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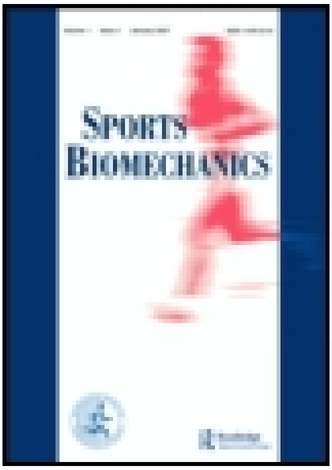

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A review on the basketball jump shot

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Abstract
The ability to shoot an effective jump shot in the sport of basketball is critical to a player's success. In an attempt to better understand the aspects related to expert performance, researchers have investigated successful free throws and jump shots of various basketball players and identified movement variables that contribute to their success. The purpose of this study was to complete a systematic review of the scientific literature on the basketball free throw and jump shot for the purpose of revealing the critical components of shooting that coaches, teachers, and players should focus on when teaching, learning, practising, and performing a jump shot. The results of this review are presented in three sections: (a) variables that affect ball trajectory, (b) phases of the jump shot, and (c) additional variables that influence shooting.

Keywords: *Shooting, ball trajectory, shooting performance, shooting variables, biomechanics*

Teams accumulate points in the sport of basketball by putting the ball through the hoop. Therefore, shooting is a very important skill and directly influences the team's success (Button, Macleod, Sanders, & Coleman, 2003; Knudson, 1993; Malone, Gervais, & Steadward, 2002). The ability to shoot a successful jump shot provides a player with the following scoring advantages: (a) accuracy, (b) speed, (c) protection against an opponent, and (d) the possibility of releasing the ball from several distances from the basket (Okazaki & Rodacki, 2012). As a result, the jump shot has been shown to be the most efficient (Knudson, 1993) and the most used shooting technique, regardless of the player's role on the team (Nunome, Doyo, Sakurai, Ikegmai, & Yabe, 2002).

The importance attributed to the jump shot in a team's offence has led researchers to identify factors that relate to its successful performance (Hudson, 1985a; Knudson, 1993). A survey of the literature reveals three categories into which the investigated factors of a successful shot can be grouped: (a) ball trajectory, (b) segmental movement organisation, and (c) variables that influence shooting performance.

Analysis of ball trajectory has identified the following components of a successful shot: (a) release angle, (b) velocity, and (c) height (Miller & Bartlett, 1993, 1996). Several researchers have analysed how these variables interact to result in successful shots (Hudson, 1985a; Knudson, 1993) both by maximising the area for the ball to pass through the basket (Miller & Bartlett, 1996) and the velocity generated at release (Brancazio, 1981; Okazaki & Rodacki,

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2012). Maximising the area for the ball to pass through the basket by taking advantage of the width of the rim permits lower spatial constraints. However, to maximise the rim's width, the ball must be released with a greater release angle (i.e. perpendicular to the rim). Similarly, as distance from the basket increases, a greater release velocity is required. The need to produce a greater velocity during a jump shot may be ill advised, however, due to speed-accuracy tradeoffs (Fitts, 1954; Fitts & Peterson, 1964). Therefore, some researchers have analysed both the outcome of the shooting motion – namely, the shooting trajectories (angle, height, and velocity) – and the manner by which the shooter organises his/her shooting motion (Knudson, 1993).

Researchers who have investigated the shooter's movement organisation have proposed phases for organising the shooting motion (Okazaki, Rodacki, & Okazaki, 2007). The phases provide both a qualitative description and a theoretical guide for coaches, teachers, athletes, and students to follow when learning the shooting motion (Knudson, 1993), considered by some researchers to be the most complex basketball technique (Okazaki & Rodacki, 2005). The shooting motion may be influenced by several factors, such as: (a) distance from the basket (Elliott, 1992; Elliott & White, 1989; Miller & Bartlett, 1993, 1996), (b) the presence of an opponent (Rojas, Cepero, Ona, & Gutierrez, 2000), (c) body posture at ball release (Ripoll, Bard, & Paillard, 1986), (d) other movements completed by the player before shooting (Lorenzo & Aragón, 2003), (e) weight and width of the ball (Okazaki & Rodacki, 2005), (f) the player's expertise level (Button et al., 2003; Hudson, 1985a), (g) field of view (Oudejans, van de Langerberg, & Hutter, 2002; Ripoll et al., 1986), and (h) physical characteristics of the player (Hudson, 1985b; Rojas et al., 2000). Consequently, the segmental movements used by the player when shooting a jump shot have been analysed through qualitative procedures, mathematical models, and experimental evidences (Knudson, 1993). However, few studies have attempted to apply a systematic review of the application of the scientific knowledge of the factors that influence the basketball shot for the purpose of improving the learning process.

Therefore, the purpose of this study was to perform a review of the existing literature on shooting in basketball in order to identify variables related to performance of the basketball jump shot. The analysis is divided into three sections: (a) ball trajectory, (b) phases of the jump shot, and (c) additional variables that influence shooting. A pictorial summary of the variables presented in each section is summarised in Figure 1.

