A BIOMECHANIST LOOKS AT BASKETBALL

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Basketball is a game composed of many skills, ie, running, jumping, throwing and catching. The mastery of the mechanics of these actions is one of the primary keys to successful performance. Cooper (1987) states that understanding athletic movement is complex for the following reasons.

1) Usually athletes do not know or cannot describe what they do in performing skills. They often perform intuitively. It is an asset for a player to perform a skill without thinking about it.

2) Men and women perform skills in about the same way. While there are slight differences in height, strength and speed, feats performed only by men years ago are now accomplished by women. For example, women basketball players can now dunk the ball and hang in the air.

3) Good form today is often unacceptable tomorrow. A debt is owed to performers of the past upon whom present performances are based. At one point, the two-hand set shot in basketball was considered the ultimate in mechanical execution.

4) Coaches make statements about performance that are usually correct, but at times may be incorrect. Athletes may execute plays in accordance with coaches' dictates, some of which may be wrong. Some actions advocated by coaches may be impossible to perform; consequently, the athletes may have to perform otherwise without being aware of it. Coaching instructions are frequently based on experience and not necessarily on scientifically or experimentally proven information. However, as new facts become known, the intelligent coach makes use of them.

5) Any person, regardless of height, speed or strength, should be regarded as a potential basketball player. Even with such deficiencies as small hands, slowness, short legs and poor jumping ability, individuals can become good players.

Prenatal influences help mold the final human movement patterns, but they are not absolute determinants. Undirected basketball play in childhood may also affect behavior on the court in later years. New ways of moving and shooting in basketball are often

developed in undisciplined and unsupervised environments. The so-called "playground" moves may be incorporated later in the play of disciplined, team-oriented players.

Being able to focus during performance on an aspect of a movement is called "the high point of attention." Usually, a performer is only able to think of one thing at a time, certainly no more than two. It would be much better to have all the moves automatic.

The brain orders a certain movement to take place, but it leaves the execution of the action to lower levels of the nervous system. In other words, to be automatic in a basketball skill, conscious thought is not utilized. It is very difficult to change the form of a player after reaching the college level. As the saying goes, "bad habits die hard."

Performance Concepts

Player movements executed the same way every time can become so familiar to others that they may become easy to defend. After a performer starts a movement, it is difficult to stop. Yet, a controlled movement intended to deceive can be stopped because it is often done with subjaximal effort. The offensive player knows what is intended in a given moment and should have the advantage over the defensive player. In basketball, the desired strength and speed needed to play effectively may not be attained in practice and during games. Therefore, additional exercises and speed maneuvers may be necessary to attain a proficient playing level.

Flexibility is important for basketball players. They should focus on flexibility exercises for the pelvis, back, legs, feet and arms. Players are one-eyed and one-footed. The dominant eye's role in shooting is evident as the head turns slightly to one side or the other. Also, one particular foot is often used in the first step of a drive by the offensive player.

The Coach as Observer and Corrector

Basketball coaches, who spend considerable time observing players' actions, should follow these guidelines:

1) The human eye sees action at about 10 to 12 frames per second (fps). Very fast action is difficult to observe. First determine the action of the large body parts. Then the movements of small parts, such as the hand, can be partially seen.

2) Several viewings of a motion are necessary, because you can see only one body part at a time.

3) Coaches may get too close to a player, blurring the view. Move back and look "through" players and occasionally look out of the corners of your eyes. While peripheral vision picks up action sooner than direct vision, it does not usually perceive color or a clear image of the action.

4) Fight the tendency to see what you expect.

5) Observe from many vantage points: from above, from the rear, at a distance and close up. (Cooper, 1987).

Brief Historical Statements

Basketball is an American game invented by a Canadian for recreational purposes in the USA. Some of the skills were first used in other games. For example, throwing or putting a shot is a skill used in both soccer (throwing the ball in bounds) and rugby (the toss).

