OPTIMIZING RACQUETHEAD-SHUTTLE INTERACTION FOR AN EFFECTIVE OVERHEAD FOREHAND CLEAR IN BADMINTON

by

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ABSTRACT

The purpose of this investigation was to determine the difference in selected kinematic variables of the shuttle-racquet head interaction for players of different ability levels executing the badminton overhead forehand clear. These variables included, 1) resultant velocity of the racquet head at contact, and 2) time between peak velocity and contact. This study also examined the total horizontal displacement of the shuttle after contact, the angle of deviation of the shuttle, the time of flight of the shuttle, the angle of projection of the shuttle after contact, and the shuttle velocity after contact. Six volunteer male subjects were divided equally into three groups corresponding to their ability: novice, intermediate, and advanced. Data were collected using a high speed motion picture camera. The data did not establish significant differences between the three groups with respect to the racquet head velocity at contact, or for the time differences between peak velocity and contact time. However, it was found that the angle of projection of the shuttle as well as the flight time of the shuttle decreased with ability.
RESUME

Le but de la présente étude est de déterminer, lors de l'exécution du dégagé du coup droit au badminton, s'il existe des différences significatives lors de l'interaction racquette-volant pour certaines variables kinématiques sélectionnées soit, 1) vitesse de la tête de la racquette lors du contact, et 2) la différence du temps entre le point de vitesse maximale et le point de contact. La présente étude examine aussi les variables suivantes; déplacement horizontal du volant après contact, l'angle de déviation du volant, le temps d'envol du volant après contact, l'angle de projection du volant après contact, et la vitesse du volant après contact. Six volontaires, males, furent divisés en trois groupes égaux correspondant à leur niveau d'habileté, soit; novice, intermédiaire, ou avancé. Les données furent recueillies à l'aide d'une ciné-caméra à haute vitesse. Les résultats obtenus indiquent qu'il n'existe aucune différence significative entre les trois groupes en ce qui concerne la vitesse de la tête de la racquette lors du contact et la difference du temps entre le point de vitesse maximale et du point de contact. Cependant, l'étude démontre une difference en ce qui concerne l'angle de projection du volant et le temps d'envol du volant qui tous deux décroissent avec une augmentation de l'habileté.
ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

Recreational and competitive badminton is enjoyed by people of all ages. Since the equipment is light enough for beginning players to handle, they are able to sustain long hitting rallies; more experienced players enjoy the physical and strategical challenge presented by a skilled opponent. In addition, special shuttle designs allow players to regulate the pace of the game and to develop long and interesting rallies. In the province of Quebec badminton is a close second to tennis in popularity and considerably ahead of swimming, cross country skiing and even hockey, basketball, and volleyball (Lavoie and Lavallée, 1983). Badminton is also one of the few sports in which men and women can participate together up to international levels of competitions (Johnson 1974) including the Olympics. A total of 60 national organizations were full members of the International Badminton Federation in 1979 (Canadian Badminton Association 1979), attesting to the international popularity of this sport.

While it is necessary to develop the basic skills to fully enjoy the sport of badminton, the initial ease with which these skills are attained makes badminton popular with novice players. However, the skills required to play elite badminton challenge the most advanced athlete (Johnson 1974).
1.1 Nature and Scope of the Problem

The overhead forehand clear is the most widely employed badminton stroke in the singles game (Canadian Badminton Association, 1979; Cranston, 1967; Hashman and Jones, 1977; Mills and Buttler, 1974). It is also considered to be the basis of all other overhead forehand strokes (Mills and Buttler 1974). From a strategical point of view, the clear is used to "push" the opponent to the back of the court in order for the player executing the stroke to 1) open the front court area, 2) tire the opponent, and 3) place the opponent in a precarious hitting position. The longer the flight time and the higher the apex reached by the shuttle, the more time for adversaries to position themselves properly and set up the return. Furthermore, if the shuttle is not "deep" enough into the backcourt, opponents will have a greater variety of options, a shorter distance to the net, and a better angle of attack.

