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Research article

Increased distance of shooting on basketball jump shot

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Abstract
The present study analyzed the effect of increased distance on basketball jump shot outcome and performance. Ten male expert basketball players were filmed and a number of kinematic variables analyzed during jump shot that were performed from three conditions to represent close, intermediate and far distances (2.8, 4.6, and 6.4m, respectively). Shot accuracy decreased from 59% (close) to 37% (far), in function of the task constraints ($p < 0.05$). Ball release height decreased ($p < 0.05$) from 2.46 m (close) to 2.38m (intermediate) and to 2.33m (long). Release angle also decreased ($p < 0.05$) when shot was performed from close (78.92°) in comparison to intermediate distances (65.60°). While, ball release velocity increased ($p < 0.05$) from 4.39 m/s (close) to 5.75 $m\cdot s^{-1}$ (intermediate) to 6.89 $m\cdot s^{-1}$ (far). These changes in ball release height, angle and velocity, related to movement performance adaptations were suggested as the main factors that influence jump shot accuracy when distance is augmented.

Key words: Jump shot, distance of shooting, basketball, motor control, biomechanics.

Introduction

Basketball is a highly dynamic sport, in which players must perform shots from several distances from the basket (Rodacki et al., 2005). Longer shots demand greater accuracy (Elliott, 1992; Okazaki et al., 2004) because the horizontal virtual target decreases as shooting distance increases (Figure 1). Thereby, the greater the shooting distance the greater the spatial accuracy constraint the shooter must master. In addition, when the shooting distance increases the force requirements change and the player needs to take into account this task constraint.

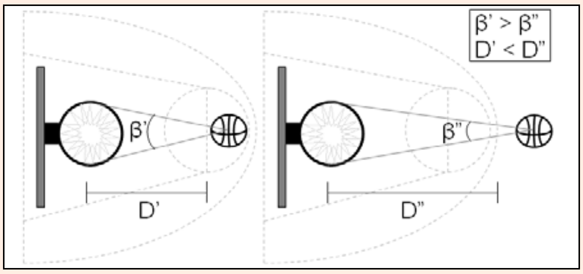

Figure 1. **Schematic representation (top view) of the virtual horizontal target (β) at freethrow and three point distances. 'D' represents the distance of shooting and 'β'represents the virtual horizontal target.**

When the shooting distance increases, the player must reduce the ball release angle and the ball follows a flatter flight path (Miller and Bartlett, 1996; Satern, 1993). The release angle and the entry angle are directly related to each other (Brancazio, 1981) and alter the size of the vertical virtual target, as indicated in Figure 2. For instance, when the ball reaches the basket with an angle close to 90º, the passage area is given by the difference between the ball and basket areas (Miller and Bartlett, 1993). When the entry angle decreases the vertical virtual target is reduced and produce a smaller entrance area (Miller and Bartlett, 1993, 1996). Thus, shoots performed from far distances decrease the release angle and increase accuracy demands.

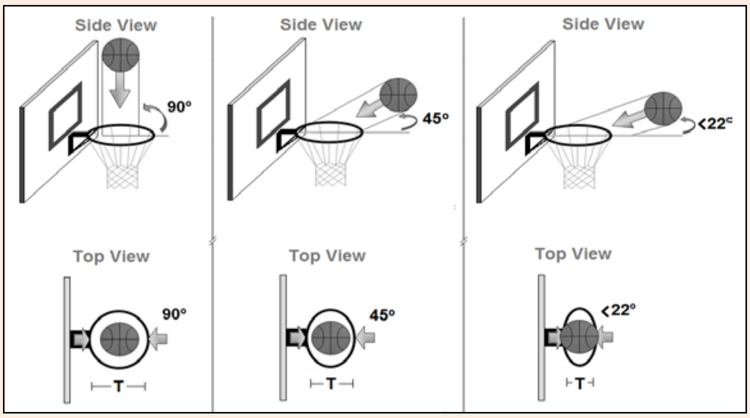

Figure 2. **Schematic representation (side and top views) of the vertical virtual target (T) in function of baskets angles of entry (adapted from Miller and Bartlett, 1993).**

