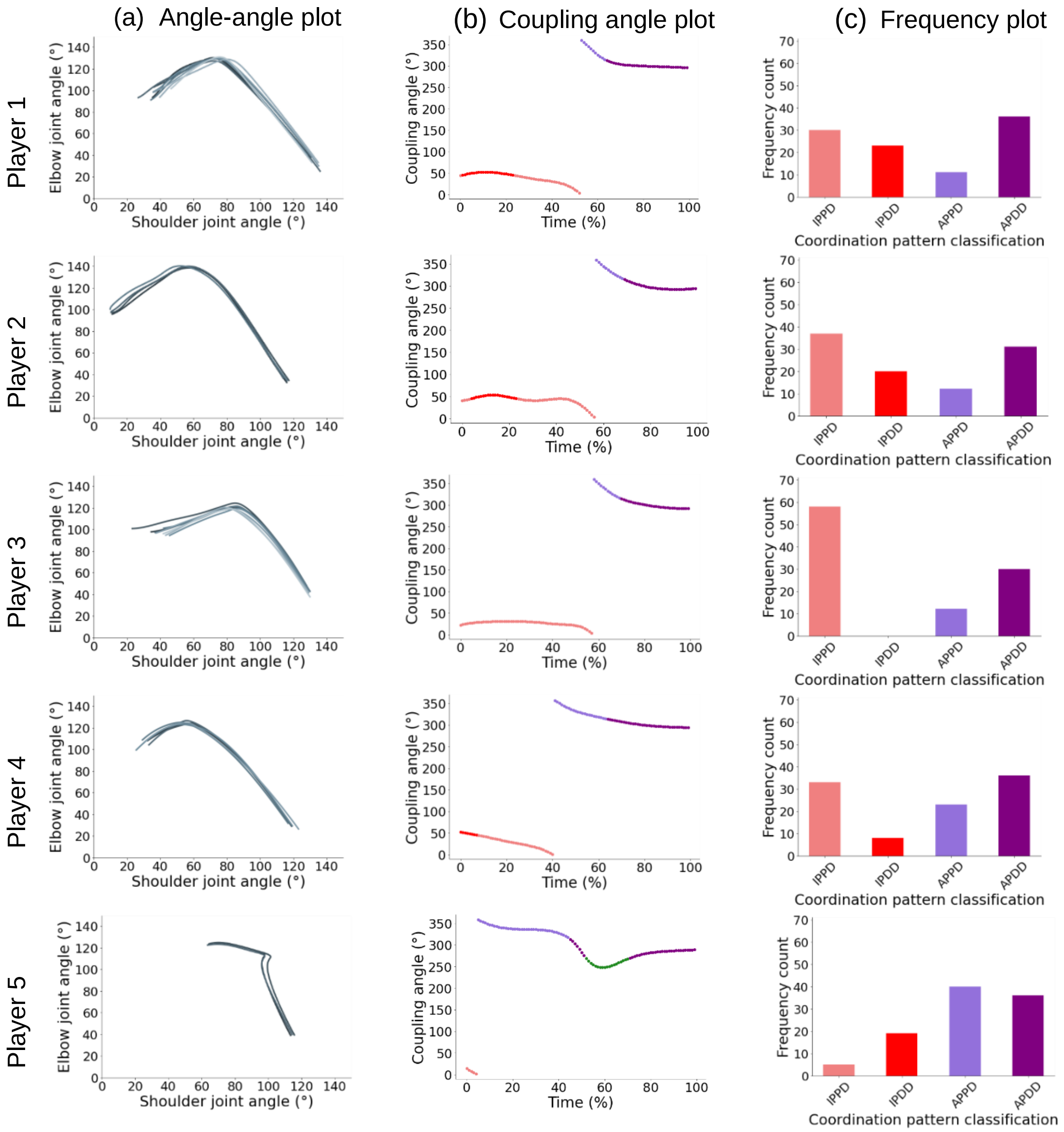

Figure 1. Five individual player's (a) angle-angle plot; (b) mean coupling angle plot; (c) coordination pattern frequency plot on shoulder-elbow sagittal plane coordination during the 3-point shots. Player 1, 2, 3 were high-skilled (3P: ≥30%), player 4 were mid-skilled (3P: 20 to <30%), and player 5 were in low-skilled (3P: 10 to <20%) level.