In the overhead forehand clear, it is observed that on most occasions, the clear executed by the novice player has a shorter horizontal displacement of the shuttle than that of an advanced player (Davidson and Gustavson 1955). Indeed, the novice seems to exert a lot more effort in executing the strokes than the advanced player. It can be postulated that the advanced player has a better developed or more "mature" movement pattern which results in a more efficient stroke. However, beyond the issue of movement maturity, the question
remains; Can a novice player generate the necessary racquet head velocity needed to propel the shuttle from one end of the court to the other for an effective clear? If the novice player can generate similar racquet head velocity to that of the advanced player, then this would suggest that the deficiencies of the novice player would be the result of some other factor(s). Potential critical factors may include the angle of the racquet at contact (in respect to both the horizontal and sagittal planes), velocity of the racquet head at contact, and the angle of projection of the shuttle. These factors represent the most basic kinematic factors affecting the outcome of the shuttle's trajectory. It must be realized that these factors are directly affected by the movement pattern of the stroke. Although it is not the purpose of the present study to analyze the movement pattern of the stroke, the results of this study may be used to gain insight into the movement pattern.

Thus, before the coach, or instructor is able to modify the movement pattern of the less skillful player in an attempt to improve on the shuttle's resultant trajectory, it must be established whether the less skillful player can produce the appropriate racquet head velocity and contact parameters to propel the shuttle from one end of the court to the other. Once this question is satisfied, further study on other possible sources of performance variance would then be appropriate.
It then becomes imperative to determine if, in fact, there does exist a difference in racquet head velocity and projection velocity at contact in order to proceed in the examination of other possible inhibiting factors.

No study to date has compared biomechanical characteristics of the racquet and shuttle interaction at contact for the overhead forehand clear in badminton across ability levels. Therefore, very little information is available concerning differences between one level of ability to the next from which to form coaching strategies.

1.2 Statement of the Problem

The three major interaction factors between the racquet and the shuttle at contact include: 1) the velocity of the racquet head, 2) the orientation of the racquet head, and 3) the direction in which the racquet is moving (Ranzmeyer & Niesner 1987). Of prime concern in this study was the first factor, racquet head velocity at contact. In order to establish a proper interaction model for each category of skill level, the intent of this study was to compare 1) the resultant velocity of the racquet head at contact, and, 2) coordination, as represented by the time between peak resultant racquet head velocity and shuttle contact. These two variables were chosen because of their importance in the execution of the overhead forehand clear. Three groups of badminton players of varying ability levels, namely novice, intermediate, and advanced, were investigated in order to
establish these relationships and their effects on performance. These particular levels of ability were chosen as being representative of the Canadian Badminton Association ranking categories.

The results were intended to provide coaches and teachers with an indication of the ability of less skillful players to duplicate the racquet head velocity of the advanced players. This will identify the importance of maximal racquet head velocity in the success of the overhead forehand clear and provide insight concerning the deficiencies of the less skillful players.

1.3 Hypotheses

The information obtained from this study was examined in light of the following null hypotheses:

1- There will be no significant differences in the resultant velocity of the racquet head at contact with the shuttle among the three different skill groups.

2- There will be no significant differences among the three levels of ability in the peak resultant racquet head velocity in the forward direction and shuttle contact time differences.

3- There will be no significant differences among the three levels of ability in the angle of projection of the shuttle after contact.
1.4 Delimitations

1. Subjects for the study will include male volunteers between the ages of 18 and 28 years.

2. The subjects will be required to stand stationary in the middle of the odd service court and at the back of the court between the two service lines, in order to hit a served shuttle.

3. The same racquet and nylon shuttles will be used by all subjects.

1.5 Limitations

1. Spatial and temporal aspects of the stroke will be recorded via cinematographical procedures and are subject to the measurement error inherent in film analysis.

2. There will be only 2 subjects per ability level selected for this study.

1.6 Definitions of Terms

The following terms have been defined in accordance with their particular use in the present study.

Forehand - Any stroke executed with the palm of the racquet hand facing the oncoming shuttle. Contact with the shuttle is made on the same side as the racquet arm.
Overhead clear - A forceful badminton stroke in which the shuttle is struck above the level of the hitter's head resulting in a flight which takes the shuttle deep in the opponent's court and above the player's extended reach.

Defensive clear - A forceful badminton stroke in which the shuttle is struck above the level of the hitter's head resulting in a very high and deep shuttle trajectory. This stroke is usually used to give the player executing the stroke time to recover his central position on the court.