Comparison of Early and Modern Shooting, Guarding and Passing Mechanics

The manner in which the ball (soccer) was thrown to a teammate at the peach basket is not known. Some of the conceptual (guessed) styles of shooting, guarding, dribbling and passing are presented here. (Figures 1-3)

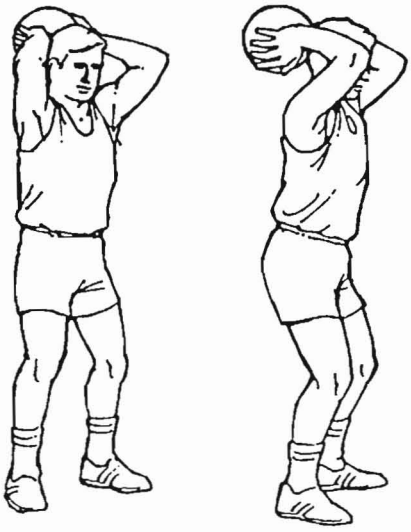


Figure 1. A toss at the basket, similar to the soccer throw from out-of-bounds. These are conceptual representations since there are no pictures or statements about early shooting styles.

Figure 2. A toss at the basket, similar to a shot put throw.

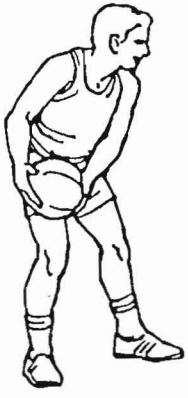


Figure 3. Shooting style similar to a rugby pass, from which the underhand shot developed.

The velocity of the throw probably was not very high. The rugby pass is, in my opinoin, the key throwing skill influencing the future styles since the ball could be thrown the longest distance, coupled with greater accuracy and with greater ease than others that were mentioned. The range of motion is greatest and the momentum (m x v) would be largest. The evolution of shooting styles (shown in Figures 4, 5a and b) shows the ball held higher and from two to one hand to improve accuracy (uses less body action) and to release the ball quicker. Finally the jump shot is released much higher than any other.

Figure 4: Hand position for two-hand set shot, 1940s. The ball is held much higher than when using the two hand undrhand shot.

Figure 5a: Modern one-hand set shot. The position of the ball is above eye level.

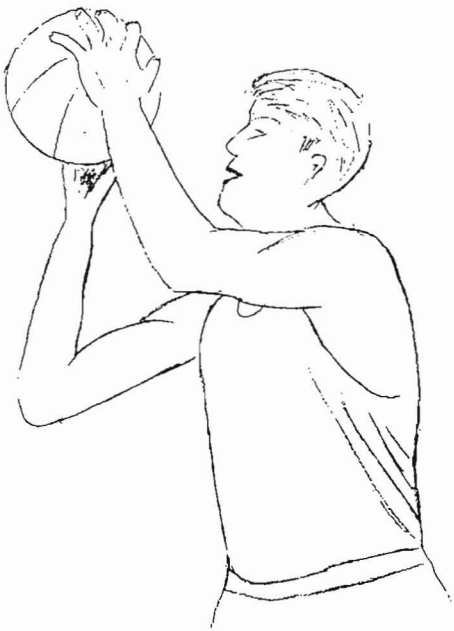
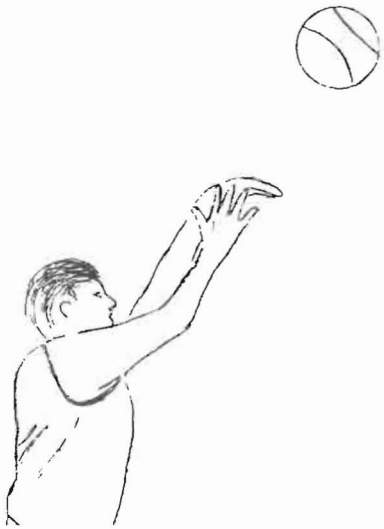


Figure 5b: Follow through, one-hand set shot. Note the position of the right hand (this is a left handed shooter) just after release. Such a position prevents the right hand from hindering the left hand in applying force to the ball in a given direction.



Incidentally, note the figure showing a young lady shooting a one-hand shot (1895). The grace and style is more of a dance action than what the men performed.

Figure 6a.
Young lady shooting a one hand shot. Perhaps women were the first to actually use a one hand shot. It is reported that this style of shooting was adopted because the women wore corsets and could not turn their bodies very much. Other styles of shooting were thought to be too masculine. This is drawn from a picture of material in the archives of Tulane University. Clara Bare is the author of the *Sophie Newcomb Memorial College for Women, Basketball Rules for Women and Girls,* Printed in 1895 in New Orleans, Louisiana.

The guarding positions (Figures 7 and 8) depicted the mechanics of past and present styles. The past style was a stationary one with a high center of gravity. No attempt was made to intercept a pass or interfere with a shot at the basket, but just to stay in one place and hold the position to prevent the offensive player from moving toward the basket. The lower COG of the present style enables a player to go forward and backward quicker and helps prevent an offensive player from driving toward the basket.

