ISSN : 0974 - 7435 Volume 10 Issue 6

BioTechnology
An Indian Journal

FULL PAPER

BTAIJ, 10(6), 2014 [1472-1480]

Biomechanics analysis-based basketball shooting technical quality evaluation indicators research

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ABSTRACT

Field-goal percentage is an important parameter that decides team is winning or losing in basketball contest, domestic and foreign scholars and basketball practitioners are very concerned about field-goal percentage influence factors. The paper analyzes basketball field-goal percentage influential biomechanical factors from sports biomechanics, to better explore the relations between the two, in the paper, it firstly explores field-goal percentage influential physical factors, and then analyzes shooting process human body sports biomechanical features, and finally establishes coordinating connections between biomechanics and field-goal percentage, which provides theoretical references for basketball training. Research shows basketball player upper limbs each joint angle in basketball release instant decides basketball release angle, and basketball release angle is an important indicator to evaluate shooting technical quality, in order to create best mechanical conditions for shooting and releasing, it needs athlete to put special emphasis on body stability in shooting proves, shooting release point height gets bigger, then field-goal percentage will be higher.

KEYWORDS

Motion trajectory;
Physical factors;
Biomechanics;
Force analysis;
Collision;
Hit rate.

INTRODUCTION

Shooting is one of important techniques in basketball, is unique way to get scores, is a kind of most important technique in basketball techniques, is also core link in assigned basketball tactics, no matter which kind of offensive tactics, it finally will be result in field goal, and defensive purpose is to restrict, prevent opponent shooting, so that create more scoring opportunities for itself, therefore field-goal percentage is a technical indicator of each basketball team concerns. The paper carries out analysis of basketball development status and shooting technical development orientations main background, proposes field-goal percentage and athlete human body sports biomechanics influence factors relative research issues, applies mathematical model method to analyze field-goal percentage influential physical factors, utilizes video image data collection method to analyze sports biomechanical features in shooting process, explores biomechanics and physical factors connecting points, which provides theoretical basis for basketball shooting technical training.

For basketball shooting technique and sports biomechanics research, lots of scholars have successively made researches on them, these scholar provided opinions and suggestions are of great help to improve ath-

lete field-goal percentage, from which Xu-Yan and others (2012) made three-dimensional video analysis of basketball athlete shooting techniques, analyzed athlete each main sports joints motion features, shooting hand motions and ball motion features, got that only well handled with upper and lower limbs exertion, release points height and angles as well as ball releasing instant motions relations when shot then could really improve shooting hit rate[1]; Wu Zhong-Yi and others (2012) applied human anatomy and sports biomechanics theory, analyzed basketball far distance single hand above shoulder shot motion process and technical principles, stated far distance single hand above shoulder shot motion mechanism and technical specification, proposed opposite views against classic theory, which was the view as "aiming point" during shooting is hoop back edge furthest point, shooting motion allowed elbow joint to abduct to a certain degree[2];Liu Hao (2013) put forward reasonable suggestions that it should focus on basketball basic skills exercising, form into good technical motions, combine shooting exercise s with mistake correction, start from actual combat and combine with theory to gradually adapt to actual combat situations, strengthen application ability in confrontation, and improve athlete catching and shooting joint ability, increase shooting training difficulties, make training in interference and high intensity fierce confrontation fast moving, which provided experience guiding for basketball jump shot technique training[3].

The paper on the basis of predecessors' researches, carries out analysis of basketball shooting technical biomechanical features, and starts from field-goal percentage influential physical factors perspective, explores each physical factor and shooting process biomechanical connections, which provides feasible references for broad basketball players' training and field-goal percentage improvement.

RESEARCH BACKGROUND AND PROBLEM POSING

Basketball is well received by people in the world, the sports has numerous enthusiasts, which provides good basis for basketball market more deeply development. The paper studies basketball shooting techniques from sports biomechanics perspective, in the hope of exploring field-goal percentage and human body sports features relations, and provides theoretical basis for basketball technical scientific development. In order to reflect historical background and basketball situation demands, basketball technique should more based on modern basketball development status and development orientations, therefore the chapter starts from modern basketball development status and its technical development orientations to make analysis, puts forward sports biomechanics influential factors on basketball field-goal percentage, which provides basis for human sports biomechanics factors research in basketball shooting process.

Basketball development status and basketball technical development orientations summary

Modern basketball features mainly reflect in fast speed, high height, comprehensive technique and high accuracy these four aspects, in the following; it makes statements on above four aspects, in the hope of exploring basketball shooting technique development orientations.