Offensive clear - A forceful badminton stroke in which the shuttle is struck above the level of the hitter's head resulting in a low and deep shuttle trajectory and just barely passes over the opponent's extended reach. This stroke is used to force the opponent to commit a mistake by not allowing enough time to setup a proper return.

Striking mass - The theoretical mass of the racquet, hand, and arm, as determined by the momentum of the shuttle after impact divided by the difference in tangential racquet velocity prior to and after impact.

Novice player - A badminton player who has followed an instructional course at McGill University and has participated in less than 3 provincial C level tournaments.
Intermediate player - A player with moderate tournament experience (more than 10 competitions) at the regional and provincial B level but who was never ranked nationally in any category.

Advanced player - A player who finished in the top 20 of a national tournament sanctioned by the Canadian Badminton Association, and with extensive competition experience.

Resultant velocity - A mathematical computation of the value of the velocity obtained from the horizontal and vertical velocity values. In the present investigation, resultant velocity will be substituted for tangential velocity.
CHAPTER II

REVIEW OF LITERATURE

Despite growing recognition as a strenuous physical activity and its long time popularity as a recreational pastime, the sport of badminton has been the subject of very little scientific research. Gowitzke and Waddell (1979) stated that much of the existing literature, which can be found in the form of books and coaching manuals, is limited to a brief description of the badminton strokes and game strategies. Most of these appear to have been derived from the authors personal observations and experiences as a coach, teacher and/or player (Bloss, 1983; Canadian Badminton Association, 1979; Davidson and Gustavson, 1955; Davis, 1970; Davis, 1974; Devlin and Lardner, 1973; Downey, 1975; Mills and Buttler, 1974; Poole, 1973).

Published studies of badminton primarily cover the various methods of teaching skills, performance tests, and the physiological and psychological aspects of the sport. Of the existing studies, only a small number have attended to the kinematic analysis of the badminton stroke (Adrian and Enberg, 1971; Barth, 1961; Blank, 1971; Gowitzke and Waddell, 1977, 1979, 1980; Gowitzke, 1979; Johnson and Hartung, 1974; Poole, 1970; Tétreault, 1964; Waddell and Gowitzke, 1977; Waddell, 1979). The focus of the present study is the overhead forehand clear, and among the existing literature, only Blank (1971), Gowitzke (1979), Gowitzke and
Waddell (1977, 1979, 1980), Waddell (1979), and Waddell and Gowitzke (1977) have examined this stroke.

As the name implies, the overhead forehand clear is executed on the forehand side with the contact point of the shuttle located above the executing player's head. The trajectory that the shuttle follows should take it across the net and deep to the back of the opponent's court. The height of the shuttle trajectory varies with tactical considerations. The trajectory should, nevertheless, be such that the shuttle will "clear" or pass over the opponent's extended reach. Opposing players should not be able to make contact, or "cut" the shuttle, until they are at the back of the court. The higher the apex reached by the shuttle, the more vertical the downward trajectory will be and the longer the flight time. Therefore, the executing player must choose the desired trajectory so that the shuttle just clears the opponent and lands deep in the backcourt.

Although the study of the movement pattern of the overhead forehand clear is not an essential part of the present study, it does offer an understanding of the actions which effect the dependant variables used. The following description encompasses the observations of several authors (Canadian Badminton Association, 1979; Gowitzke and Waddell, 1979).

To facilitate understanding, it is useful to break down the movement into three phases; the preparatory phase, the execution phase, and finally, the follow-through phase. The
badminton overhead forehand clear is a multi-segmental movement and as such it follows the principle of summation of velocity from the larger more proximal muscles to the smaller more distal muscles and segment (hand). As a result of this principle, the total movement cannot be segregated into distinct phases but must be broken down segmentally. Thus, it is possible, for instance, for the legs to be in the execution phase but have the arm still in the preparatory phase.