Ball trajectory

Several studies have investigated the determinant variables of the basketball shot (Hudson, 1985a; Knudson, 1993; Okazaki, Rodacki, Dezan, & Sarraf, 2006). The angle of entry of the ball into the basket has been considered to be one of the main factors that determine shooting success (Miller & Bartlett, 1993; Okazaki & Rodacki, 2012). Increasing the angle of entry of the ball into the basket increases the width of the basket. Conversely, the virtual target area is reduced when the angle of entry decreases (Brancazio, 1981; Miller & Bartlett, 1993, 1996) (Figure 2). The angle of entry for the ball is determined by three ball factors: (a) vertical displacement, (b) horizontal displacement, and (c) velocity.

Ball vertical displacement is inversely related to release height and directly related to release angle (Miller & Bartlett, 1993). Therefore, the lower the release height and/or the greater the release angle, the greater the vertical displacement of the ball. On the other hand, ball horizontal displacement is related to the distance between the shooter and the basket. Thus, shots performed from greater distances require greater horizontal velocity for the ball

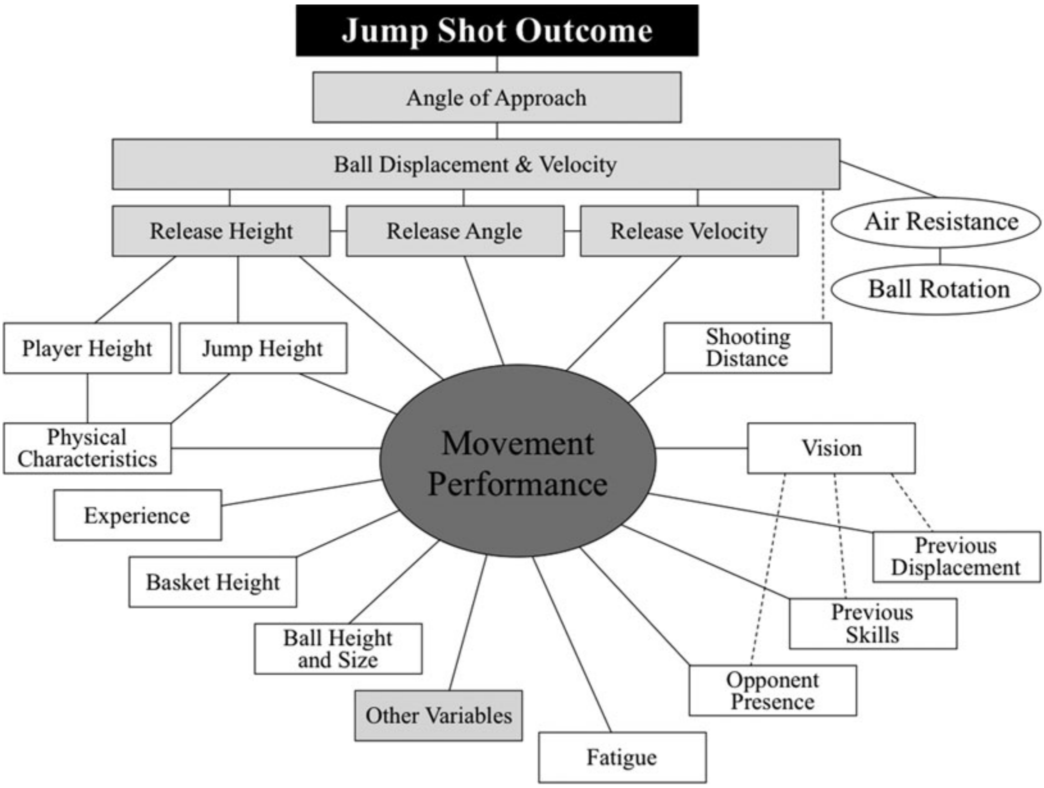

Figure 1. Variables that influence the basketball jump shot.

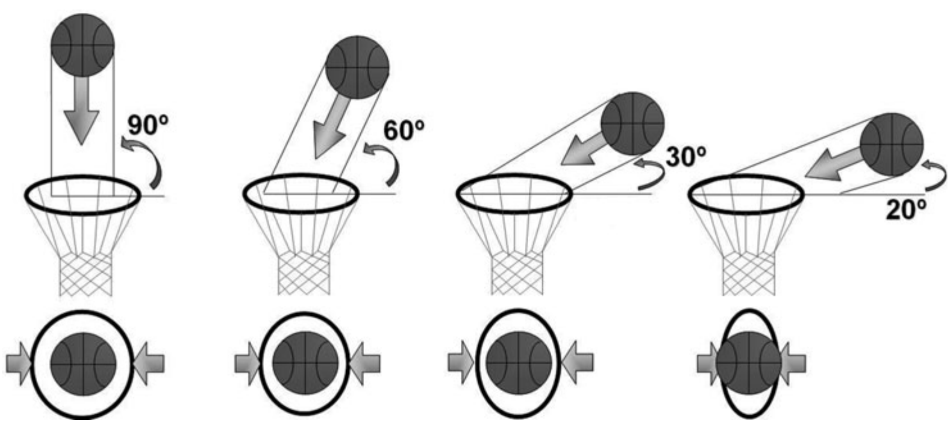

Figure 2. Virtual target of the basket ring as a function of the angle of entry of the basketball. (Adapted from Miller & Bartlett, 1993).

to reach the basket. These three factors (ball vertical displacement, horizontal displacement, and velocity) are affected by release velocity, angle, and height (Miller & Bartlett, 1996).