The underhand foul shot (Figure 9) was also the set shot from the floor that was used in the 1910's to 1920's. Mechanically, it is a sound shot, easy to execute and involves an arm swing action common in everyday motions. Note the differences from modern shooting styles (two-hand set, then one-hand set) where the ball is held high in an attempt to prevent the defense from blocking it.

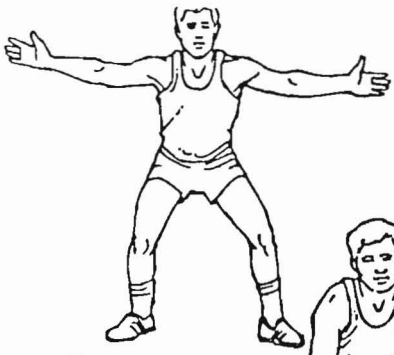


Figure 7.
Guarding position on the court in the 1920's.

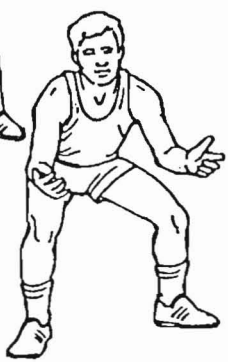


Figure 8.
Present day guarding out on the court.

Figure 9. Underhand foul shot, 1920s–1940s.

Dribbling was first intended as an escape mechanism to the rear, not an advancing procedure. (At one time so much dribbling took place in games that the rules committee contemplated eliminating it.) Note the low body position of the dribbler of the past who kept the ball in front knowing that the guard would retreat and no interference was expected. The modern dribbler must have good body position and kinesthetic awareness of the ball by hand coordination. (Figures 10, 11 and 12). Observe the speed dribbler (Figure 13) whereby the ball has taken on the momentum of the dribbler since it rests against the hand for a brief moment.

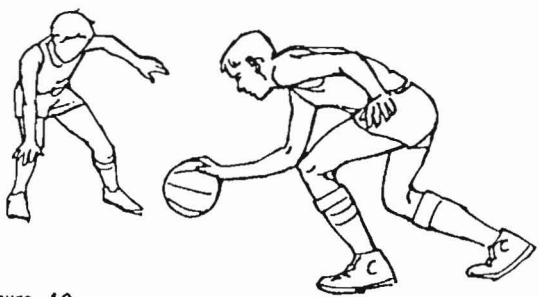


Figure 10.
Dribbling technique (as well as guarding position of the 1920s)

Figure 11.
Modern between-the-legs dribble.

Figure 12.
Modern behind-the-back dribble.

Balance is one of the keys to good dribbling performance.

Figure 13. Speed dribbler. Since the ball is in front, it indicates it has taken on the momentum of the moving dribbler.

Passing was, at first, accomplished by throwing the ball like a soccer throw-in or a rugy pass (Figures 1 and 2). Modern players pass the ball using one or two hands. The modern passer shows the pronation of the forearm and hands in executing the two-hand push pass. The velocity of the ball greatly exceeds the ball thrown in the early days and is more accurate.

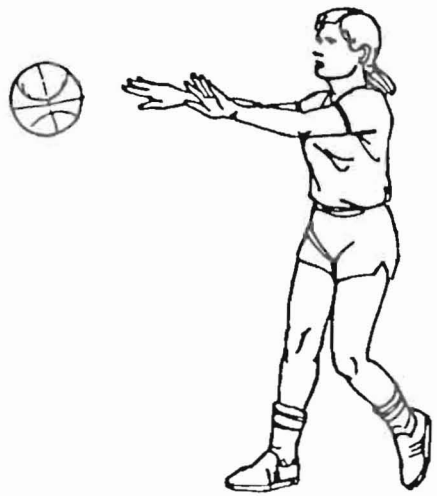


Figure 14: Chest or push pass. Note the pronation of the hands at release. This is an indication that the force is directed in a straight line.

Some Physical Laws and Principles

Most physical principles that are utilized in any motion apply to the actions performed by basketball players. A brief description of some of these is presented in basketball terminology.

Acceleration is time rate of change. It may be positive or negative. In basketball one must be able to accelerate and decelerate quickly. The player needs to keep his/her velocity under control so that charging directions is easily accomplished. Quickness in changing direction is of more value than sheer speed.