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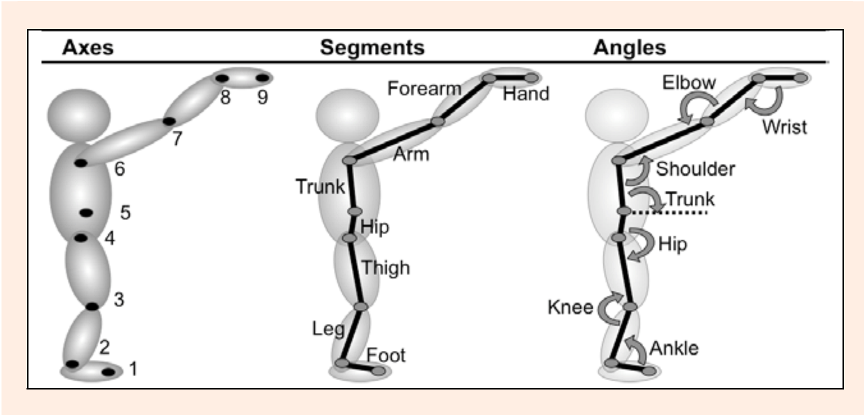

Figure 3. Schematic representation of the biomechanical model and joint convention. Legend: (1) basis of the fifth metatarsal phalange, (2) fibulas lateral malleolus, (3) femurs lateral epicondyles, (4) femurs great trochanter, (5) iliac crest, (6) humerus great tubercle, (7) humerus lateral epicondyles, (8) ulnar styloid process, and (9) basis of the fifth metacarpal phalange.

Shots performed from long distances, also require greater impulse to propel the ball towards the basket (Miller and Bartlett, 1993, 1996; Satern, 1993; Walters et al., 1990). Impulse increases have been shown to decrease accuracy (Meyer et al., 1988; Okazaki et al., 2008b; Schmidt et al., 1979). Indeed, small accuracy has been observed on shots performed at long distances during real game situations (Okazaki et al., 2004) and experimental conditions (Elliott, 1992). Therefore, increasing shooting distance may affect accuracy due to motor control strategies applied to control the increased task spatial constraints (vertical and horizontal virtual targets). Different movement strategies have been verified as distance increased in an attempt to account for these constraints (Satern, 1993).

Satern (1993) showed increased ball release velocity when shooting distance was increased. The players were able to increase release velocity by using greater arm joint range of motions. Similarly, Elliott and White (1989) reported greater shoulder angular velocities and greater movement amplitudes around the shoulder and wrist in female basketball players in response to shooting distance increases. Miller and Bartlett (1993) observed greater shoulder flexion, greater elbow extension and increased center of mass displacement towards the basket. These changes were considered as compensatory strategies that emerge when shooting distances are increased. Thus, different adaptive strategies are reported in the literature, but, the effects of distance manipulation with respect to movement control strategies are not clear.

Given the importance of basketball jump shot, this ability has been studied through qualitative observations, mathematical models of deductions and experimental evidences (Knudson, 1993). However, only a few studies have analyzed the performance of the jump shot when the distance is experimentally manipulated. The analysis of the shot performance with respect increases in shooting distance may help the understanding of the underlying mechanisms and the variables that influence movement accuracy. The present study analyzed the effects of distance variations on basketball jump shot performance. It was hypothesized that increasing the shooting distance decreases movement accuracy, which is accompanied by decreases in ball release angle and height and increased ball release velocity.

Methods

Sample

Ten right handed male basketball players (25 ± 2 years-old; 86.8 ± 12 kg; 1.84 ± 0.07 m; 12 ± 3 years of practice) volunteered to participate in the study and signed (or their parents) a written informed consent form, which was approved by the University Ethics Committee. Participants were free from injuries that could interfere in their jump shooting performance. All participants were attending regular training sessions (3 sessions per week) and official competitions (National and State) during the period of the study.

Experimental procedures

Before data collection, participants were allowed to warm-up for 10-20 min. Warm-up included generalized and specific exercises in which participants practiced a number of jump shots. After the warm-up period, reflective markers (1.5 cm in diameter) were placed on the skin and clothes and allowed to reconstruct the movement in two dimensions according to the biomechanical model indicated in Figure 3. Participants were instructed not to use the backboard and to shot directly through the basket ring.

