JOINT KINEMATICS AND MUSCLE ACTIVITIES TO ACHIEVE SUCCESSFUL BANK-SHOTS IN BASKETBALL FREE-THROW

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The study purpose was to investigate joint kinematics and muscle activations and compare clean-shot (CS) and bank-shot (BS) in men's basketball free-throw. Ten high school male basketball athletes were recruited and asked to perform 10 CS and 10 BS, respectively, in random order. Kinematic results indicated that the range of motions (ROM) of knee, hip, and elbow joints for BS were greater (2.9 to 15.1%) than those of CS. During the projection phase, peak angluar velocities of all joints except the wrist of BS were greater than those of CS. The muscle activity of the triceps brachii increased by about 10.5% across all phases of BS compared to CS. In conclusion, the strategy of successful BS depends on increased joint ROMs and muscle activations of the triceps but similar peak angular velocity of the wrist to CS during the projection phase.

KEYWORDS: kinematics, EMG, basketball, free-throw, clean-shot, bank-shot

INTRODUCTION: A free-throw in basketball absolutely depends on a thrower's shot ability, since there is no guard to block shooting. Even though free-throws account for only about 15% of total game scores, the success or failure of them determines the win or loss of the game or changes the momentum in a very tight game. There are two types of free-throw skills such as clean-shot (CS) and bank-shot (BS). The BS is an intended technique to hit the backboard first with a shooting ball, and to put a rebound ball into the rim.
The most popular technique of a free-throw is a CS. Sometimes even a player who usually uses CSs performs intentional BSs in highly competitive games. Anecdotally players tend to believe psychological comfort when having a simple task, hitting a ball on the specific point of the backboard to make a successful shot.
In terms of kinematics, the biggest difference between a CS and a BS is the projectile distance. Silverberg, Tran, and Adams (2011) showed that the projectile distance of the BS is about 40 cm longer than that of the CS. To increase the rate of successful BS the shot balance, the coordination of body segment rotations, must be different from the CS. The change of shot balance is practically achieved by changes of the joint angles and muscle forces.
There are few studies that explain how to modify joint kinematics and muscle activations in an attempt to achieve successful BSs (Mullineaux & Uhl, 2010). Therefore, this study purpose was to find biomechanical knowledge needed to successfully perform BSs by comparing kinematics and EMGs of successful CSs in basketball free-throw.

METHODS: Ten male high school basketball players (Mean ± SD: age 18 ± 0.7 yrs; 1.82 ± 0.05 m; 75.8 ± 8.3 kg) participated in this study. All had no musculoskeletal injuries or pain for the last 6 months and had no difficulty in shooting a free-throw. The CS was the preferred technique in free-throw situations for all participants. They were informed about the purpose and procedure of the study and submitted their signed consent forms before the experiment.
An electromagnetic-based motion capture system, consisting of six sensors (Liberty® 2.0, Polhemus, Colchester, VT, USA) with a sampling rate of 240 Hz, was used for data collection of a free-throw motion. Data were processed in an AMM 3D® program (Advance Motion Measurement Ltd., Phoenix, AZ, USA) to obtain joint kinematic variables (major joint angles between adjacent segments). The 6 sensors were placed on head (forehead), trunk (T2 spinous process), pelvis (mid of PSIS), right upper arm, right hand, and right shank. Body segment digitizing relative to sensor locations in standing posture was performed before data collection. Electromyography (EMG) was measured using a Noraxon Telemyo DTS 2400T (Noraxon, Scottsdale, AZ, USA). The system was composed of six channels with a sampling

rate of 2,000 Hz. Electrodes were placed on flexor carpi ulnaris, extensor carpi ulnaris, medial triceps brachii, biceps brachii long head, upper trapezius, and frontal deltoid. The EMG normalization followed the reference voluntary contraction (RVC), which was performed by flexion and extension of a 3 kg or 10 kg dumbbell. The post process of EMG analysis was performed using MyoRearch XP® program (Noraxon, Scottsdale, AZ, USA). The procedure of the post process followed filtering (20-200 Hz bandpass filtering), rectification, and smoothing (100 ms windows with root mean squared values).

After randomly selection of the shoot order (CS vs. BS), each athlete performed 10 CSs and 10 BSs, respectively, according to the order. Due to the issue of non-time synchronization between EMG and motion capturing systems, athletes visited gym twice at different days for separate measurement. After each shoot, success and failure were indicated in the data record, and only the successful data was selected for further analysis. The representative data were the mean ensemble values of each subject' repeated successful trials.