Attenuation is reduction or absorption of force. Basketball players in catching a ball learn to "give with the ball."

Angle of incidence and angle of reflection involves the striking

and rebounding of the ball contacting the backboard or the floor. The basketball is usually spinning at contact.

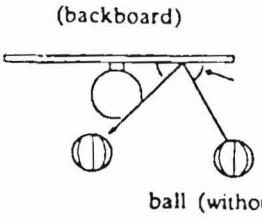


Figure 15. Effect of elasiticity will reduce angle of rebound very slightly.

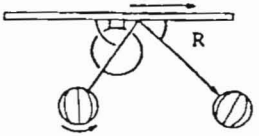


Figure 16. Horizontal velocity of rebound is greater due to friction caused by spin.

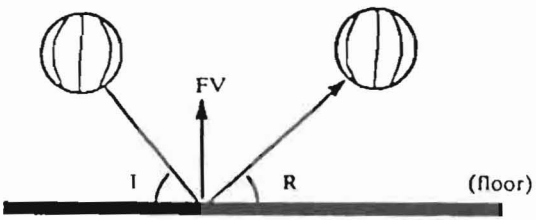


Figure 17. Ball with no spin contacting floor.

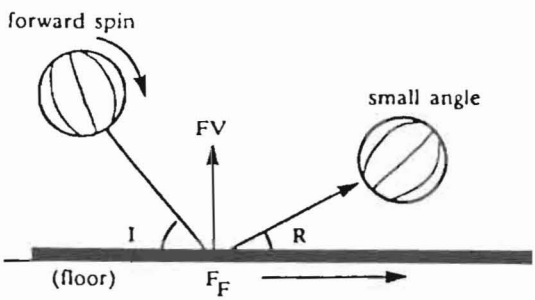


Figure 18. This is due to effects of elasticity plus increase in horizontal velocity due to friction caused by spin.

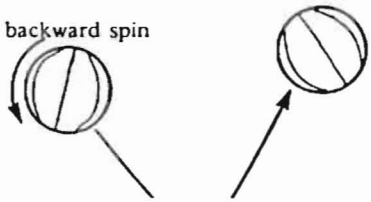


Figure 19. Greater angle due to effects of elasticity which tends to reduce vertical velocity and decrease horizontal velocity due to friction caused by spin.

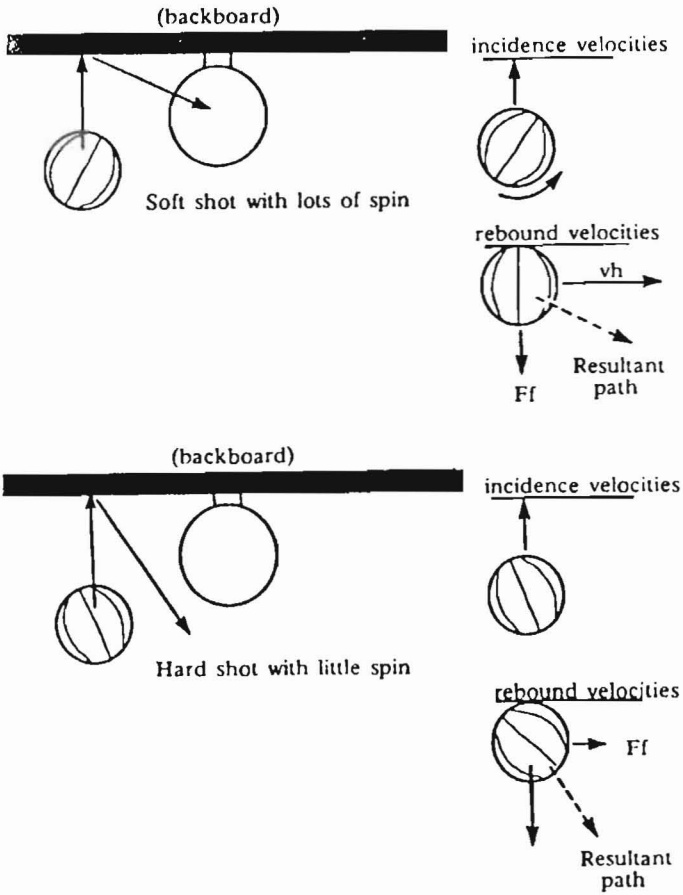


Figure 20.