Then, participants were allowed additional shots preceding the data collection, which was initiated after 2 minutes of rest. Ten jump shots were performed in a random order from three conditions to represent a close, intermediate and long distances (2.8, 4.8, and 6.8m, respectively) using a standard basket (height 3.05m). The percentage of successful shots was recorded und used to determine jump shooting accuracy.

The kinematic characteristics of the movement were determined using a standard 2D analysis. A digital camcorder (JVC model GR-DVL 9500E, Japan) recording at 100Hz was perpendicularly positioned at approximately 8 m to the sagittal plane of the dominant side of the participants. A rectangle of 2.5 m x 2.0 m was placed on the movement plan to calibrate the kinematic data. Three successful trials were randomly selected for further analysis. These trials were time normalized and the ensemble average was calculated for each subject in each experimental condition.

Movement start was defined as the instant the participant started lifting the ball (using a shoulder or elbow flexion) while movement end was defined as 10 frames (0.1s) after ball release (i.e., the instant in which ball lost hand contact). Landmarks were manually digitized by one experimenter using SIMI Motion® software (SIMI Reality Motion Systems GmbH, Germany). The center of the ball was digitized and used to identify ball-related parameters.

Ball release angle, height (vertical linear displacement at release instant), and velocity (vertical, horizontal, and resultant vector components) were also analyzed. Release angle was defined as the angle between the displacement of the ball (over a period of 0.05s; 5 frames - after ball release) and the horizontal. The use of a period of 0.05s was performed to reduce digitizing error effects, which tends to be greater when shorter periods are applied. Ball height was defined as the height at which ball release occurred.

Jump shot parameters selected to determine movement pattern included kinematic analysis of a number of variables around the ankle, knee, hip, trunk, shoulder, elbow, and wrist joints and the following variables determined: (a) temporal series of joint angular displacement and velocities; (b) minimum and maximum joint angular displacements; (c) joint range of motion (d) joint angle at ball release; (e) minimum and maximum joint angular velocities; and, (f) movement duration. Center of mass displacement and velocity (horizontal and vertical) were also analyzed. The center of mass displacement was assumed to be closely related to the displacement of the hip joint marker. The maximum displacement, displacement at release instant, maximum velocity and velocity at release of the center of mass were determined. Positive vertical velocity of the center of mass indicates that shot was performed during the jump ascending phase, while negative vertical velocity indicates the shot was performed during the jump descending phase.

Data analysis

A recursive low-pass Butterworth filter of 4th order was applied to reduce high frequency components using a cut-off frequency of 6Hz, which was determined through the residual analysis method (Winter, 1990). The filtering determination was obtained from the elbow joint angular displacement as this joint presents the fastest displacements. After filtering the coordinates, joint angular displacements and velocities were calculated. The time-series data were time normalized with respect to movement duration and are represented as a movement percentage. Data digitizing accuracy was determined using a randomly selected video that was digitized three times and variables of the elbow calculated. A one-way ANOVA showed no intra-trial differences and absolute differences were as small as 0.41^o (0.16%) 1.49^o.s^{-1} (0.18%) for joint angular displacement and velocity, respectively. Linear displacement data showed errors smaller than 0.5%.

Statistical analysis

Initially, the data sets were analyzed using descriptive statistics (mean ± standard deviations). Kolmogorov-Smirnov and Hartley tests confirmed data normality and homogeneity, respectively. A number of one-way ANOVA with repeated measures was applied to compare the kinematic variables (spatial and temporal) and shot accuracy across three experimental distances of shots. The Tukey test was applied to determine where differences occurred. The Bonferroni's correction strategy was applied to reduce type I error. The significance level was set at $p < 0.05$.

Results

Shot accuracy was decreased for the farthest distance when compared to other conditions ($p < 0.05$). Distance increase from close to far decreased the ball release height ($p < 0.05$). Balls release height decreased from the close distance in comparison to the intermediate and far conditions ($p < 0.05$). Balls release angle was also decreased when the shot was performed from intermediate when compared to closer distances ($p < 0.05$). As shot distance increased, higher balls velocities (resultant, horizontal and vertical) were observed between all experimental conditions ($p < 0.05$). This higher velocity was performed with shorter times (total time and time to release) when the jump shots were performed from the farthest distance in comparison to the other conditions ($p < 0.05$). Table 1 shows the ball shooting variables in each experimental distance.