1) Fast speed

Basketball game confrontation process intensity is highlight of audience, in order to reflect basketball high intensity, modern basketball player observation is more acute, reaction is more flexible, motion connecting is more compact, and reflection way in data is more quick attacks, high scores and short time as well as other features.

2) High height

Height here refers to basketball player height, in world basketball top team, center height is between 2.10~2.20m, forward height is between 1.98~2.10m, guard athlete height also remains above 1.95m.

Comprehensive technique: In the world, basketball top team athletes possess technology of adept in attacking and defense, athletes not only can play ball well in self advantageous planed positions, but also can process with multiple positions interchanging in the field, which has already presented technique generalization, motion refined, attack and defense equilibration and tactics systematization features, it can also provide conditions for game confrontation intensification.

3) High accuracy

Modern basketball accuracy mainly reflect in pass

and shooting two techniques, from each main games' official data statistics, it is clear that modern basketball pass is more accurate, hit rate is higher, athletes coordination and cooperation are also more tacit.

Basket shooting process is the event game scoring main process, therefore athlete takes shooting technique as one of main training technology, in basketball contest, to create proper shooting opportunities, athletes apply each kind of tactics, on above, the paper states modern basketball development status, the status is striving around improving sports confrontation intensity, then now basketball shooting technique development orientations should also bases on this as background, in the following, it states basketball technique development orientations from fast, high, far, change, full and accurate these six key points.

1)Fast

Athlete should fast get rid of opponent defense before shooting, and grasp opportunities to fast shoot, and shooting process divides into lifting ball, jumping and releasing three links, so basketball shooting technique "quick" word knack mainly reflects in fast lifting ball, fast jumping and fast releasing, it requires athlete to coordinate apply the three links.

2) High

In order to more effective get rid of opponent interference in shooting process, modern basketball player generally adopts jump shot way, applies high hand shot, leaning –backward shot and slam dunk as well as other motion techniques, so basketball shooting technique "high" word knack mainly reflects in high jumping and high releasing such two aspects.

3) Far

In order to expand shooting releasing area, shooting in opponents weak defense zone, it tends to adopt three-point shot and two-point shot, shooting in the position far away from hoop, so that can effective prevent opponent interference, and also shorten attack distance to make efforts to finally win the game, so basketball shooting technique "far" word knack main reflects in athlete far away from hoop and basketball air motion far distance two aspects.

4) Change

In basketball contest, athlete should flexible apply technique and tactics technology, can reasonable change in passing, shooting and quick attacking process and give opponent sensation of overwhelming, so that can more effective get rid of opponent defense, and also create beneficial conditions for its own players effective ace, so basketball shooting technique "change" word knack mainly reflects in passing, dribbling, breaking, defense, blocked shots timely transformation.

5) Full

In basketball contest, athlete plays games with his own predetermined role, but combat opportunities is constantly changing, only athlete can play different roles in different opportunities, and carry out effective breakthrough shooting by players roles transformation in the field, but scientific and reasonable roles transformation is based on athlete each aspect technology firm grasping, so basketball shooting technique "full" word knack mainly reflects in athlete effective breaking through position clear limitation.

6) Accurate

Only athlete well grasp "accurate" word knack then can effective get scores for its own team, quick, high, far, change and full are all processes, accurate is the purpose, field-goal percentage is an important factor that decides final game result, therefore basketball shooting technique "accurate" word knack mainly reflects in field-goal percentage.

Basketball shooting technique and sports biomechanics problems posing

Basketball shooting technique executor is athlete, athlete ontology is human body, human body sports biomechanics features are shooting technique execution merits main evaluation factors, in shooting process athlete main sports links are lower limbs movement links and upper limbs movement links, and lower limbs movement mainly reflects in knee joint, upper limbs movement mainly reflects in holding ball's hand, as Figure 1 shows before shooting athlete knee joint states, shooting releasing instant athlete knee joint state, shooting instant athlete holding motion and shooting releasing instant holding hand motion state.

Xu Yan and others(2012) pointed out field-goal percentage was the key factor to decide basketball game winning or losing, improved basketball technique was

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Figure 1 : Basketball shooting process athlete upper limbs and lower limbs movement state

crucial to athlete improve competitive level, and in current high level competitive sports training and contests, scientization degree became higher and higher, as competitive sports event, basketball competitive level improvements also relied on relative advanced science and technology support to great extent, so closely connected with sports practice, applied modern scientific technological ways, deepen organized basketball teaching and training process's scientific research and tackled the key research project was the only road to improve basketball players' competitive levels[1]. Shooting technical motions are complex and asking for high, it suffered numerous aspect impacts, relative shooting education and training aspect researches mainly concentrated on technical motions specification analysis, motion teaching method, force analysis and shooting technical evaluation as well as other fields.