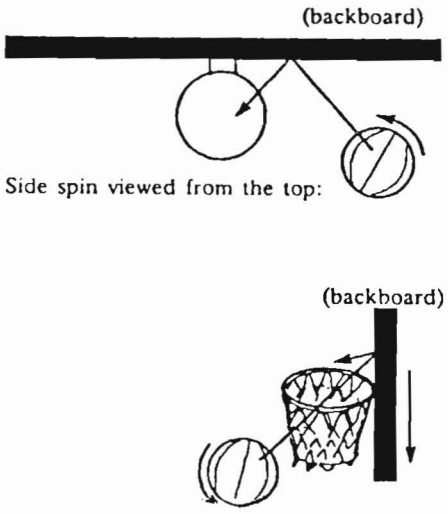


Figure 21: Back spin seen from the side. Both side spin and back spin are used in a layup shot.

Center of gravity of the body, if high or low, changes the player's movement potential. For example, the defensive player positions the body as if in a chair in order to be in a balanced position over the base of support so he/she is prepared to move in any direction. A step forward places the defensive player in a poor position, if the offensive player moves forward as the defensive player takes a step forward. Therefore, the players' COG are moving in opposite directions. A step to the side has almost the same effect.

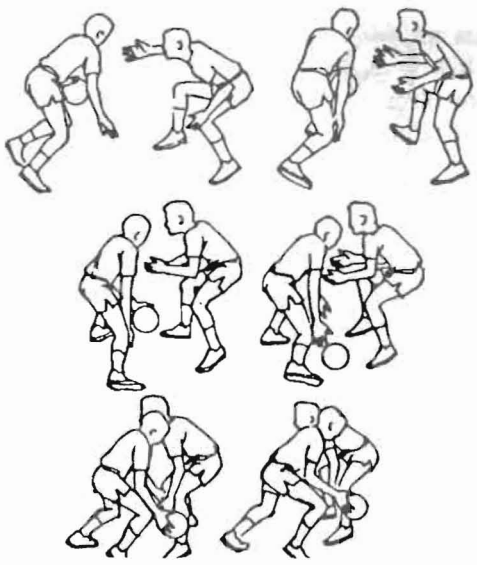


Figure 22. The approximate location of the center of gravity of the offensive and defensive player is shown here. The offensive player has caused the defensive player toshift the center of gravity too far to the right, thus enabling the offensive player to dribble by him.

Figure 22

The belt buckle may be considered the center of gravity. It is the focus of the defensive player when guarding an offensive player.

Centripetal force is present in rotary movements and is a constant force directed toward the center. There is an equal and opposite force called centrifugal force or "center fleeing force." These forces occur when a basketball player moves in a curved path. A top offensive player tries to outmaneuver a defensive player by moving quickly but under control into the curve, then accelerating on the curve. A shift of a COG toward the center, a push outward by the outside foot, and having a wide base may help in the execution to overcome the centrifugal tendency. The fact that the offensive player moves rapidly after getting into the curve causes the defensive player great difficulty.

Figure 23: Ball rests briefly in palm of hand. This dribbler is moving on a curve. He enters the curve under control and then accelerates.

Braking force is a force that helps decelerate the basketball player. Since the basketball player (offensive or defensive) is constantly stopping and starting as play progresses, it is important for the player(s) to use correct mechanics in stopping. The player places the forward foot (in stride position) so that the forward velocity of the body is slowed down or stopped by the feet pushing against the floor and the floor pushing back.

Momentum is the product of a player's mass and velocity. A large, heavy player moving at the same velocity as a lighter player will cause greater damage in a collision.

Trajectory is the path of an object in flight. Since the basket is higher than a player standing with arms extended, the player launches the ball at the basket at an angle of between 55 to 62 degrees. This is somewhere between the angle needed for maximum distance and the angle needed for maximum accuracy. The dunk is the most accurate shot if the player jumps high enough to propell the ball perpendicularly downward.

Friction is resistance to motion due to the contact of two surfaces moving relative to each other. In general, friction depends on

the load, nature and conditions of the rubbing surfaces. Starting friction is greater than sliding friction so a player will encounter greater friction in starting. A fast player has to slow down to create enough friction to stop. The player's shoe sole usually has indentations to modify the sole surface to increase friction.

Impulse is the product of force and the duration (time) of this force. A player jumping for a ball creates force against the floor in a certain time. The highest jumpers achieve the greatest impulse by producing large forces in less time.