In performing the skill, the preparatory position is characterized by the player's body being turned sideways so that his non-racquet shoulder is nearer to the net. The leg on the racquet side is drawn backwards and closer to the back line of the court, bearing most of the body weight. The non-racquet foot is forward and angled towards the post (on the racquet side). The racquet elbow is brought into position by the horizontal extension and abduction of the shoulder joint. The racquet head is brought downwards to a position somewhat near the mid line between the two scapulae by lateral rotation of the shoulder joint, supination of the forearm, and extension and radial flexion at the wrist joint. The striking phase begins with the extension of the back leg followed by a counterclockwise rotation of the pelvis (for a right handed player). The trunk and shoulders are then turned to face the net. The center of gravity is shifted forward so that the front leg now supports most of the weight. The racquet is brought overhead by extending at the elbow. As the
elbow extends, the humerus is medially rotated and the forearm is pronated in order to bring the racquet face in contact with the shuttle at right angles to the intended direction. The shuttle may be struck anywhere from the extreme outside of the body on the racquet side to a point directly above the player's head. However, according to the literature the ideal point of contact is directly above the racquet shoulder. The racquet head should be at such an angle that it gives the shuttle an arching trajectory in order to clear the opponent's extended reach. The arm follows through in a straight line towards the net, then carries across the body towards the non-racquet side as the player's racquet leg steps forward in front of the mid line of the body.

The whole sequence of movement described above is meant to generate sufficient racquet head velocity to propel the shuttle to its proper destination. In the case of the overhead clear, this corresponds to the back of the opponent's court. Thus, racquet head velocity would seem to be critical to the success of the stroke.

2.1 Movement Pattern Similarity Among Overhand Pattern Activities

As mentioned previously, very little research has been done involving the badminton overhead forehand clear. Thus it has been necessary to consult relevant literature in other sport areas in which a similar movement pattern is demonstrated. Even though overarm actions may differ, it
must be noted that the interaction at the shuttle-racquet contact point is the concern of this study and not the muscle groups employed to execute the different actions. Hence, similarities with the movement patterns of other skills are sufficient for us to draw some general biomechanic principles pertaining to the racquet and shuttle interaction at contact.

The activity which demonstrates the most similarity to the overhead forehand clear is, without question, the badminton forehand smash. Many authors (Bloss, 1983; Davidson and Gustavson, 1955; Davis, 1974; Downey, 1975; Jackson and Swan, 1939; Mills and Buttler, 1974; Rogers, 1970) agree that the movement pattern for all overhead forehand strokes (clear, drop, smash) are quite similar except for a few "minor" adjustments such as; point of contact, angle of contact, and racquet head velocity at contact. This holds true at the advanced level of play and is not apparent at the beginning and intermediate levels. As a result of the similarity between the overhead strokes, the smash is usually considered a natural progression of the overhead forehand clear. There exists a small number of studies pertaining to the forehand smash (Adrian and Enberg, 1971; Barth 1961, Gowitzke and Waddell, 1977, 1979, 1980; Jack, Adrian, and Yoneda, 1979; Poole, 1970). Of these studies, the most informative description of the stroke can be found in Gowitzke and Waddell (1979).
Table 2.1 is a summary of research done by a variety of authors on the forehand smash as reported by Gowitzke and Waddell (1979).

**TABLE 2.1**

**FOREHAND SMASH VELOCITIES**

<table>
<thead>
<tr>
<th>Study identified by author</th>
<th>m/s</th>
<th>km/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrian-Enberg (reported in ft/sec)</td>
<td>56.0</td>
<td>201.6</td>
</tr>
<tr>
<td>Poole (reported in ft/sec)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject A</td>
<td>42.1</td>
<td>151.6</td>
</tr>
<tr>
<td>B</td>
<td>30.1</td>
<td>108.4</td>
</tr>
<tr>
<td>C</td>
<td>21.1</td>
<td>76.0</td>
</tr>
<tr>
<td>D</td>
<td>26.6</td>
<td>95.8</td>
</tr>
<tr>
<td>Gowitzke-Waddell</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject 1</td>
<td>80.0</td>
<td>288.0</td>
</tr>
<tr>
<td>2</td>
<td>55.7</td>
<td>200.5</td>
</tr>
<tr>
<td>3</td>
<td>65.4</td>
<td>235.4</td>
</tr>
<tr>
<td>4</td>
<td>72.7</td>
<td>261.7</td>
</tr>
<tr>
<td>5</td>
<td>83.1</td>
<td>299.2</td>
</tr>
<tr>
<td>6</td>
<td>71.0</td>
<td>255.6</td>
</tr>
<tr>
<td>7</td>
<td>76.6</td>
<td>276.1</td>
</tr>
<tr>
<td>8</td>
<td>96.0</td>
<td>345.6</td>
</tr>
<tr>
<td>Mean of eight subjects</td>
<td>74.9</td>
<td>269.6</td>
</tr>
</tbody>
</table>

* Poole totalled the velocities of elbow, wrist and racket head to attain a "final velocity".