Release velocity of the ball

Lower release velocities are related to greater movement accuracy (Knudson, 1993; Satern, 1988), a strategy commonly observed in expert players (Hudson, 1985a; Knudson, 1993). A low release velocity decreases movement variability of the body segments, thereby increasing movement consistency (Darling & Cooke, 1987a, 1987b). Thus, reducing release velocity allows extra time for the player to perform movement corrections using visual and proprioceptive feedback and generates less neural noise (Schmidt, Zelaznik, Hawkins, Frank, & Quinn, 1979). This finding suggests that players should use release angles that allow low movement velocity. However, weaker players who are not able to generate sufficient force and/or players who have a shorter standing height and have less potential for generating greater ball release height must use a strategy of generating greater segmental velocities to perform a successful shot (Hudson, 1985b).

Another strategy used by players to reduce release velocity is to flex the wrist at ball release to apply spin to the ball and increase ball rotation during flight. Some authors suggest that creating ball rotation: (a) decreases the horizontal velocity of the ball, (b) causes a downward deflection when the ball rebounds off the backboard, and (c) maintains the velocity of the ball during flight (Hamilton & Reinschmidt, 1997; Knudson, 1993). Although mathematical models suggest that air resistance may reduce the release angle and increase release velocity of the ball (Hamilton & Reinschmidt, 1997), researchers suggest that within closed environments (e.g. inside a sports hall), air resistance is negligible and has no significant influence on the ball's trajectory (Okazaki & Rodacki, 2012). Consequently, perusal of the literature does not provide a clear picture of the importance of applying rotation to the ball. However, applying rotation to the ball through a combination of wrist flexion and radio-ulnar pronation, with a greater contribution coming from the wrist (Knudson, 1993), has been observed in the shooting performances of expert players (Knudson, 1993; Okazaki et al., 2006; Satern, 1988). If the elbow of the shooting hand deviates to the side, the shooting arm may not be able to maintain an appropriate alignment with the basket and may cause a lateral rotation to be applied to the ball at release (Knudson, 1993). In general, shots performed from the free throw line (i.e. from 4.6 m) result in the ball turning around itself two or three times before passing through the basket when spin is applied to the ball at release (Hamilton & Reinschmidt, 1997; Knudson, 1993).

Release angle of the ball

Several different angles have been reported for ball release (Table I). Release angle is related to the angle of entry of the ball through the rim of the basket (Miller & Bartlett, 1996). Thus, a perpendicular release angle provides a larger area for the ball to pass through the width of the basket (Brancazio, 1981; Miller & Bartlett, 1993, 1996; Figure 2). Although an angle of entry closer to 90° would allow a player to use the full width of the basket, a basketball shot with an angle of entry closer to 90° would require the player to use a greater release angle and release velocity. The trade off for producing a shot that could potentially capitalise on using the real width of the basketball rim to reduce the spatial constraint required for target accuracy would require specific mechanical demands on the shooter, especially as the distance from the basket is increased (Miller & Bartlett, 1993, 1996). As a result, the shooter must use an angle that requires more motor efficiency to ensure shooting accuracy.

Brancazio (1981) used projectile motion principles to propose a theoretical optimal release angle based on the smallest possible release velocity. Mathematically, he determined the best ball trajectory that would result in a successful shot when shooting from any distance from

Table I. Different release angles reported in the literature.

Author(s)	Angles	Evidence
Mortimer (1951)	54°–58°	Theory
Hartley and Fulton (1971)	45°	Theory
Brancazio (1981)	45°–55°	Theory
Satern (1988)	52°–55°	Free Throw (Women)
Elliott and White (1989)	~53°	Jump Shot (Women)
Elliott (1992)	44°–47°	Jump Shot (Men)
Elliott (1992)	48°–50°	Jump Shot (Women)
Miller and Bartlett (1993)	47°–52°	Jump Shot (Men)
Knudson (1993)	~52°	Theory
Southard and Miracle (1993)	~58°	Free Throw (Women)
Miller and Bartlett (1996)	48°–55°	Jump Shot (Men)
Hamilton and Reinschmidt (1997)	55°–63°	Free Throw (Theory)
Rojas et al. (2000)	44°–47°	Jump Shot (Men, with and without opponent)
Nunome et al. (2002)	50°–60°	Free Throw (Wheelchair)
Malone et al. (2002)	55°–59°	Free Throw (Wheelchair)
Okazaki and Rodacki (2012)	~65°	Jump Shot (Men)
Okazaki, Lamas, Okazaki, and Rodacki (2013)	~63°	Jump Shot (Children)

the basket. The optimal angle was calculated using the difference between release height and hoop height (h), distance from the basket (d), and inclination angle (Φ). The inclination angle (Figure 3) is an angular measure formed by the intersection of a line projected from the point of ball release to the basket and the point of ball release with the horizontal, given by the formula: $\Phi = arctan\ (h/L)$. By considering the inclination angle, Brancazio (1981) calculated a release angle (θ) that required the smallest velocity using the formula: $\theta = 45° + \frac{1}{2}\ \Phi$. Although the rationale behind Brancazio's concept may be logical when considering the outcome requirements of the shot, calculating a theoretical optimal release angle has not been the focus of studies that analysed the trajectory used by players performing an actual basketball shot. Rather, the results of the studies reported in this review of literature identified different shooting angles (Table I), but failed to establish the relationship between the variables that determined the release angle and the release height of the ball.