The shooting motions was dissected into 4 events such as readiness (E1), lifting top (E2), release of the ball (E3), and follow-throw (E4). Three phases were defined by the time period between events such as lifting phase (P1), projection phase (P2), and deceleration phase (P3) (Figure 1A). The joint angle was defined as the two-dimensional relative angle between adjacent segments (Figure 1B). EMG measures were defined as average integrated EMG (AIEMG) and maximum muscle activity. The AIEMG was obtained by dividing the area under the EMG graph of the whole section (integral value) by the value of RVC. The maximum muscle activity, obtained only in the projection phase, was the muscle activity expressed as %RVC as well.

In order to see the statistical difference of results between CSs and BSs, the paired t-test with a significance of .05 was performed in SPSS® (ver. 20, IBM Corp., Armonk, NY, USA).

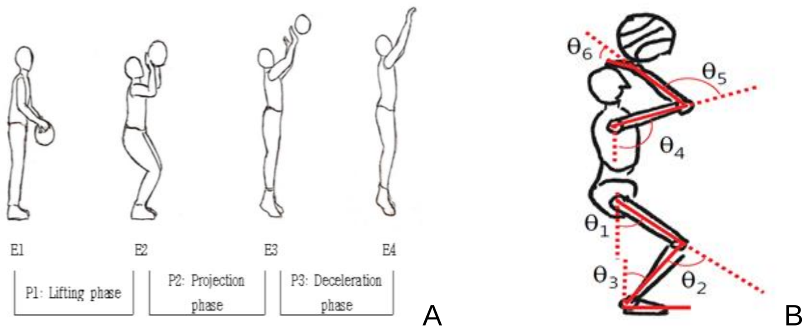

Figure 1: A. Definition of major events and phases, and B. Definition of upper and lower joint angles. θ_1=hip angle, θ_2=knee angle, θ_3=ankle angle, θ_4=shoulder angle, θ_5=elbow angle, θ_6=wrist angle.

RESULTS:

Table 1: Comparisons of range of motion (ROM) across all phases and maximum angular velocity during projection phase (E2 to E3) according to shot types [mean (S.D.)].

	ROM(deg) across all phases				Max. angular velocity (rad/s)			
	CS	BS	*t*	*p*	CS	BS	*t*	*p*
Ankle	27.1(3.4)	28.4(3.7)	1.98	.083	3.46(0.50)	3.85(0.65)	4.06	.004*
Knee	57.8(7.9)	61.4(7.7)	3.02	.016*	5.90(1.13)	6.72(1.25)	8.33	.000**
Hip	32.8(7.2)	37.8(7.9)	3.79	.005*	3.05(0.90)	3.61(1.05)	6.14	.000**
Shoulder	130.4(14.5)	130.3(18.3)	-.04	.972	8.20(1.25)	8.86(1.32)	4.30	.003*
Elbow	95.1(11.2)	97.8(9.9)	3.30	.011*	17.1(1.42)	17.9(1.48)	2.80	.023*
Wrist	94.8(21.2)	94.9(20.6)	.04	.975	34.9(5.34)	36.1(5.18)	1.47	.181

*p<.05, **p<.01 : Statistical differences between clean-shot and bank-shot, CS: clean-shot, BS: bank-shot

Table 1 shows the results of ROM across all phases and the maximum angular velocity in the projection phase. There were statistically significant differences in ROMs of knee (6.2% increase in the BS), hip (15.1% increase in the BS), and elbow (2.9% increase in the BS) between CS and BS. The maximum angular velocities of all joint in the BS except the wrist were significantly faster than those of the CS (p <.05).

Table 2: Comparisons of AIEMG across all phases and peak EMG during projection phase (E2 to E3) according to shot types [mean (S.D.)].

	Average AIEMG% across all phases				Peak EMG% during projection phase			
Muscle	CS	BS	*t*	*p*	CS	BS	*t*	*p*
Ext. carpi ulnaris	27.5(13.6)	20.0(12.3)	-1.22	.253	48.2(26.9)	44.1(21.1)	-1.21	.258
Fl. carpi ulnaris	58.9(27.5)	62.2(25.4)	1.13	.287	196(73.8)	216(70.3)	2.27	.050*
Tricps brachii	74.7(39.2)	82.5(41.2)	2.40	.040*	216(94.0)	240(103.5)	1.53	.160
Biceps brachii	10.5(16.5)	6.72(6.35)	-1.13	.289	40.5(77.4)	22.1(22.3)	-1.04	.328
Trapezius	37.3(23.6)	39.1(22.7)	1.16	.276	87.7(50.8)	82.8(40.3)	-.60	.561
Deltoid	63.5(19.3)	63.6(15.7)	.04	.965	143(44.3)	140(30.7)	-.42	.686

**p*<.05 : Statistical differences between clean-shot and bank-shot, CS: clean-shot, BS: bank-shot

Table 2 indicates muscle activities of CS and BS in %RVC. The AIEMG of only triceps brachii of CS was significantly 10.5% greater than that of BS across all phases (*p* <.05). The peak muscle activity of the wrist (flexor carpi ulnaris) in the projection phase (E2 to E3) was significantly different between two types (p <.05). The BS value was 10.2% larger than the CS.