Shooting technique application effects mainly are up to holding athlete presented sports biomechanics features in shooting process, shooting sports biomechanics influential factors have mainly grasping on ball rotating sports features, scientific selection on aiming points, best shooting release angle grasping and reasonable motion application four aspects, in order to explore basketball field-goal percentage influential biomechanics factors, analyzes from basketball flight mathematical model, basketball collision mechanical model and human body upper and lower limbs motion biomechanics features, in the hope of providing reasonable suggestions for athlete field-goal percentage improvements.

In order to do data collection for basketball trajectory and human body each link sports features, the paper adopts Hough transformation method to calculate basketball gravity in video images, finally gets basketball motion trajectory, known round mathematical equation is as formula (1)shows, transforms $x-y$ plane's round to $a-b-r$ parameter space, it can arrive at image control any one point round corresponding parameter space's one three-dimensional conical surface, obtained image's all basketball gravity centers by Hough transformation method, can get different time basketball flight corresponding pixel points, and finally gets basketball flight sports trajectory, as Figure 2 shows.

$$(x-a)^2+(y-b)^2=r^2 \quad (1)$$

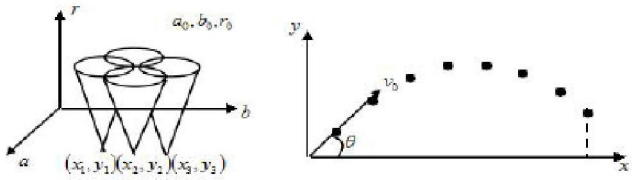

Figure 2 : Parameter image and flight trajectory

SPORTS FEATURES ANALYSIS AFTER BASKETBALL RELEASING

Basketball flight mathematical model

Well grasp basketball motion trajectory is an important way to improve field-goal percentage, field-goal percentage influential physical factors are release height, release initial speed, release angle, entering angle, shooting distance and hoop height, if it doesn't consider basketball rotation and force status except for gravity, motion trajectory after basketball releasing should be a parabola, as Figure 3 shows basketball motion trajectory space presentation way after releasing.

According to Figure 3 basketball motion trajectory space presentation schematic diagram, it is clear that basketball releases speed V_0 and figure's variables mathematical relation is as formula (2) shows:

$$V_0^2=\left[2\cos^2\theta\left(\tan\alpha+\frac{h}{L}\right)\right]^{-1}\cdot gL \quad (2)$$

Basketball position decisive factor is sphere center horizontal speed and vertical direction speed, it is constant motion in horizontal direction and constant vari-

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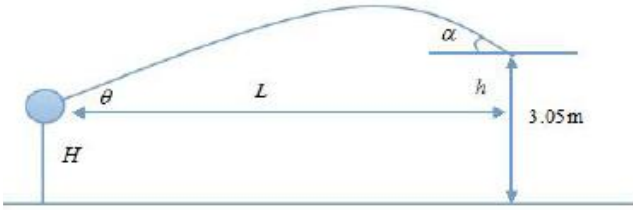

Figure 3 : Center motion trajectory after basketball releasing

able motion in vertical direction, so horizontal direction's speed $V_{//}$ is always equal to $V_0 \cos\theta$, and vertical direction speed is accelerated speed as g, initial speed as $V_0 \sin\theta$ constant variable linear motion, so when enter into hoop, entering angle α meets formula (3):

$$\tan^2\alpha = \tan^2\theta - 2gh \cdot \left(V_0^2 \cos^2\theta\right)^{-1} \quad (3)$$

By formula (3), it is clear that in case shooting horizontal distance is certain, to ensure proper entering angle, it should improve release height and meanwhile reduce release angle and release speed.

On the premise that basketball release height is certain, which is also h is certain, entering angle α and horizontal distance L relation is as formula (4) shows:

$$\tan\alpha = Lg \cdot \left(V_0 \cos\theta\right)^{-1} - \tan\theta \quad (4)$$

By formula (4), it is clear when shooting release position and hoop horizontal distance gets further, it needs to diminish release angle, in the hope of increasing horizontal speed.

