BIOMECHANICAL PRINCIPLES APPLIED TO BADMINTON POWER STROKES

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The purpose of the present paper is to review biomechanical research carried out over the last thirty years on the execution of badminton power strokes, and to share with the coach important implications of that research. Emphasis is on the forehand and backhand clear and smash. Results emphasize the importance of the rotational movements at the shoulder and radio-ulnar joints. Appropriate coaching cues are devised to assist coaches and players in assessing and improving performance.

KEY WORDS: badminton, biomechanics, power strokes, joint actions, coaching cues

INTRODUCTION: The purpose of the present paper is to review biomechanical research carried out over the last thirty years on the execution of badminton power strokes, and to share with the coach important implications of that research.

Thirty years ago, very little research had been done on the game of badminton generally and none biomechanically. Only hypothetical evidence was available regarding the 'fast' strokes of the game, commonly known as power strokes, i.e., clear and smash. Players and coaches alike passed along their perceptions of how the power strokes were played, but none had the benefit of high-speed cameras or other scientific instruments to reveal details of the performances. In the early 1960's, Waddell hypothesized that power emanated from pronation and supination. He based his theories on analysis of his own power strokes as well as many static photographs of players performing power strokes, which clearly showed that "wrist snap" was not involved. Poole (1969) wrote, "we . . . rarely 'snap' the wrist", and "all badminton strokes are made with forearm rotation rather than wrist snap." Subsequently, when Poole gathered evidence of this for his dissertation on the upper extremity movements of world class players (1970), he had to acknowledge that the technology available to him at that time, cinematographic cameras operating at speeds up to 64 frames per second (fps), caused him to write a less than definitive qualitative analysis of the clear and the smash.

Other studies concerned with analyses of strokes included Adrian and Enberg (1971), and Johnson and Hartung (1974). The former study emphasized the importance of outward or lateral rotation at the shoulder joint prior to the "forward movement" of the shoulder and elbow, and the latter concluded that rotational movements of the lower arm were the key elements to superior performance. A provocative article by Rantzmayer (1977) drew similar conclusions to those of Poole in his dissertation.

The first in-depth biomechanical studies of badminton performance were carried out by Gowitzke and Waddell, and were reported at the first international coaching conference held in conjunction with the World Badminton Championships in Malmo, Sweden in 1977 (Gowitzke and Waddell, 1977; Waddell and Gowitzke, 1977). Kinematic analyses of badminton power strokes were the major focus, and results contradicted that found in the badminton literature, including manuals of sports governing bodies. An estimation of the joint contributions made to the velocity of the shuttle in the badminton smash attributed 53% of the final output to shoulder rotation and radio-ulnar pronation. The early research focused on the overhead power strokes performed by Canadian nationally and provincially ranked players. Later, the research included top international players. The myth of "wrist snap" was reportedly laid to rest. Over the years, Gowitzke and Waddell (1979, 1980, 1986, 1989, 1990, and 1991), have presented research papers that expanded on the concepts related to forehand and backhand clears and smashes. They also delved into other aspects of badminton stroke production such as reaction and movement times, and physiological measures of young badminton athletes.

Sakurai, et al (1989) studied cut and drop shots, providing perhaps the first attempt to perform a three-dimensional analysis of some of the strokes employed in badminton. Their results revealed the importance of radio-ulnar pronation, elbow extension, and wrist ulnar

deviation in the cut shot. In 1993, Lee compared standing and jump smashes, and found jump smashes to produce superior racquet-head angular velocity and shuttlecock velocity. In 1995, Tang et al provided a three-dimensional cinematographical analysis of the badminton forehand smash, focusing on the forearm and hand. Luhtanen (1996) further explored concepts related to the clear in junior badminton players. Tsai and Chang (1998) studied smash and jump smash performances of elite and collegiate players and noted that generally, elite players achieved greater angular velocity of elbow movement (taken to mean radio-ulnar pronation), and the movement times (from preparation phase to point of contact) were less than those of collegiate players.