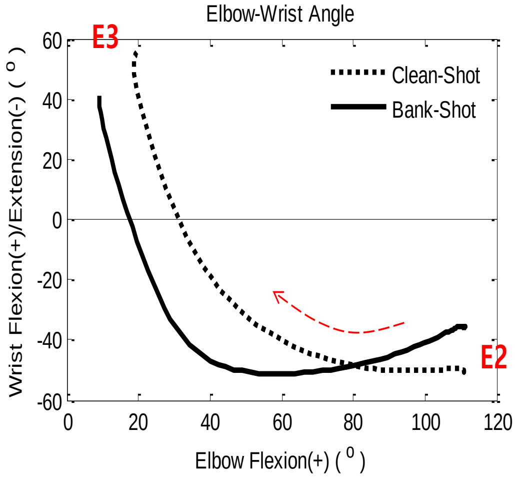

Figure 2: Comparison of elbow angle-wrist angle plots between CSs and BSs during the projection phase.

Figure 2 is the angle-angle plot of elbow and wrist joints during the projection phase. Qualitatively it shows that the wrist was extended in accordance with elbow extension in CS, while the wrist was flexed and then extended according to extension of the elbow in BS.

DISCUSSION: This study tried to find the biomechanical knowledge necessary for successful BSs by comparing the results of kinematics and EMGs with those of CS. There were differences in the shooting postures and muscle activities between CS and BS. Since the projectile distance of the BS is farther than that of the CS (Silverberg et al., 2011), the athletes were expected to slightly adjust the joint forces and kinematics in an attempt to achieve successful BSs. The actual horizontal reach is greater than 0.4 m since the BSs are higher than the rim height (Silverberg et al., 2011). In this study, athletes bent their ankles (3.7%), knees (5.4%) and hips (10.2%) in the lifting top position (E2) of BS more than those of CS in order to obtain successful BSs. These differences resulted in significant increases in the ROMs of knee (6.2%), hip (15.1%), and elbow joints (2.9%) across all phases. Even though this study did not measure the ground reaction force (GRF), it is speculated that the increased ROMs could further press the body center of mass downward in order to take an advantage of propulsive forces from the ground. Then the added GRF could increase the angular momentum of major joints in following phases.

The maximum joint angular velocities of BSs during the projection phase were 8.0 to 18.4% faster than those of CSs across the major joints (ankle, knee, shoulder, and elbow) except the wrist during the projection phase. The projection phase is the process of putting the transferred momentum on the ball while extending the flexed joints. It was expected that maximum angular velocities would increase in all joints, but this was not so. The maximum angular velocity of the wrist just prior to releasing the ball for BS remained similar to the CS. This implied the importance of the wrist joint adjustment regardless of the CS and BS. According to a study by Wilkes (1982), a complete wrist snap at release produces better follow-through motion. In other words, it is necessary to consistently bring out the original feeling of projection in CS rather than to increase excessive angular velocity of the wrist at the final projection moment.

This result of wrist kinematics seemed not to be in accordance with that of EMG, since only peak EMG% of the wrist during the projection phase showed significant increase than BS (10.2% increase). This was interpreted by the wrist motion of BS in comparison with CS during the projection phase (Figure 2). Since the wrist of CS only flexed, there was enough time for concentric contraction during the last part of projection phase. However, the wrist of BS was first extended and then flexed (countermovement). Thus, there was not enough time for concentric contraction at the end in considering muscle force-velocity relationship. The increase in peak muscle activation in the last part of projection phase might be attributed to this impulsive concentric contraction.

CONCLUSION: For high school basketball players to make a successful BS, increasing the ROMs of major joints by about 2.9 to 15.1% was required in comparison with the successful CS. In addition, the overall muscle activity of the triceps brachii increased by about 10.5% across all phases of BS compared to CS. During the projection phase, the control of the wrist joint seems to be very important with keeping similar maximum angular velocity to the level of the clean shot regardless of increase in muscle activities of wrist flexors.

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