The shots close to the basked were performed using higher jump heights, when compared to the shots performed from an intermediate distance ($p < 0.05$). Shooting close to the basket also allowed the ball release to occur at the instant of highest jump height in comparison to the shots performed far from the target ($p < 0.05$). Increasing the distance caused a greater horizontal velocity of the center of mass in comparison to the shots executed from the longest distance ($p < 0.05$). The closest

Table 1. Ball-related kinematics of jump shots performed from different distances. Data are means (± standard error).

	Distance of Shooting			Statistics	
Variables	**6.4 m**	**4.6 m**	**2.8 m**	**F**	**Significance**
Accuracy (%)	37.0 (11.6)^{bc}	62.0 (12.3)^{a}	59.0 (20.3)^{a}	$F_{2,27} = 8.10$	p = .003*
Release Height (m)	2.33 (.14)^{c}	2.38 (.14)^{c}	2.46 (.11)^{ab}	$F_{2,27} = 11.0$	p < .001*
Release Angle (°)	69.32 (10.58)	65.60 (12.54)^{c}	78.92 (8.84)^{b}	$F_{2,27} = 5.4$	p = .014**
Release Resultant Velocity (m·s^{-1})	6.89 (.62)^{bc}	5.75 (.50)^{ac}	4.39 (.36)^{ab}	$F_{2,27} = 80.7$	p < .001*
Release Horizontal Velocity (m·s^{-1})	4.18 (.34)^{bc}	3.56 (.40)^{ac}	2.66 (.24)^{ab}	$F_{2,27} = 75.2$	p < .001*
Release Vertical Velocity (m)	5.46 (.69)^{bc}	4.44 (.62)^{ac}	3.48 (.43)^{ab}	$F_{2,27} = 49.4$	p < .001*
Total Time (s)	.666 (.083)^{bc}	.738 (.097)^{a}	.774 (.108)^{a}	$F_{2,27} = 13.4$	p < .001*
Time Until Ball's Release (s)	.573 (.080)^{bc}	.641 (.101)^{a}	.675 (.105)^{a}	$F_{2,27} = 12.3$	p < .001*

Significant difference (p < 0.05) when compared to the shot performed at ^{a} 6.4 m, ^{b} 4.6 m, and ^{c} 2.8 m; effect size with $^{*}\alpha$>0.92 and $^{**}\alpha > 0.78$.

Table 2. Center of mass variables (mean and standard error) of the jump shots performed from different distances. Data are means (± standard error).

Variables	Distance of Shooting			Statistics	
	6.4 m	4.6 m	2.8 m	F	Significance
Maximum vertical displacement (m)	1.25 (.05)	1.24 (.08)[c]	1.30 (.08)[b]	$F_{2,27} = 5.08$	p = .017**
Maximum horizontal displacement (m)	.503 (.180)	.509 (.124)	.397 (.131)	$F_{2,27} = 2.14$	P = .146
Release vertical displacement (m)	.388 (.089)[c]	.432 (.078)	.462 (.070)[c]	$F_{2,27} = 4.0$	P < .036**
Release horizontal displacement (m)	.303 (.062)	.310 (.165)	.203 (.186)	$F_{2,27} = 2.1$	P = .156
Maximum vertical velocity ($m \cdot s^{-1}$)	2.22 (.244)	2.25 (.25)	2.34 (.20)	$F_{2,27} = .9$	P = .41
Maximum horizontal velocity ($m \cdot s^{-1}$)	1.05 (.32)[c]	.91 (.28)	.76 (.21)[a]	$F_{2,27} = 5.0$	P = .018**
Release vertical velocity ($m \cdot s^{-1}$)	.984 (.693)[bc]	.399 (.754)[ac]	-.256 (.618)[ab]	$F_{2,27} = 54,0$	P < .001*
Release horizontal velocity ($m \cdot s^{-1}$)	.171 (.407)	.086 (.325)	.028 (.159)	$F_{2,27} = 1.05$	p = .370

S ignificant difference (p < 0.05) when compared to the shot performed at [a] 6.4 m, [b] 4.6 m, and [c] 2.8 m; effect size with * α>0.98 and ** α=0.75 to 0.63.

shots were performed at the descending phase of the jump, i.e., after the instant of maximal jump height. On the other hand, ball release of the shots performed from intermediate and long distances occurred in the ascending phase of the movement. A greater vertical velocity of the jump was observed as shooting distances increased ($p < 0.05$). Table 2 showed the shot center of mass variables across the experimental conditions.