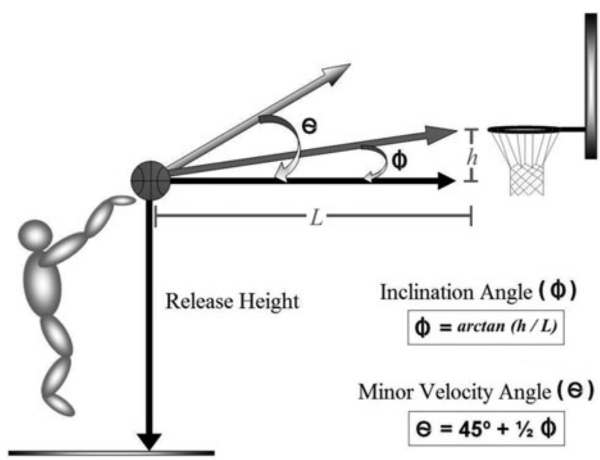

Figure 3. Release angle that requires the smallest ball release velocity (Adapted Brancazio, 1981).

The process by which the shooter organises the sequence of joint movements that define his/her movement pattern when performing the jump shot may be adjusted to perform several different release angles. For example, it is possible to perform a jump shot using a smaller release angle by holding constant the relative timing for the coordination of all moving joints by decreasing the angle of shoulder flexion at the instant of ball release (Okazaki & Rodacki, 2012). If joint range of motion is held constant but joint peak velocities vary, it is possible to use a smaller or larger release angle, depending on the player's movement organisation. Investigation of the strategies of movement organisation adopted by different players, however, requires an analysis of the phases of the shooting motion.

Release height of the ball

Increasing the height of release of the ball permits the player to use a smaller release angle, thereby reducing the need for high movement velocity to execute a successful shot (Hamilton & Reinschmidt, 1997; Malone et al., 2002; Miller & Bartlett, 1993). The player's standing height, jump height, and his/her organisation of segmental movements (Miller & Bartlett, 1996) are variables that influence release height of the ball.

The player's standing height and his/her jumping ability are directly related to ball release height. Thus, a taller player who is able to jump higher will have a higher release height of the ball. In general, players are encouraged to release the ball at the highest point of the jump when shooting a jump shot (Elliott, 1992; Knudson, 1993). Following this advice results in an increased height of release plus increased stability because the player's vertical velocity is almost null if the ball is released at the peak of the jump (Elliott & White, 1989; Knudson, 1993). However, results reported in the literature reveal that ball release often occurs slightly before or after the instant of peak height of the jump (Elliott, 1992; Okazaki et al., 2006; Rojas et al., 2000). Releasing the ball before the highest point in the jump may allow players to transfer part of the vertical velocity resulting from the vertical displacement of their body to the ball to generate greater impulse at ball release (Elliott, 1992). On the other hand, releasing the ball after the instant of peak height of the jump requires greater force generation to propel the ball to the basket (Knudson, 1993). However, more research is required to confirm these assumptions because it is not clear if the body's vertical velocity may be considered a significant factor for transferring velocity to the ball during the final instants of the shot (Elliott, 1992; Knudson, 1993).

Shoulder flexion prior to ball release has been reported to be an important factor for increasing the release height of the ball (Knudson, 1993; Satern, 1988). Greater shoulder flexion closer to ball release results in greater ball release height (Malone et al., 2002; Miller & Bartlett, 1996). Although trunk inclination may affect release height (Satern, 1988), trunk inclination may also be associated with shooting instability (Knudson, 1993). For this reason, some researchers suggest that the trunk should be closer to a vertical position at ball release (Knudson, 1993). In addition, elbow extension has been suggested as a strategy for increasing release height (Knudson, 1993) and for generating greater velocity by the elbow that can be transferred to the ball at release (Elliott, 1992; Malone et al., 2002). Movement organisation of the lower limbs and trunk can also influence release height. Thus, optimising the organisation of the lower limbs and trunk may increase jump height (Coleman, Benham, & Northcott, 1993; Samson & Roy, 1976), which may also increase release height of the ball (Miller & Bartlett, 1993). Therefore, an appropriate movement organisation from the body segments during the learning process may contribute to the development of a shooting movement pattern that results in a successful shot.

Phases of the jump shot

Movements that define the jump shot can be organised into five phases: (a) preparation, (b) ball elevation, (c) stability, (d) release, and (e) inertia (Okazaki et al., 2007). The phases of the basketball jump shooting motion are illustrated in Figure 4.

Preparation phase

During the preparation for the jump shot, players use both hands to position the ball close to the body at waist height, with only the fingers touching the ball (Okazaki et al., 2007). The fingers must be spread out to allow the ball to slide through them during ball release. Only one hand, placed under the ball, is used to generate the impulse required to contribute to the angle and velocity of the ball at release (Knudson, 1993; Satern, 1988). The non-shooting hand is placed on the side of the ball and helps to support the ball during the preparatory motion (Ripoll et al., 1986). The feet are spread shoulder width apart, with the player's body weight being equally divided between both feet. The foot on the same side of the body as the arm used to shoot the ball is placed slightly in front of the body to increase stability (Elliott, 1992; Hudson, 1985b; Knudson, 1993) and to reduce shoulder, trunk, and pelvic rotation during the release phase (Elliott, 1992; Hudson, 1985b; Knudson, 1993). This foot placement also prevents forward and backward movements of the player's body during the jump and helps to keep both the shooting arm and the ball aligned with the basket (Hudson, 1985b; Knudson, 1993). The ankle, knee, and hip joints begin to flex in preparation for the jump (Miller & Bartlett, 1996; Knudson, 1993; Satern, 1988), which results in a slight forward inclination of the trunk (Miller & Bartlett, 1996). The eyes are focused on the front rim of the basket rather than on the ball (Ripoll et al., 1986). Players use the rim of the basket as a visual reference point before, during, and after the shot. Changing the visual focus point during the shooting motion may affect accuracy and consistency of the shot (Ripoll et al., 1986).