DISCUSSION: The purpose of this study was to investigate shoulder-elbow coordination patterns during 3-point shots of basketball players with different skill levels via vector coding analysis. While there were between-player differences in frequency of coordination patterns and mean coupling angles, the findings of frequency of coordination patterns in relation to skill level revealed that high- and mid-skilled players showed in-phase with shoulder dominancy and anti-phase with elbow dominancy as major coordination patterns, but the low-skilled player showed anti-phase with shoulder dominancy and anti-phase with elbow dominancy as the marked coordination patterns. Analysis of mean coupling angles over the entire shooting movement showed that mid- and low- skilled players use different shoulder-elbow joint couplings and coordination strategies compared to high-skilled players.
Frequency counts and mean coupling angles showed that anti-phase with elbow dominancy is the common coordination pattern during ball release phase. This pattern was consistent for the shooting task regardless of the skill level. However, the differences of shoulder-elbow coordination were noticeable between groups and individual players when they raise the ball upward to the set position (i.e., preparation phase).

Mean coupling angles of high-skilled players displayed in-phase coordination (i.e., shoulder and elbow flexion) during shot preparation phase (~60%). Some studies suggest that 3-point shooting biomechanics, such as greater elbow flexion, higher basketball height positioning and less horizontal COM movement during the shot preparation phase, were characteristic of more proficient players (Cabarkapa et al., 2021; Knudson, 1993). Based on a simulation study, kinematic model estimates suggest that shoulder rotation contributes to upward ball release velocity and elbow rotation contributes to horizontal ball release velocity (Okubo & Hubbard, 2015). Given that our findings showed that high-skilled players spent relatively more time flexing both joints with a shoulder dominant strategy during shot preparation phase, it appears that such coordination patterns enable them to elevate the ball to maximize the height of release until the set position.
The mid-skilled player used in-phase with shoulder dominancy during the shot preparation phase similar to high-skilled players, but the relative duration of the phase was shorter (~40%). The low-skilled player on the other hand showed unique coordination patterns, where shoulder-elbow coordination is mainly anti-phase with shoulder dominancy during shot preparation phase. The results indicated the coordination patterns of mid- and- low skilled players might be associated with inefficient shoulder-elbow coordination that adversely affect shooting accuracy during 3-point shots. Lastly, it is important to note that these findings are based on a pilot study with a limited number of participants, thus should be interpreted with caution for generalizations.

CONCLUSION: The current pilot study used vector coding analysis to examine shoulder and elbow coordination patterns between basketball players of different skill levels during 3-point shots. The results showed that the pattern of shoulder and elbow coordination during ball release phase was consistent among all players, while the coordination patterns and phase durations were variant during the shot preparation phase. Specifically, high-skilled players used relatively longer duration to adjust shoulder dominant in-phase coordination during shot preparation, which may suggest their potential advantage in shooting 3-point shots accurately.

REFERENCES

Button, C., Macleod, M., Sanders, R., & Coleman, S. (2003). Examining movement variability in the basketball free-throw action at different skill levels. *Research quarterly for exercise and sport*, *74*(3), 257-269.

Cabarkapa, D., Fry, A. C., Cabarkapa, D. V., Myers, C. A., Jones, G. T., & Deane, M. A. (2021). Kinetic and Kinematic Characteristics of Proficient and Non-Proficient 2-Point and 3-Point Basketball Shooters. *Sports*, *10*(1), 2.

Chiang, H. Y., & Liu, Y.-T. (2006). Coordination of basketball shooting movement of different skill level players. ISBS-Conference Proceedings Archive,

Fichman, M., & O'Brien, J. R. (2019). Optimal shot selection strategies for the NBA. *Journal of Quantitative Analysis in Sports*, *15*(3), 203-211.

Knudson, D. (1993). Biomechanics of the basketball jump shot—Six key teaching points. *Journal of Physical Education, Recreation & Dance*, *64*(2), 67-73.

Miller, S., & Bartlett, R. (1996). The relationship between basketball shooting kinematics, distance and playing position. *Journal of sports sciences*, *14*(3), 243-253.

Needham, R. A., Naemi, R., Hamill, J., & Chockalingam, N. (2020). Analysing patterns of coordination and patterns of control using novel data visualisation techniques in vector coding. *The Foot*, *44*, 101678.

Okazaki, V. H., Rodacki, A. L., & Satern, M. N. (2015). A review on the basketball jump shot. *Sports biomechanics*, *14*(2), 190-205.

Okubo, H., & Hubbard, M. (2015). Kinematics of arm joint motions in basketball shooting. *Procedia Engineering*, *112*, 443-448.

Robins, R., Wheat, J., Irwin, G., & Bartlett, R. (2006). The effect of shooting distance on movement variability in basketball. *Journal of Human Movement Studies*, *50*(4), 217-238.