The increased distance of shooting did not change the maximum and minimum joint angles ($F_{2,27} < 3.5$; $p > 0.05$). Joint angular amplitudes also showed with no significant modifications, independently of the shooting distance for the lower limbs ($F_{2,27} < 3.5$; $p > 0.05$), trunk ($F_{2,27} = 1.43$; $p = 0.263$), shoulder ($F_{2,27}$=0.192; $p = 0.827$), and wrist joints ($F_{2,27} = 1.85$; $p = 0.185$). The elbow angular amplitude ($F_{2,27} = 8.92$; $p = 0.002$) increased in the shots performed from the nearest distance, when compared to the others ($p < 0.05$). Joint angles during the release instant were not altered for the lower limbs ($F_{2,27} < 1.5$; $p > 0.05$), trunk ($F_{2,27} = 2.75$; $p = 0.091$), elbow ($F_{2,27} = 1.24$; $p = 0.313$), and wrist joints ($F_{2,27} = 2.07$; $p = 0.155$). The shoulder joint ($F_{2,27} = 6.05$; $p = 0.0097$) showed shorter flexion when the shots were performed from the farthest distance in comparison to the shots performed from the closest distance ($p < 0.05$). Table 3 shows the joint angular displacement variables across the experimental conditions.

Distance manipulation did not influence the maximum angular velocity of the ankle ($F_{2,27} = 0.972$; $p = 0.397$), knee ($F_{2,27} = 0.087$; $p = 0.916$), hip ($F_{2,27} = 1.13$; $p = 0.343$), trunk ($F_{2,27} = 0.597$.; $p = 0.561$), shoulder ($F_{2,27} = 3.14$; $p = 0.067$), and wrist ($F_{2,27} = 2.00$; $p = 0.164$) joints. However, the maximum angular velocity increased around the elbow joint ($F_{2,27} = 23.84$; $p < 0.001$) in all experimental conditions The minimum joint angular velocity was not modified around the ankle ($F_{2,27} = 1.21$; $p = 0.319$), knee ($F_{2,27} = 1.48$; $p = 0.254$), hip ($F_{2,27} = 1.52$; $p = 0.245$), trunk ($F_{2,27} = 0.716$; $p = 0.502$), shoulder ($F_{2,27} = 2.74$; $p = 0.091$), and elbow ($F_{2,27} = 0.168$; $p = 0.846$) when the jump shot distance was increased. The minimum joint angular velocity of the wrist ($F_{2,27} = 4.66$; $p = 0.0234$) increased during the shots performed at the closest distances when compared to the longest shooting distances ($p < 0.05$). At the ball release instant, there were no distance effect on the velocities of the ankle ($F_{2,27} = 2.48$; $p = 0.112$), knee ($F_{2,27} = 0.44$; P=0.646), hip joints ($F_{2,27} = 0.51$; $p = 0.611$) and the trunk segment ($F_{2,27} = 1.81$; $p = 0.192$). However, angular release velocity increased around the shoulder ($F_{2,27} = 48.48$; $p < 0.001$), elbow ($F_{2,27} = 16.57$; $p < 0.001$) and wrist joints ($F_{2,27} = 5.45$; $p = 0.014$) in all experimental conditions ($p < 0.05$). The joint angular velocity variables in all experimental conditions

Table 3. Angular displacements of jump shots performed from different distances. Data are means (± standard error).