Release angle and entering angle relation is as formula (5) shows:

$$\tan\theta = \tan\alpha + 2h \cdot L^{-1} \quad (5)$$

By formula (5), it is clear that two angles changes are in positive correlated change trend in case other factors are fixed.

When L, h is certain, minimum speed angle θ_m and minimum speed $V_{0\min}$ can be got by extremum differential ways, as formula (6) shows:

$$\begin{cases} \theta_m = \dfrac{\pi}{4} + \dfrac{1}{2}\arctan\left(\dfrac{h}{L}\right) \\ V_{0\min} = \sqrt{gh + g\left(h^2 + L^2\right)^{0.5}} \end{cases} \quad (6)$$

Adopt international standard basketball radius 0.120m and hoop radius 0.225m, it can get hollow shot expected basketball minimum entering angle is 32.29°, and then entering angle range should be 32.29°~90°.

Basketball collision process mechanical analysis

Except for hollow shot, basketball shooting also exists shooting form as basketball and hoop or rebound collide and rebound into hoop, which is also shooting process aiming points defining problem, the writer summarizes four aiming points except for hollow shot hoop central point, which are respectively hoop back edge, hoop front edge, hoop right above 20cm area and whole hoop.

1) When athlete aiming point is hoop back edge, it will appear following three cases:
2) When athlete shooting used force is smaller, it will appear basketball edge cannot contact to hoop back edge and lead to ball drop into hoop center to make a goal.

   When athlete shooting used force is proper and basketball is back spinning, after basketball and hoop back edge colliding and rebounding, it will just spring to hoop and make a goal.
3) Athlete shooting used strength is very small or big, it leads to basketball doesn't contact with hoop back edge and cause ball hasn't been hit.

When athlete aiming point is hoop front edge, it will also appear three cases as following shows:

1) When athlete shooting used force is smaller, it will appear basketball edge cannot contact with hoop front edge and cause ball cannot be hit.
2) When athlete shooting used strength is just proper that let ball to contact with hoop front edge, and basketball motion is back spinning, after basketball and hoop back edge rebounding, it will cause basketball cannot make a goal.
3) When athlete shooting used strength is slight big, it will appear basketball and hoop back edge collision case, which lead to basketball to rebound and enter into hoop.

Take aiming point as hoop back edge as examples to make spinning collision mechanical analysis, spinning divides forward spinning and back spinning, after forward spinning and barrier colliding, it will rush forward, after back spinning and barrier colliding, it will rebound backwards, as Figure 4 showed forward spinning and back spinning as well as basketball back edge collision process basketball force analysis.

When basketball and rebound occurs to non-spin-

Figure 4 : Spinning ball and hoop back edge collision force analysis

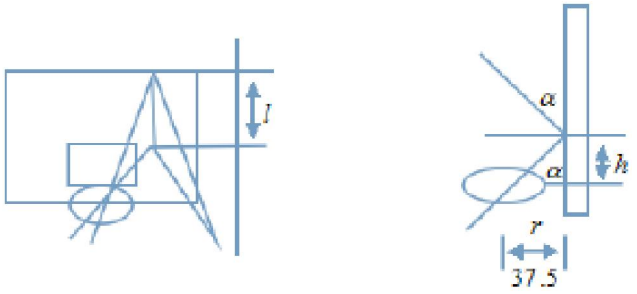

Figure 5 : Basketball motion trajectory after non-spinning lateral hitting board and front hitting board

ning collision, it meets horizontal direction momentum conservation law and reflection law, basketball lateral hitting board shooting and front hitting board shooting process motion trajectory as Figure 5 shows, in Figure6 it illustrates non-spinning front hitting board, back spinning front hitting board, non-spinning spring out by rebound, forward spinning spring out by rebound, sphere non side spinning hitting board and hoop right side shooting sphere side spinning hitting board process's basketball force analysis schematic diagram.

In Figure 6, F is bounce, f represents friction force, F_T represents resultant force.