Ball elevation phase

The ball elevation phase begins with flexion of the shoulder and elbow to position the ball for release (Okazaki et al., 2007). Specifically, the shoulder lifts the ball by flexing to an angle

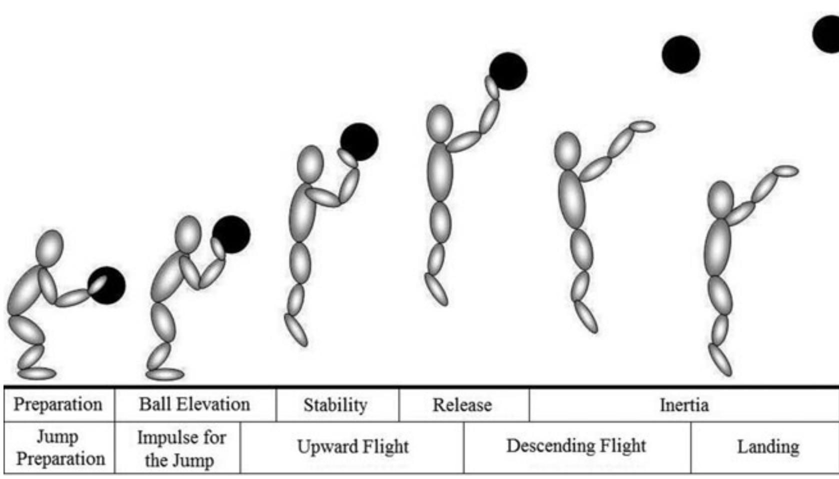

Figure 4. Phases of the jump shot.

between 90° and 135°. The elbow is positioned under the ball in line with the basket (Hudson, 1985b; Knudson, 1993). To improve shooting accuracy, movements of the arm, forearm, and hand occur in a single plane of motion (Button et al., 2003; Hudson, 1985b; Satern, 1988) that results from the alignment of the shoulder, elbow, and wrist (Knudson, 1993; Miller & Bartlett, 1993). The ball is placed close to the body to increase stability and decrease horizontal displacement (Hudson, 1985b; Knudson, 1993; Satern, 1988). Extension of the ankle, knee, and hip joints occur simultaneously as the ball is elevated to initiate the jumping motion (Elliott, 1992) and the stability phase (Okazaki et al., 2007).

Stability phase

Movement stability and control are essential features for shooting accuracy (Okazaki et al., 2006). Stability is characterised by small periods of change in angular displacement of the elbow and shoulder joints (Okazaki et al., 2006, 2007). During the stability phase, the lower limbs extend from their preparatory flexed position to initiate the jump and ascension of the body in flight (Okazaki et al., 2007). In the upper body, the wrist of the shooting arm hyperextends during the ball elevation phase to position the ball for its release that will occur at the peak of the jump. Players use the weight of the ball supported by the shooting hand to optimise wrist hyperextension prior to ball release. The countermovements of the joint (i.e. wrist hyperextension during preparation followed by wrist flexion during ball release) allow the wrist muscles to use elastic energy to initiate wrist flexion. Pre-stretching the wrist flexors generates greater force and velocity that can be applied to the ball at release (Okazaki et al., 2006). Some players may use a reduced or absent stability phase (Button et al., 2003) as a strategy to capitalise on the potential energy created by the elbow extensor muscles instead of the wrist flexors (Button et al., 2003; Okazaki et al., 2007). Regardless, both strategies (i.e. wrist or elbow pre-stretch) generate greater force and speed that can be applied to the ball at release (Okazaki et al., 2006), thereby decreasing the muscle effort needed to release the ball for a successful shot (Okazaki & Rodacki, 2012; Okazaki et al., 2006).

Release phase

The release phase begins with elbow extension and wrist flexion and ends with ball release (Okazaki et al., 2007). Some authors consider elbow extension to be the most important part of the ball release phase and suggest that elbow extension is the determining contributor to ball velocity at release (Button et al., 2003; Miller & Bartlett, 1993). They support their assertion by identifying complete elbow extension as a characteristic of expert shooting performance (Elliott, 1992; Knudson, 1993). However, the countermovement of the wrist joint performed by both novice and expert players (i.e. moving from hyperextension to flexion) suggests that the wrist is an additional contributor to the application of impulse to the ball at release. Moreover, some novice and expert players apply a movement in phase between the joints of the upper extremity (i.e. simultaneous movement of the shoulder, elbow, and wrist) to optimise impulse applied to the ball at release (Okazaki et al., 2006). Some players also use a small lateral deviation (i.e. pronation of the radio-ulnar joint) to accompany wrist flexion, but the pronation occurs only after the elbow is completely extended. On the other hand, some players flex their wrists before their elbows are completely extended to use the energy generated by the joints responsible for the release (Okazaki et al., 2006). It has also been suggested by some researchers that ball release must be performed through finger and wrist flexion to provide a parabolic trajectory and a backward rotation of the ball during flight (Elliott & White, 1989; Knudson, 1993).