Joint	Distance of Shooting			Joint	Distance of Shooting		
	6.4 m	4.6 m	2.8 m		6.4 m	4.6 m	2.8 m
Maximum angular displacement (°)							
Ankle	153.8 (6.5)	152.5 (4.3)	151.0 (6.9)	Shoulder	131.0 (6.3)	130.1 (5.9)	131.2 (8.4)
Knee	168.9 (4.7)	171.1 (2.8)	171.2 (3.3)	Elbow	160.4 (9.5)	160.3 (11.4)	157.8 (12.6)
Hip	180.6 (6.5)	180.3 (4.7)	179.2 (6.5)	Wrist	217.1 (18.9)	219.0 (16.6)	219.1 (16.5)
Trunk	92.6 (6.8)	94.3 (5.1)	97.8 (12.0)				
Minimum angular displacement (°)							
Ankle	95.2 (9.6)	94.5 (7.3)	94.8 (10.6)	Shoulder	35.1 (13.2)	34.5 (10.9)	37.1 (12.2)
Knee	104.4 (8.7)	105.2 (9.0)	106.5 (6.6)	Elbow	54.5 (9.5)	57.2 (12.3)	64.0 (14.2)
Hip	147.0 (10.8)	146.2 (9.0)	147.5 (10.9)	Wrist	138.9 (18.6)	146.9 (18.6)	148.5 (13.3)
Trunk	95.2 (9.6)	94.5 (7.1)	94.8 (10.6)				
Angular amplitude (°)							
Ankle	58.7 (5.6)	58.1 (6.5)	56.2 (7.4)	Shoulder	95.8 (15.2)	95.6 (13.2)	94.1 (15.2)
Knee	64.4 (10.6)	65.9 (8.6)	64.7 (6.0)	Elbow*	105.9 (9.4)[c]	103.1 (13.5)[c]	93.8 (16.8)[ab]
Hip	33.6 (10.0)	34.1 (6.6)	31.6 (8.3)	Wrist	78.2 (18.9)	72.1 (17.4)	70.6 (20.3)
Trunk	36.8 (8.0)	40.1 (8.3)	38.8 (7.0)				
Release Angle (°)							
Ankle	148.4 (11.9)	148.1 (6.3)	149.0 (5.8)	Shoulder*	117.5 (6.9)[c]	118.6 (6.3)	122.4 (9.1)[a]
Knee	166.4 (5.6)	168.3 (4.1)	168.1 (3.9)	Elbow	134.3 (8.4)	135.8 (8.5)	138.2 (13.9)
Hip	178.0 (5.2)	178.4 (4.8)	177.8 (5.8)	Wrist	187.8 (11.0)	191.1 (11.5)	190.1 (9.7)
Trunk	89.7 (4.9)	92.3 (4.8)	95.8 (10.6)				

Significant difference (p < 0.05) when compared to the shot performed at [a] 6.4 m, [b] 4.6 m, and [c] 2.8 m; effect size with * α>0.82.

Table 4. Angular velocities of jump shots performed from different distances. Data are means (± standard error).

Joint	Distance of Shooting 6.4 m	4.6 m	2.8 m	Joint	Distance of Shooting 6.4 m	4.6 m	2.8 m
Maximum angular velocity (°/s)							
Ankle	456.6 (40.6)	442.7 (29.1)	419.2 (86.6)	**Shoulder**	374.2 (94.6)	316.01 (64.54)	333.3 (55.7)
Knee	436.1 (83.3)	427.0 (61.5)	435.3 (76.2)	**Elbow**	851.6 (103.8)^{bc}	743.3 (138.6)^{ac}	665.8 (154.7)^{ab}
Hip	191.8 (52.1)	178.2 (43.3)	165.0 (49.3)	**Wrist**	179.2 (95.7)	205.7 (94.6)	217.9 (79.5)
Trunk	132.4 (34.5)	128.3 (32.3)	122.5 (25.7)				
Minimum angular velocity (°/s)							
Ankle	-77.4 (21.9)	-72.8 (32.1)	-109.6 (85.9)	**Shoulder**	-35.2 (77.5)	-63.4 (63.7)	-78.6 (44.0)
Knee	-186.0 (38.9)	-164.9 (48.4)	-186.2 (47.4)	**Elbow**	-278.5 (120.9)	-288.1 (165.7)	-298.1 (191.2)
Hip	-75.6 (36.8)	-55.5 (30.8)	-62.4 (27.2)	**Wrist**	-912.4 (286.0)^{c}	-760.3 (229.6)	-730.9 (219.4)^{a}
Trunk	-31.9 (29.7)	-20.0 (23.7)	-28.3 (28.2)				
Release velocity (°/s)							
Ankle	96.4 (169.3)	66.1 (139.6)	-3.3 (24.8)	**Shoulder**	346.5 (92.8)^{bc}	272.7 (84.5)^{ac}	223.1 (89.2)^{ab}
Knee	42.5 (130.4)	26.6 (111.0)	5.4 (33.1)	**Elbow***	741.6 (130.8)^{bc}	645.2 (169.5)^{ac}	539.0 (195.8)^{ab}
Hip	-23.4 (74.1)	-19.4 (57.9)	-6.3 (23.3)	**Wrist**	-795.1 (208.3)^{bc}	-648.2 (206.7)^{a}	-664.4 (198.0)^{a}
Trunk	-0.52 (51.6)	18.81 (29.2)	27.48 (25.84)				