Suffice it to say that all of the studies emphasized that, in performing power strokes, such as the forehand clear, smash, or cut shot, the forearm action, anatomically described as pronation of the radio-ulnar joints, played a predominant role in the success of the stroke. The significant distinguishing action for backhand power strokes also lay with the forearm action, and is technically called supination.

METHODS: The early research by the authors focused on the overhead power strokes performed by Canadian nationally and provincially ranked players performing in the laboratory. Two high-speed 16-mm cameras operating at 400 frames per second were used to record the athletes' movements as they played overhead clear and smash, forehand and backhand. Kinematic analysis of the film revealed that the hypotheses of the investigators on the biomechanics of stroke production were supported.

Subsequently, performances of world class players at Commonwealth Games and World Championships were filmed and the results confirmed those of the earlier studies.

More detailed studies of badminton strokes were carried out by analyzing the ground reaction forces of overhead power strokes by use of a force platform. Attention was focused on the components of force in the vertical direction and was compared to the weighting and unweighting phases of a vertical jump for height.

RESULTS AND DISCUSSION: Whether playing a clear or a smash, an elite badminton player takes advantage of long resistance torque distances for rotational movements at both the shoulder and radio-ulnar joints in order to produce the power needed in these strokes with a minimum energy cost. After preliminary movements are used by a player to move the racquet backward during the 'wind-up' phase of a stroke, a player will 'move out from under the arm' by a combination of hip and trunk rotations. This is followed by accelerating the racquet forward and upward principally by medially rotating the shoulder, and pronating the radio-ulnar joints (Gowitzke and Waddell, 1977, 1979). In addition, it should be noted that use of a flexed elbow during the shoulder rotation portion of the stroke, maximizes the contribution of the shoulder action to the stroke. As well, a marked angle between the racquet and the forearm maximizes the contributions of radio-ulnar pronation.

The term "power grip" was coined by Rantzmayer and Niesner (1987) and stemmed from the recognition that the angle formed between the racquet and the forearm may be as large as ninety degrees if the grip has the fingers well flexed and bunched together instead of a 'shake-hands' grip. With this grip, rotations at the shoulder and radio-ulnar joints move the racquet head in an even larger arc than would be possible with the traditional grip.

Force platform studies revealed that all overhead power strokes were played with the body elevated and the platform "unweighted". For the forehand smash, for example, all players were airborne and the feet were not in contact with the floor at impact, which supported the observations of the authors that every smash is a "jump smash". For all smashes, contact with the shuttle was made during the last part of the unweighting phase while the body was descending from its high point (Gowitzke and Waddell, 1980).

Whether playing forehand or backhand strokes, if the objective of the stroke is power, some basic biomechanical principles emerge:

1. <u>Employing sequential joint actions.</u> A sequence of joint actions is employed, with the larger more proximal muscles of the body initiating the action, and the smaller, more distally located muscles following up through contact with the shuttle (Gowitzke, 1979;

Lee, 1993). This may be referred to as a whip-like action.

2. Making use of the backswing with continuous action. A continuous action from backswing to follow-through should be stressed so that no discernible instant in time may be specified as the time when the backswing stops and the forward swing starts. In forehand overhead power strokes, for example, the following description summarizes the action (Gowitzke and Waddell, 1977; 1979);

- The proximal joints, principally hip and intervertebral joints, rotate away from the hitting direction first.
- While hip rotation reverses, intervertebral joints may still counter-rotate.
- The intervertebral rotation then reverses and commences in the hitting direction while upper arm lateral rotation at the shoulder joint commences.
- As well, elbow flexion and radio-ulnar supination start.
- At the appropriate time, medial rotation at the shoulder commences, even while the elbow and radio-ulnar action lag behind.
- Finally, elbow extension and radio-ulnar pronation occur.