As a result of a faster filming speed as well as a greater number of subjects, the studies by Gowitzke and Waddell (1979) yield the most probable values for the forehand smash of elite players. These values provide a basis for comparison with the forehand clear values of the present study.
Authors have noted and commented on the similarities of overhead arm movements used in a variety of sports (Anderson, 1979; Barth, 1961; Broer, 1973; Cooper, Adrian and Glassow, 1982; Piscopo and Baley, 1981; Shambes and Campbell, 1973; Wells and Luttgens, 1976). Although the arm actions are not identical, the similarity in both the pattern and objective provide a basis for discussion. The discussion, however, will be limited to the contact point or release point.

Jack, Adrian, and Yoneda (1979), state that in the overarm stroke of racquet sports, similar movement patterns are found in part, in the trunk rotation, shoulder circumduction, flexion and extension of the elbow joint, pronation and supination of the radius on the ulna, and flexion and extension of the wrist joint. In their study, the forearm and wrist movement patterns of overarm strokes in tennis, squash, racquetball, and badminton were examined using electrogoniometry. The amplitude and maximum angular velocity of the wrist flexion prior to contact were not similar when subjects executed the four overarm strokes. However, none of the subjects appeared to change their wrist movement pattern for the four sports. This is in agreement with Adrian and Enberg's (1971) conclusion that similar movement patterns might actually replicate the one best skill of highly skilled performers. Thus, the highly skilled tennis player will tend to use the same movement pattern (of tennis) in the other three sports. According to these studies, the uniqueness of the wrist and forearm movements appear to be more a function
of ability rather than racquet type or objective of the stroke.

2.2 Biomechanical Principles Applied to Stroke Production

In performing the overhead forehand clear, the objective is to be as accurate as possible with the placement of the shuttle. The player intends to direct the shuttle so that it will land in a specific area on the opponent's back court. Furthermore, the trajectory must be sufficiently high as to circumvent any attempt to "cut off" the shuttle too early. Two factors predominate in governing the accuracy of the projectile flight. These factors are the release velocity (in this case, velocity after contact) and the angle of projection. The latter can be broken down into 1) the angle of racquet head after contact, and 2) the direction of travel of the racquet head at contact.

A basic factors chart of the overhead forehand clear in badminton has been presented in Figure 1 as a summary. It illustrates the biomechanical factors affecting accuracy and their interactions. The darker boxes indicate factors examined in the present study.
When describing throwing, Broer (1973) states that the distance the ball will travel is dependent upon several factors such as velocity of release, angle of projection and the action of external forces. Such forces include gravity, air resistance, spin, shape and surface drag of the object. In badminton, very little can be done to modify these forces. At the instant of release, the velocity of the hand in the desired direction of movement is the sum of the directional components of the proximal segments linear velocities moving at that instant. Kunz (1974) noted that in ball and javelin throwing, the velocity that is imparted to the object is the most important factor for obtaining maximal distance. At a given angle of release, the distance the thrown object will travel depends on the speed of the projectile at the moment of release. In the case of the badminton clear, this corresponds to the velocity at the instant following contact.