Significant difference ($p < 0.05$) when compared to the shot performed at ^{a} 6.4 m, ^{b} 4.6 m, and ^{c} 2.8 m; effect size with * α>0.90 and ** α=0.89 to 0.70.

are reported in Table 4.

Discussion

The increased distance leaded to greater spatial constraint over the shot movement. Greater distances of shooting resulted in smaller virtual targets (horizontal and vertical) in addition to the greater ball displacement required from release point to the basket (Satern, 1993; Walters et al., 1990). This greater constraint required the performers to change movement control strategies to preserve accuracy and produce a large impulse to propel the ball at the release instant. These strategies imposed height, angle and velocity changes at ball release instant and have been suggested as the main determinants of the shot (Brancazio, 1981; Miller and Bartlett, 1996). Such strategies are also closely related to accuracy loss in shots performed from far distances.

Shots performed at farther distances from the basket presented smaller release heights. Shots performed from long distances demand the generation of a large impulse to propel the ball over a long trajectory to reach the basket. Small release height and great release impulse to propel the ball have been related to less accurate shots (Brancazio, 1981; Knudson, 1993; Miller and Bartlett, 1996). A reduced ball release height has been described as to occur before the highest jump height is reached (Elliott, 1992). In addition, these shots are also characterized by a reduced shoulder flexion (Elliott and White, 1989; Miller and Bartlett, 1993) and a decrease jump height (Miller and Bartlett, 1993). The present study also confirmed the use of such strategy that includes a premature ball release instant with respect to the jump height peak and has been applied to allow the use part of the jump energy in an attempt to optimize the impulse to release the ball (Elliott, 1992; Knudson, 1993). On the other hand, this strategy has been suggested to reduce shot stability (Knudson, 1993; Okazaki et al., 2006b). Shots performed near to the basket (closest condition) presented the ball release instant close to the maximum jump height. Therefore, shots performed closer to the basket allowed greater stability, smaller travelling ball distance and less demand to generate large amounts of impulse to propel the ball at the release instant. These factors helped to understand the higher accuracy found in shots performed close to the basket.

The lower ball release height did not cause jump height decreases. This corroborates with the consistency of the lower limb kinematics, irrespective of the shot distance. It is also indicative of players of low experience level (i.e., novices). The greater horizontal velocity of the center of mass towards the basket was found as shot distance increased. Indeed, the vertical velocity of the center of mass increased in response to distance increments. These greater velocities have been associated to the strategies of the reuse of the energy generated on jump to be transferred to the upper limbs to optimize the impulse to release the ball (Elliott, 1992; Knudson, 1993; Okazaki et al., 2006b). This strategy has been found on shots performed from farther distances (Elliott, 1992) and in players with diminished capacity to generate force or and with less experience (Okazaki et al., 2006b). However, the strategy of optimizing the impulse by releasing the ball at instants closer to the highest velocity of the center of mass (vertical and horizontal velocities) has been related to less shooting accuracy which helps to explain the low accuracy found in shots performed from far distances.