The same description applies to backhand overhead power strokes except that the terms, medial rotation, pronation, lateral rotation and supination, respectively, may be substituted for the underlined words. Niesner and Rantzmayer (1982) referred to the continuous action as "the loop" and stressed "there must not be any break between the preparatory movement and the force-producing movement".

3. Maximizing impulse while minimizing time. The ideal power stroke is one that maximizes impulse (the product of force and time) by delivering a very large force over the shortest possible time. A quick, but not necessarily long backswing is taken with no hesitation between backswing and forward swing. This means that during the backswing, the muscles that are about to be operative in the force-producing phase, are stretched. This takes advantage of the elastic properties of muscle and inherent proprioceptive reflexes.

Badminton drives, that is strokes played in the area of waist height, have not been researched. Generally, it is considered that in all drives the racquet head is higher than the hand holding the racquet. Thus, there is a flexion of the wrist toward the radial side.

The authors suggest that biomechanically, the sequential actions are generally different for strokes that are played above the waist as opposed to those played below the waist. On the forehand side, strokes played above the waist generally are struck with the wrist flexed to the radial side, and the forearm pronates during the stroke. When the shuttle is struck below the waist, the racquet head is below the hand, the wrist is flexed to the ulnar side and the forearm supinates during the stroke.

The reverse is true for the backhand side. In strokes played above the waist, the forearm supinates and for those strokes played below the waist, the forearm pronates. These observations and qualitative analyses are at odds with that found in the badminton literature.

PRACTICAL APPLICATIONS: The common question of coaches after listening and observing biomechanical analyses of power strokes is "never mind the technical analysis – how do I train my athlete to improve his(her) smash?" The question reveals the importance of clarifying the nature of sport biomechanics and how biomechanical principles can be used to assist coaches. From the practical point of view, for coaches, the development of power is solely dependent on maximizing the joint actions in a sequential fashion.

Not having high-speed cinematography or videography on court poses a major problem for coaches to analyze and correct or improve stroke production. Since the whole power stroke takes place in about 1/10 second, the problem of observing the actions is very difficult. Fortunately, the results of research provide a base for devising cues for coaches on what to look for when coaching an athlete and how to improve his(her) stroke production.

When teaching the forehand clear or smash, it is a foregone conclusion that the direction in which the racquet faces at contact with the shuttle is indicative of the direction in which the shuttle will fly; i.e., upward for clear and downward for smash. However, the power for these strokes emanates from the turning motions discussed in the results section.

Cues are devised to maximize the biomechanical actions of joints in the upper extremity, since they are the most important and the most difficult to monitor because of the speed with which they are carried out. The coach must be alert to catch the necessary "glimpse" of racquet and/or arm position cues that designate the correct execution of overhead power strokes on court.

Coaching cues:

1. From a position behind the player, at the start of the backswing, the coach should look for the racquet to move upward 'on edge' – that is, so that the edge of the racquet is seen rather than the 'flat' of the racquet. (This is a difficult cue and needs considerable practice to recognize easily.) Near the top, when the racquet head is moving quickly, it may be impossible to see that the racquet 'face' will turn toward the shuttlecock. In viewing performance from the player's racquet side, in the follow-through, when the racquet is slowing down, the coach should look for the "flashing" of the 'face' of the racquet for an instant, especially when the smash is being performed. The sequence of the forehand action is as follows:

- Preparation: The wrist is radially flexed; the racquet shaft is at an angle with the hand to the radial side of the forearm. The racquet head is 'on edge' to the hitting direction. The preparatory position is maintained until the last instant before commencing the stroke.
- Backswing: The racquet is drawn back quickly, with the racquet head sweeping back and down to the hitting side.
- Forward swing: The racquet head moves upward in the 'on edge' position when viewed from behind the player. The elbow remains high during contact. A moment after the shuttlecock is struck, the elbow is still high but flexed, the racquet head down, and the 'face' of the racquet is toward the observer when viewing from the player's racquet side. In powerful strokes, i.e., all smashes, the lower extremity on the hitting side is flexed at the hip and carried forward as the stroke is completed.