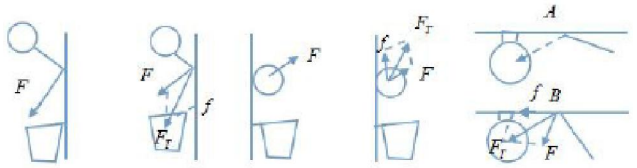

Figure 6 : Non-spinning and spinning as well as rebound colliding force analysis

BASKETBALL ATHLETE SHOOTING PROCESS BIOMECHANICAL FEATURES ANALYSIS

In shooting process, basketball dynamic source can be divided into basic dynamic and functional dynamic, Wu Zhong-Yi and others (2012) pointed out shooting motion dynamic starting point is originated from two legs pedaling, before two legs pedaling, two knees slightly bend such standing postures, let triceps surae, tibialis posterior, peroneus longus, flexor digitorum longus and other flexor ankle joint muscle group, quadriceps femoris and other extension knee joint muscle group, quadriceps femoris muscle and other extension knee joint muscle group, gluteus maximus, biceps femoris muscle and other extension hip joint muscle group is in the state of lightly stretching, shooting hands, shoulders, elbow, wrist inflexional holding posture, let triceps brachii, anconeus and other elbow joint muscle group as well as flexor carpi radialis, ulnar flexor of wrist, Palmaris longus as well as other flexion wrist joint muscle group to be in the state of stretching, when pedaling, bending ankle, stretching knees, extending hip muscle contraction generated strength to transmit to trunk, drive body to move toward upper front side in the synergistic effect of trunk muscle, form into shooting motion basic dynamic; Shooting technique functional dynamic is stretching arms, bending wrists and finger plucking generated force acting on ball, when trunk gets basic dynamic, whole body moves upper front side, pectoralis major, coracobrachialis, deltoideus front part, biceps brachii long head and others let shoulder joint flexion muscle and triceps brachii, anconeus and other elbow joint extension muscle to contract, big, small arms stretch, compound shooting motion generated strength into force towards upper front direction, concentrate on acting on ball gravity center, and propel to sphere to move towards upper front side, and meanwhile, flexor carpi radialis, ulnar flexor of wrist, Palmaris longus as well as other flexion wrist muscle is contracted, let hand to bend in wrist joint, and form into hand (finger) to make circular motion in sagittal plane with wrist joint as axis, and generated strength accordingly to act on sphere gravity center, and further gradually transit to act on ball surface, let sphere to get dynamics of flying in upper front direction and back spinning along self frontal axis[2]. In the following, it makes biomechanics analysis of basketball player shooting process lower limbs motion, upper limbs motion and whole body coordination motion, in the hope of providing theoretical references for athlete field-goal percentage improvement.

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Shooting process athlete lower limbs joints biomechanical features analysis

Correct basic standing posture is two legs left, right or front and back open and stand, with the same width of shoulder, right foot lies in the front, knee joint looses and slightly bends, upper body slightly leans forward, right hand palm center holds ball in upper front side, left hand supports ball, right elbow joint naturally drops, let arm stretching muscle to be stretched, stores elastic potential energy, faces to hoop, neck muscle looses, body gravity center lies between two feet, such basic standing posture, every link upward stretching generated inertia force will act on total gravity center dropped supporting plane[4].

Athlete lower limbs joints motion in shooting process mainly reflects in bending knees squatting and knee joints pedaling and stretching such two aspects, from which bending knees squatting motion is with the help of lower limbs muscle group eccentric contraction states stretching, it can provides good body posture and exertion posture for shooting motion, by Hough transformation method, it carries out data collection of video images and can get athlete left and right knee joint knee angle changing status, in the paper, it presents as TABLE 1 showed knee joint flexion angles status.

Use TABLE 1 data to make biomechanical analysis of shooting process, it is clear that excessive knee joint flexion will give excessive loads on extension muscle group, affect knee extension speed and body other links cooperation, if knee flexions is too small and cannot fully stretch knee extension group, it will affect elastic potential energy storage, and further affect knee extension strength, let body cannot get good vertical speed, data shows when athlete left and right knee joint angle changing range are respectively as 34°~163°and 77°~162°, human body can get best body exertion states, and meanwhile can make full preparation for cooperative fulfilling upper limbs motions.

And knee joint pedaling and stretching effects are letting body to accelerate upward, and provide accelerated speed for upper limbs exertion and fulfilling shooting, according to collected video data, it is clear that in shooting process knee joint pedaling and stretching motion, athlete left knee joint and right knee joint average angular speeds are 26.6rad/s and 94.7rad/s, their average pedaling and stretching range are29.3°and76.2°, now it is athlete best exertion state, from data, it also presents left knee pedaling and stretching range and angular speed is one third of that in right knee, thereupon athlete pedaling and stretching exertion is mainly implemented by relying on right leg extensor muscle group fast contraction.