Greater wrist flexion, coupled with the application of rotation to the ball at release, has been observed as a characteristic of the performance of expert players (Button et al., 2003; Okazaki et al., 2006).

Inertial or follow-through phase

The inertial phase begins with ball release and is characterised by sustained wrist flexion (Knudson, 1993; Satern, 1988) and reduced shoulder flexion and elbow extension (Okazaki et al., 2007). Decreased movement during the follow through may change wrist velocity and result in lower ball release velocity and ball rotation (Knudson, 1993). Consequently, some researchers recommend complete wrist flexion at release and during the follow-through motion (Knudson, 1993; Okazaki et al., 2007). The jump shot ends with the shooting elbow extended, the hand parallel to the floor, and the fingers pointing toward the basket.

Phases of the jump shot

Despite the universal characteristics of the phases of the basketball jump shot, researchers have identified an inter-individual variability in movement patterns across players (Button et al., 2003; Satern, 1988). This variability is greater in novice players and less evident in expert players (Button et al., 2003; Okazaki et al., 2006). Therefore, playing experience is one factor that influences inter-individual variability when performing a jump shot. However, it has been proposed that variables that regulate the intrinsic dynamics of the shooting motion (i.e. physical and motor characteristics) and the control strategies used by different players to generate velocity and to maintain accuracy are the main determinants over this variability. Thus, although some segmental movements have been identified as common to the movement patterns used by all players to shoot a jump shot, each individual player has a pattern that is unique to his/her performance characteristics (Hudson, 1985a; Satern, 1988).

Additional variables that influence shooting

Several studies have been performed to analyse the effect of variables found in game situations on the jump shot. The following variables were identified as having an influence on the shooting motion used to perform the jump shot: (a) physical characteristics of the player (Elliott & White, 1989; Hudson, 1985b), (b) playing experience (Button et al., 2003; Hudson, 1985a; Okazaki et al., 2006), (c) basket height and ball size/weight (Chase, Ewing, Lirgg, & George, 1994; Okazaki & Rodacki, 2005; Satern, 1988), (d) fatigue (Woolstenhulme, Bailey, & Allsen, 2004), (e) shooting distance (Miller & Bartlett, 1993; Okazaki & Rodacki, 2012), (f) additional basketball skills and movements that occur before the jump shot (Lorenzo & Aragón, 2003), (g) field of view (Oudejans et al., 2002; Ripoll et al., 1986), and (h) the presence of an opponent trying to block the shoot (Rojas et al., 2000). The effect of these and other variables on the jump shot will be discussed in the following sections.

Physical characteristics

Physical characteristics that influence performance of the basketball jump shot include the player's height, limb length, and his/her ability to generate force and velocity. Player height and limb length affect ball release height (Miller & Bartlett, 1996). Therefore, taller players who have longer limbs will have a higher ball release height (Hudson, 1985b). Higher ball release heights require less vertical distance for the ball to travel, thereby requiring a lower release angle and velocity to produce accurate shots (Knudson, 1993; Satern, 1988). Players who are less able to generate force have a harder time performing the jump shot (Hudson, 1985b; Looney, Spray, & Castelli, 1996). For example, novice, children (Okazaki et al., 2006), and female players (Elliott, 1992) require higher shoulder, elbow, and wrist velocities to shoot a successful shot when compared to their adult male counterparts. Furthermore, a greater contribution from the shoulder joint to generate the impulse applied to the ball at release was found in female players (Elliott, 1992) and children (Okazaki et al., 2006). Thus, players who are less able to generate force require more movement velocity (Hudson, 1985b). Similarly, players who have less capacity to generate velocity must generate more force to release the ball. However, researchers caution that increases in force or velocity generation may reduce the player's success because both are related to movement variability (Schmidt et al., 1979).

Experience

Expert players are more consistent in their selection of appropriate control parameters to perform a successful jump shot (Okazaki & Rodacki, 2012; Okazaki et al., 2006). For example, Miller and Bartlett (1996) revealed that guards demonstrate more consistent adaptations of their kinematic patterns when shooting from greater distances compared to centres because guards have more experience with performing jump shots from greater distances. Button et al. (2003) also found greater consistency in the kinematic patterns of free throw shooters in players who had more playing experience. In contrast, novice players constrain the degrees of freedom of their joint movements (Anderson & Sidaway, 1994; Temprado, Della-Grasta, Farrell, & Laurent, 1997) to simplify the 'controlling' demands placed on the central nervous system (Newell & Vaillancourt, 2001; Vereijken, van Emmerik, Whiting, & Newell, 1992) by reducing the involvement of the concomitant actions of the shoulder, elbow, and wrist joints during the release phase of the jump shot (Okazaki & Rodacki, 2005; Okazaki et al., 2006). However, this 'freezing' organisational movement pattern does not allow the novice player to use strategies that have been verified in the performances of expert players such as using a counter-movement strategy around the elbow joint to optimise force generation (Okazaki et al., 2006). This strategy also provides advantages such as lower movement velocities in order to optimise movement accuracy (Okazaki et al., 2006). As a result, novices are (a) unable to synchronise peak joint angular velocities with the instant of ball release (Okazaki et al., 2006), (b) have lower accuracy and ball release height (Hudson, 1985a; Okazaki et al., 2006), (c) show greater centre of gravity displacement in the direction of the basket, and (d) have greater trunk backward inclination. Together, these findings are characteristics of higher instability in the shooting performance of novices in comparison to those demonstrated by their more experienced counterparts (Hudson, 1985a).