Some Mechanical Differences in Playing in Non-Stressful Situations and in Tight Games

1. A player under stress often "telegraphs" the planned path of the ball by looking toward the potential receiver. On the other hand, the "look away" pass enables the passer to move the defensive player in the direction opposite to the final path of the passed ball. The COG of the defensive player moves in the wrong direction and often can't be corrected.

2. An offensive player may jump into the air when attempting to pass the ball to a teammate. However, often all easily seen teammates are closely guarded, and there is no one to receive the ball. The offensive player can't turn the body in a new direction, lacking time and having no base to produce force. The passed ball is often deflected or intercepted under these circumstances.

3. When trying to save the ball from going out-of-bounds in the air, the player should prepare for making a turn to face the court before jumping. It was found that blind passes (those thrown with the back to the playing court) were intercepted 65% of the time as observed from ten games in the Big Ten Conference. The action should be a normal throwing motion with the player facing to the court.

4. In rebounding situations, a quick jump by one player, may be used to offset the opponent's ability to jump higher. A quick leaper leaves the floor in a shorter span of time than a higher jumper, but the impulse is not as great and the quick jump doesn't go as high in the air. However, since most rebounds are caught below the rim the quick jumper has an advantage over a slow jumper.

5. Since a layup is executed by the offensive player by first flexing the shooting arm and then extending it (Figure 24), the defensive player must be aware of this to possibly knock the ball away. Some players try to delay the arm extension until the last second, to fool

the defense. The present day jump hook shot is an attempt to disguise shot motion.

Figure 24: Lay up. Note shooting arm is flexed and will extend at release. The ball is unprotected at this point.

6. Mechanical styles or habits of motion learned early (but later considered inappropriate under certain circumstances) are frequently used under stress. An example would be, attempting to shoot a layup shot on the left side of the basket with the right hand. The left hand should have been used so as to prevent the shot from being blocked easily.

Answers to Some Coaching Questions Through Biomechanics

1. How may bad habits be corrected?

By repetition of correct mechanics and by attempting to depress incorrect mechanics. Players must work to correct moves so that they become intuitive or automatic.

2. What causes fouls to take place?

In a close study of a 1987 college game, it was indicated in the judgement of three experts that eight out of ten fouls were caused by the defensive player being out of position. That is, the center of gravity of the defensive player was moved too far right or left in conjunction with the offensive player. Also, the defensive player was out of position with some part of the body, arm, leg, etc.

3. When, if ever, should a basketball player use an unsound mechanical move in playing the game effectively?

Shooting on an upward movement in a jump, jumping off the wrong foot in shooting a layup and shifting the ball from one hand to

another, are examples of perhaps unsound mechanics done for deception.

4. Which is the fastest pass, the bounce pass or the push pass?

In 20 passes of each done with the same initial force, the push pass was slightly faster by an average of .1 second. Apparently, friction has a greater affect than gravity but not much more.

5. What are the mechanical characteristics of fatigue in basketball?

Review of several game films and in disucssion with two physiologists, the following were determined: a) Bending over at the waist with hands placed just above the knees, b) mouth open, c) evidence of tension in the neck, d) failure to come back on defense fast enough, and e) taking shorter steps than normal when running down the court.

6. Is there such a thing as hanging in the air while shooting?

Yes, Bishop and Hay (1979) found that .2 seconds was added to the time in the air by manipulating the body about the center of gravity so the body parts can be delayed slightly at the peak of the jump.

7. Is dribbling slower than running? If so, how much?

Two studies conducted at Indiana University and Lewis and Clark College, Portland, Oregon, revealed that subjects running 47' were faster than subjects dribbling over the same distance by .25 seconds. The mere handling of the ball causes a reduction in running speed; mechanically it added an additional element not present in pure running. So in many instances, it is best to run without the ball when possible if time is of the essence.

9. Are the jumping heights of basketball players greatly exaggerated?

Yes, a study by Williams (1983) using the "jump and reach method" found no one in an entire conference who could jump higher than 29". Greater impulses (time x force) are achieved with time less and more forces. From a stationary position the jump is less than reported.

10. What makes shooting a difficult skill to master?

The player must: a) concentrate on more than one object in many situations, b) the action should be kept linear in most instances, c) confidence is important, d) if the movement of the head occurs before release, it may change the path of the ball, e) the player relys on feedback from previous shots, f) a good number of revolutions must be imparted to the ball, and g) the mechanics of movement must be correct, exact and consistent.

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