Combine biomechanical analysis basis with kinematics principle, it can get when athlete keeps same shooting motion rhythm, due to body only suffers gravity external force impacts after leg pedaling and leaving ground, body gravity center height when foot pedaling and leaving ground together with vertical rising speed can decide gravity center motion trajectory in vertical direction, which is also one of field-goal percentage main influence factors that discusses in the paper.

Shooting process athlete upper limbs motion biomechanical features analysis

In shooting process, upper limbs motion movement process can divide into holding stage and shooting releasing stage, Zhang Shu-An (2001) points out normative shooting hand motion should stretch triceps brachii by elbow joint adduction, raising upper arm and stretching elbows to shot, directly face to basket, hand holds ball on shoulder, elbow joint moving route should be vertical and upward, ball is in near supporting, shoulder, elbow, wrist, finger and ball in the same plane, shooting exertion order should be carried out from bottom to up in the form of successive transiting[5].

By Zhang Shu-An analysis, it is clear that when pitching and releasing, athlete lower limbs pedaling strength is generated by transiting with the help of human body machine chain, wrist pressing down, and finally finger acting on sphere bottom front, in such bot-

TABLE 1 : Shooting process athlete knee joint flexion angle data collection result

Parameter type	Knee joint angle when ball is released	Minimum knee joint angle	Knee joint flexion time (s)	Knee joint flexion angle	Knee angle when human body gravity center is lowest
Left knee joint	163.1°	136.3°	0.53s	34.1°	130.6°
Right knee joint	161.8°	91.8 °	0.61s	76.8°	95.7°

tom up transitive exertion process, it requires shooting arm to fast and sufficient stretch straightly, in the hope of obtaining best shooting trajectory. Liu Lu-Jun (2007) pointed out that sphere parabola composed plane was surely consistent to holding plane, the whole motion requires to fulfill in human body sagittal plane so that let body each link motion unified flexing in sagittal plane, and provide powerful conditions for every joint motion prime moving muscle activities and joint motions consistency[6]. When releasing, basketball horizontal speed size adjustment mainly relies on fingers tipping, if finger fitting towards basketball flight trajectory tangential direction, it will generate back spinning, on the contrary it will generate forward spinning, and spinning can effective reduce air resistance impacts on basketball parabola trajectory, which is of great help to improve field-goal percentage.

In shooting process releasing stage, athlete needs to fully stretch shooting arms, stretching process is the process to provide dynamics for basketball, according to Newton's second law, it is clear that force is the cause of changing object original state, if athlete can reasonable control ball before leaving hand, sphere center trajectory controlling will also relative perfect, which is key factor to improve field-goal percentage.

In basketball game confrontation process, shooting process needs to meet fast speed features, there is certain mathematical relation among speed, time and distance, if on the premise speed is improving, keep arms working at ball, let it to generate larger dynamic energy, then it needs to extend arms to ball acting time and acting distance, which is also main cause of arms fully extension demands in shooting process, the paper collects as TABLE 2 showed basketball releasing instant human body upper limbs shoulder joint, elbow joint and wrist joint angles status, in the hope of provides data references for basketball shooting.

Basketball player upper limbs each joint angle in basketball releasing instant decides basketball releasing angle, and basketball release angle is also an important indicator to evaluate shooting technical quality, in order to create best mechanical conditions for shooting releasing, it needs athlete to pay special attentions to body stability in shooting process, according to practical shooting experiences, it is clear that shooting release point height gets bigger, it will be of greater help to field-goal percentage.

TABLE 2 : Basketball player upper limbs each joint angle data in basketball releasing instant

Upper limbs joint angle type	Left limb	Right limb
Shoulder joint angle (°)	103.6°	141.7°
Elbow joint angle(°)	127.2°	176.0°
Wrist joint angle(°)	147.9°	125.6°

CONCLUSION

The paper firstly states modern basketball development status and shooting technique development direction, which provides basis for shooting technique biomechanical analysis expectation defining, and on this basis, it puts forward field-goal percentage and sports biomechanics relation, which builds basis for following analysis. From after basketball releasing sports trajectory mathematical model and mechanical analysis of basketball and barriers colliding, it gets basketball field-goal percentage influential physical factors, which provides theoretical basis for sports biomechanics and physical factors connection. Finally, the paper analyzes shooting process human body lower limbs each joint movement status and upper limbs each joint movement status from biomechanical perspective, and combines human body sports biomechanics features and kinematics field-goal percentage influential physical factors, it explores biomechanics impacts on field-goal percentage, which provides theoretical references for athlete teaching and training.

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