Basket height and ball size/weight

Researchers have investigated changes in the shooting motion that result from changes in basket height and ball size in children (Chase et al., 1994; McKey & Halliday, 1997; Okazaki & Rodacki, 2005; Satern, 1988; Satern, Messier, & Keller-McNulty, 1989). Satern (1988) found that children shooting free throws at baskets of different heights modified their shoulder angles and the angle of projection of the ball at release. Specifically, ball size (i.e. weight and circumference) affected the release velocity of the ball, vertical position of the forearm at release and flexion of the elbow during the preparatory phase of the movement (Satern, 1988; Satern et al., 1989). Chase et al. (1994) analysed the efficacy of free throws performed by children using two different ball sizes (men's and women's) in combination with two basket heights (~2,45 m and 3,05 m). Although the children were more accurate when shooting at lower basket heights (Chase et al., 1994), using balls of different weights did not affect their shooting effectiveness. Okazaki and Rodacki (2005) found that using balls of different weights and circumferences did not affect the shooting motion used by children who had more than two years of basketball playing experience, but did result in modification of the control variables used for the basketball shot. Therefore, when considered together, the results of these studies suggest that changes in basket height and/or ball size may result in changes in shooting kinematics (i.e. movement efficiency) and/or movement response (i.e. effectiveness/accuracy).

Fatigue

One factor that may interfere with the performance of a motor task is fatigue (Enoka, 1995). Basketball is a dynamic sport that involves the use of different types of basketball skills (e.g. dribbling, passing) and player movements. Therefore, fatigue is a variable that may be present in several game and/or training situations (Woolstenhulme et al., 2004). Fatigue can be defined as the reduction in the capacity of the muscle to generate force (i.e. peripheral fatigue) and/or reduction in the neural activity of the muscle (i.e. central fatigue) that results from exercise and leads to a player being unable to continue moving at the same level of performance (Jaric, Radovanovic, Milanovic, Ljubisavljevic, & Anastasijevic, 1997; Woolstenhulme et al., 2004). Analysis of the effect of a strength training routine on shooting accuracy and other physical variables, such as vertical jump and anaerobic power, revealed no change in any of the variables as a result of the induced fatigue (Woolstenhulme et al., 2004). It should be noted, however, that changes in shooting effectiveness were not reported in this study because movement efficiency was not analysed. Therefore, the effect fatigue had on the performance of the basketball jump shot is not clear. Studies that analysed the effect of fatigue on motor skills such as the vertical jump (Rodacki, Fowler, & Bennett, 2002), however, revealed that when the primary muscles responsible for the jumping movement were fatigued, the movement resulted from greater involvement of the synergistic muscles. Thus, these results suggest that fatiguing the muscles involved in basketball shooting (e.g. fatiguing the lower limbs that perform the jump or the upper limbs that perform ball release) may result in a decline in the player's level of performance.

Shooting distance

Changing the distance the shot is taken from the basket influences the height, angle, and velocity of ball release. Specifically, as shooting distance increases, the shooter must generate greater ball velocity at release (Miller & Bartlett, 1996, 1993) by re-organising the coordination of the body segments to meet the demands of the new task (Okazaki & Rodacki, 2012). Changes in shooting distance also influence ball release height and angle. As shooting distance increases, release height decreases through a decrease in jump height (Miller & Bartlett, 1993) and shoulder flexion (Elliott & White, 1989; Miller & Bartlett, 1993) because the ball is released before the jumper reaches the highest point of the jump (Elliott, 1992). To accommodate the decrease in release angle, release velocity increases (Miller & Bartlett, 1993, 1996) through a series of several associated factors, such as: (a) increased angular velocity of the shoulder (Elliott & White, 1989; Miller & Bartlett, 1996), elbow (Miller & Bartlett, 1993, 1996), and wrist (Okazaki & Rodacki, 2012); (b) increased velocity (Miller & Bartlett, 1996; Okazaki & Rodacki, 2012) and displacement of the centre of gravity towards the basket (Elliott, 1992; Miller & Bartlett, 1993; Okazaki & Rodacki, 2012); and (c) increased amplitude of the shoulder (Elliott & White, 1989), elbow (Okazaki & Rodacki, 2012), and wrist (Elliott & White, 1989). In addition, as shooting distance increases, some researchers found (a) increased angular velocity of the shoulder (Elliott & White, 1989; Miller & Bartlett, 1993) and elbow at ball release (Miller & Bartlett, 1993); (b) greater forward trunk inclination (Elliott & White, 1989); and (c) greater generation of force to release the ball (Miller & Bartlett, 1996). Changes in release height, angle, and velocity of the ball through the reorganisation of the body segments have been suggested as the main variables that reduce shooting accuracy as shooting distance increases (Okazaki & Rodacki, 2012).