The release height reduction can be also explained by a decreased shoulder flexion at balls release instant. As the ball was released with lower shoulder flexion, the throwing hand achieved a lower height position. It has been proposed that the shoulder largely determines the balls release angle (Okazaki et al., 2008a). The results of the present study are in consonance with these arguments because shot distance increases were characterized by lower shoulder flexion and lower ball release angle

The decrease on ball release angle has been also reported when distance of shooting increases (Miller and Bartlett, 1996; Satern, 1993). The lower release angle on jump shots performed far from the basket can be viewed as an attempt to minimize the larger demand to propel the ball. If the release angles were unaltered, shots performed from far distances would require more force and jeopardize accuracy and increase error ratio (Meyer et al., 1988; Schmidt et al., 1979; Okazaki et al., 2008b). It seems that mastering the appropriated movement strategies to use the release angles that do not compromise the ball entry angle and preserve lower velocity generation may increase performance outcomes (Brancazio, 1981; Miller and Bartlett, 1996).

Increasing shooting distance caused greater ball release velocities. As a result of the well-known speed-accuracy tradeoff (Fitts, 1954; Meyer et al., 1988; Okazaki et al., 2008b), the increased release velocity may have also influenced the accuracy loss of shots performed from long distances. Thus, it was suggested that the emphasis on impulse generation to basketball jump shot is detrimental to accuracy. When shooting from far distances follow strategies were observed: (a) greater center of mass horizontal velocity toward to the basket and (b) greater vertical velocity to increase jump height, (c) increased elbow amplitude, (d) greater elbow extension velocity, (e) greater wrist flexion velocity, and (f) increased angular velocity at ball release around the shoulder, elbow, and wrist joints.

The increased center of mass velocity was also reported by others (Miller and Bartlett, 1996; Walters et al., 1990) and associated to increase the impulse momentum toward to the basket (Elliott, 1992; Miller and Bartlett, 1993; Satern, 1993). Other studies showed that shooting from long distances increases the demand of the movement, which is accomplished by greater the flexion amplitude around shoulder (Elliott and White, 1989) and wrist joints (Elliott and White, 1989; Rodacki et al., 2005). A decreased shoulder and wrist (Miller and Bartlett, 1993; Elliott and White, 1989) angular displacement at ball release instant were also observed, although a greater forward trunk inclination occurred (Elliott and White, 1989). These data suggest the existence of different strategies, which are also detected in the present study, as relatively large standard deviations were found. It was noticed that each player applies a particular strategy to control the movement parameters, which is dictated by the players' intrinsic dynamics (cf. Kelso, 1995) that encompasses physical (anthropometry, strength, power etc.) and motor aspects (experience) (Okazaki et al., 2009). It is interesting to observe that variability increased at the ball release instant in a proximal to distal order (Table 3 and 4). The adjusting the movement form proximal to distal seems to be beneficial, as small corrections in the relative timing of joint reversals can be performed. It is likely that these adjustments can constitute a strategy to allow the athlete to perform small adjustments and preserve accuracy. It seems that distance does not influence such proximal-distal variability.

Conclusion

In conclusion, as distance increases shot accuracy decreases. This decrease can be explained by spatial constraints of the task (horizontal and vertical) and were associated with changes observed on movement performance. The decreased balls release height and angle and the increased balls velocity at the release instant, were modified in response to chances on movement control parameters, as they constitute the main factors that lead to less accuracy when jump shot distance increases. The different strategies of movement control parameters and were influenced by inter-individual variability on shot pattern (due to the intrinsic dynamic factors) and the strategy adopted to regulate the impulse generation while trying to sustain accuracy.

It is suggest studies further studies to manipulate the ball releases height, angle and velocity to understand the basketball shot control strategies. Furthermore, studies that consider the inter-individual variability may provide further subsides for the understanding of the basketball jump shot strategies.

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Key points

- The increased distance leads to greater spatial constraint over shot movement that demands an adaptation of the movement for the regulation of the accuracy and the impulse generation to release the ball.
- The reduction in balls release height and release angle, in addition to the increase in balls release velocity, were suggested as the main factors that decreased shot accuracy with the distance increased.
- Players should look for release angles of shooting that provide an optimal balls release velocity to improve accuracy.

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