2. It is safe to say that the backhand clear or smash is almost a mirror image of the forehand strokes. The 'end' position of the forehand clear, for example, is the beginning position of the backhand clear. And the 'end' position of the backhand clear is the beginning position of the forehand clear. In both forehand and backhand strokes, a significant feature to look for is the position of a high elbow, with the upper extremity well abducted from the trunk. Therefore, from a position behind the player, at the start of the backswing, a coach should look for the racquet to move upward 'on edge'. In the follow-through, from a position beside the player, the coach should look for the 'flat' of the racquet, although it is only for an instant. The sequence of the backhand action is as follows:

- Preparation: The preparatory position is identical to that of the forehand power stroke with the racquet head 'on edge'.
- Backswing: The racquet head is drawn quickly downward as the elbow moves sharply upward and is best viewed from behind the player.
- Forward swing: As the elbow rises, the racquet is drawn up 'on edge' when viewed from behind the player. As the elbow straightens, the elbow appears to stop or even back up when viewed from the side of the player. As the stroke ends, after contact, the entire upper extremity comes to an abrupt stop, as the racquet continues forward and exposes the 'flat' of the racquet to an observer standing beside the player.

Awareness of the required sequential joint actions in power strokes as well as the ability to use the cues to ascertain their presence do not in themselves provide the coach with the knowledge to improve the stroke action and increase the power.

When the coach does not see views of the racquet position as described above, work has to be done on these joint actions, commencing with the forearm actions. In an overhead stroke, there should be enough power using only pronation on the forehand side and supination on the backhand side to clear the shuttle from the back doubles service line to the back doubles service line. This stroke should be practiced regularly using as little elbow extension as

possible. When satisfactory power has been achieved, elbow and shoulder action can be built into the full sequential action chain.

When "controlled" power rather than full power is needed, only the terminal elements of the sequential action may be required. For example, in performing an attacking clear, a player may invoke deception by holding back on the use of hip and intervertebral joints, but invoking to the fullest extent the use of the distally located joints and muscles in maximizing the impulse to perform the stroke.

When training to improve badminton drives, important consideration should be given to the turning of the forearm in both forehand and backhand strokes. For example, in employing small weights, it is much more important to carry out pronation and supination exercises, than to use wrist curls.

Lastly, the high singles serve is a power stroke and has been the main serve employed in singles over the years. Recently, however, the short serve has been used extensively. It is interesting today to see some of the international players using the backhand serve. And why not; it is the most deceptive stroke by far. By making use of the power in pronation action, short serves can be interspersed with "attacking clear" services to great advantage. The serve becomes an 'attacking' shot and not the defensive stroke that it has been for so long. The appropriate use of pronation of the forearm provides for power and deception in the backhand serve.

GLOSSARY OF TERMS:

1. The following terms are used to describe racquet position relative to the view of the coach:

- 'On edge' refers to viewing the racquet so that the strings cannot be seen.
- 'Flat' of the racquet refers to viewing the strings so that the entire circumference of the racquet head can be seen.
- "Face" of the racquet refers to viewing the strings on the hitting side only.
- 'End' position refers to the follow-through position of the racquet immediately after impact with the shuttle when its angular velocity has diminished toward zero.

2. The following terms are the anatomical terms used to describe actions at joints.

- Upper extremity – includes all bones, muscles, and joints of the upper arm, forearm, and hand.
- Radial flexion -- an angle at the wrist between forearm and hand so that the hand is angled to the thumb side.
- Ulnar flexion -- an angle at the wrist between forearm and hand so that the hand is angled to the little finger side.
- Pronation – an action about an axis through the radio-ulnar joints so that the palm is turned downward or backward.
- Supination – an action about an axis through the radio-ulnar joints so that the palm is turned upward or forward.
- Medial rotation – an action about an axis through the shoulder joint so that the forearm and palm are facing inward or downward.
- Lateral rotation – an action about an axis through the shoulder joint so that the forearm and palm are facing outward or upward.

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