Additional basketball skills and player movements

Basketball is a dynamic sport that requires players to develop proficiencies in skills in addition to shooting. Therefore, before a player takes a shot during a game, other skills (e.g. dribbling and passing) or player movements (e.g. getting open to receive a pass) may be used. Using additional skills and player movements have been shown to affect shooting performance (Lorenzo & Aragón, 2003; Southard & Miracle, 1993). For example, Lorenzo and Aragón (2003) reported that performance of skills prior to shooting, such as catching a pass, making a cut, and offensive rebounding, decreased shooting effectiveness. Southard and Miracle (1993) reported that shooting accuracy decreased when the timing and rhythmicity of the rituals performed before shooting a free throw were changed under the following four conditions: (a) players performed their standard pre-free throw shooting ritual, (b) the absolute time to complete the same pre-free throw shooting ritual behaviours was reduced by one-half, (c) the absolute time to complete the same ritual behaviours was doubled, and (d) the relative timing of performing the pre-free throw shooting ritual behaviours was altered but performed during the same absolute time period. They found that relative timing of the pre-shooting ritual behaviours (i.e. the rhythmicity with which the players performed their ritual behaviours) had a greater impact on success of the free throw than the absolute time allowed to perform the pre-free throw shooting ritual behaviours (Southard & Miracle, 1993). The collective findings of these studies suggest that future research should consider the effect that actions occurring prior to basketball players taking a shot may have on their shooting performance (i.e. accuracy).

Field of view

As noted previously, basketball is a dynamic sport that requires players to make constant changes in their offensive and defensive play. Consequently, changes in the players' field of view may occur with several game situations that are dictated by their opponents, their movement around the court, and/or the skills they demonstrate prior to shooting (e.g. dribbling) (Lorenzo & Aragón, 2003). As these situations change the visual information the player receives, they may also affect the player's shooting performance (Oudejans et al., 2002; Ripoll et al., 1986). For example, Oudejans et al. (2002) reported that interrupting the player's visual information decreased shooting accuracy, especially when visual information was interrupted during the later phases of the shooting motion (Oudejans et al., 2002). Moreover, Ripoll et al. (1986) found that expert shooters tend to focus their vision toward the basket in a quicker manner in comparison to novice players. They suggested that using this strategy allowed the expert player more time to select the control parameters required for success before shooting the jump shot. Therefore, the findings of these studies suggest that the player's field of view before and during the shooting motion is important to shooting accuracy.

Presence of an opponent

In the game of basketball, the player with the ball is frequently in close proximity to one or more opponents over the course of the game. As a result, the offensive player is frequently required to perform a jump shot when guarded by an opponent that is trying to block his/her shot (Rojas et al., 2000). Analysis of the influence of this type of defensive presence has revealed that the shooter responds by using (a) a higher ball release angle, (b) greater elbow extension, (c) greater shoulder flexion, (d) lower vertical displacement of the centre of gravity, and (e) lower ball release height (Oudejans et al., 2002). Researchers suggest that players used these strategies when guarded closely to access a faster shooting motion to prevent the opponent from blocking the shot while trying to use a higher release height to maintain movement accuracy (Oudejans et al., 2002). Therefore, they concluded that an opponent who is trying to block a player's shot may influence both the shooter's response (i.e. his/her shooting motion) and performance (i.e. accuracy of the shot).

Additional variables

The variables presented thus far in this review reflect the variables that have been studied to date and reported in the literature. However, performance of the basketball jump shot may be affected by additional variables that have not been studied. For example, the time constraint placed on a player's shot posed by the possession time clock when time is running out or the presence of a counter-attack transition may result in a player performing the shooting motion more quickly than under ideal conditions and may reduce movement efficiency. Indeed, variables such as stress, confidence, leadership, self-esteem, anxiety, competition, concentration, etc., have been identified in other movement-related research studies as variables that can influence sports performance (Jackson, Thomas, Marsh, & Smethurst, 2001). Therefore, it is reasonable to consider that these psychological variables may also influence the performance of the basketball jump shot and should be investigated in future research.

Final remarks

A comprehensive review of the literature on basketball shooting revealed a number of factors that influence shooting performance under a variety of conditions. The analysis of the trajectory of the ball during the basketball jump shot suggests that a higher release angle and release height in combination with a lower release velocity are the preferred combination when executing a successful jump shot. Using a higher release, angles provide a greater target area for the ball to pass through the basket's circumference area to produce a successful shot. In addition, higher release heights result in less horizontal distance travelled by the ball during flight and decreases the demand placed on the player to produce force and generate velocity to apply to the ball at release. Lower release velocities result in greater movement consistency and shooting accuracy.

Investigations into the shooting performance of successful jump shots revealed the following segmental movement variables that result in greater release height: (a) reduced backward inclination of the trunk, (b) greater shoulder flexion and elbow extension at release, and (c) synchronising ball release with the peak of the jump. Additional aspects related to the performance of expert basketball jump shots include: (a) aligning the trunk close to vertical at release, (b) aligning the shoulder, elbow, and wrist in the same plane of motion, (c) releasing the ball at the highest point of the jump, (d) reducing horizontal displacement of the centre of gravity during the shooting motion, (e) increasing movement time used by the shooter to select the control parameters used in the shooting motion, (e) keeping the ball close to the body during the preparation phase, and (f) generating less velocity by the lower limbs, upper limbs, and trunk to release the ball.

Understanding the interaction of all the variables that influence the movement pattern used by a player when executing a jump shot demonstrates the complexity that defines the performance of this important movement skill in the sport of basketball. Coaches and teachers should consider these variables during the time they spend with their players in instruction and practice to optimise the players' shooting performance. Additional research that analyses the relative importance of the variables identified on learning how to perform the basketball jump shot under different types of practice organisational structures will result in greater understanding of the relative importance of each variable to the development of players who can execute successful basketball jump shots.

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