In order for the racquet head to have sufficient velocity to propel the shuttle to the back of the court, the player must initiate the movement with the larger more proximal muscles (hip and trunk) (Johnson, 1974; Piscopo and Baley, 1981). As the larger, most proximal segment decelerates, an acceleration of the subsequent link follows in order to maintain the system's total amount of angular momentum. In an ideal situation, as this second segment reaches near maximal velocity resulting in near zero acceleration, it starts to decelerate. In order for the system's angular momentum to be conserved, the subsequent distal segment must accelerate.
This sequence occurs from segment to segment, from proximal to distal until the end of the chain is reached. Since the mass of each segment decreases from the proximal to distal end, the rotational inertia becomes progressively less. As the larger mass segment loses a small amount of velocity, it transfers this loss of momentum to the lighter segment, which in turn gains a large amount of velocity in order to maintain the total amount of angular momentum of the system (Scrutton, 1973; Kreighbaum and Barthels, 1985). Van Gheluwe and Hebbelinck (1985) examined this in a study of two advanced tennis players executing a serve. Their results demonstrated that the maximal forward velocity values of several joints of the striking arm did not occur in proximity to the moment of contact, but somewhat prior to that moment. The more distal the joint, the closer the maximal velocity value approaches impact time. This suggests that the maximum velocity value should correspond to contact time, and further, that a significant time difference would indicate an inefficient stroke as a result of the submaximal velocity. As a result, it was decided to include the time difference between the maximal velocity and contact time as a variable representing coordination in the present study.

A large amount of racquet head velocity at contact is not sufficient to assure the optimal results; the direction in which it is applied is also consequential. The more the application of the force exerted by the racquet is aligned with the desired motion, the more effective the application.
In the case of the badminton stroke production, the forces are applied tangentially to the path of the racquet head at contact. The trajectory of the shuttle is determined by the racquet face-shuttle relationship during contact. Most of the basic strokes should be executed by striking the shuttle with the strings perpendicular to the desired direction of travel if high shuttle velocity is desired. Failure to contact the shuttle at right angle causes dissipation of the force along the strings and imparts the shuttle with additional rotation causing a decrease in the shuttle's linear velocity. In some advanced strokes, the "slicing" of the shuttle is desirable. This technique is used for deception to the stroke by decreasing the resulting velocity of the shuttle compared to the racquet velocity at contact. Such is the case with the sliced drop shot, for example, but it is not recommended in the execution of a clear.

The application of force will be most effective when applied at the center of percussion of the racquet. Force is transmitted from proximal to distal segments until it imparts a portion of that force to the shuttle via the racquet strings. The center of percussion (or "sweet spot") of the racquet lies approximately at the center of the racquet strings. A better force application will result if the shuttle is contacted at the center of the racquet head. When contact is made at the center of percussion, the racquet translates about the center of mass. However, if contact is made at a distance (towards the edge of the racquet frame)
from the center of percussion, then the racquet will rotate around the center of mass, as well as translate. The further away from the center of percussion that the contact is made, the more rotation will be imparted to the racquet. It must be noted that the center of percussion will vary as a result of the profile of the racquet such as racquet stiffness and string tension. The stiffer the racquet, the higher the rebound velocity (Baker and Wilson, 1978; Brody, 1979). The lower the string tension (to a reasonable point), the more energy is stored in the strings and transmitted to the projectile (Brody 1979). Accuracy will also be greater if contact is made at the center of the racquet head. It can be expected that the angle of incidence will be equal to the angle of reflection relative to the plane of the strings only if the strings deflect symmetrically as contact is made at the center (Brody 1979). If the contact point is made off center, then the asymmetrical string deflection tends to deflect the projectile towards the center (of the racquet face). As a result of the pattern in which the racquet is strung, the force is dissipated evenly along the racquet head thus minimizing the chances of having the shuttle stray from its intended trajectory.

The coefficient of rebound, or coefficient of restitution, is dependent on; 1) the string tension, 2) the type of strings, 3) the point of contact on the strings, and 4) the composition of the shuttle. As in tennis, the tension of the strings will greatly affect rebound velocity. However,
in badminton, the range of variability in string tension is not as great as in tennis. In badminton, a tension of 14 lbs. (62 N) is considered to be fairly "loose" and a tension of more than 18 lbs. (80 N) is considered to be very "tight". The effect of too much string tension is more apparent in badminton. The light mass and the shuttle's low velocity prior to contact does not indent the tight strings to a great extent. Furthermore, the head of the shuttle does not compress on itself as does the tennis ball. A badminton shuttle has a very low coefficient of restitution. As a result, a racquet which is too tightly, or too loosely strung, will produce a poor transfer of momentum from the strings to the shuttle. The type of string also affects the coefficient of restitution.

Other factors affecting the outcome of the strokes include forces acting on the racquet, which can be broken down into 1) racquet flexibility, and 2) the period of oscillation of the racquet. The racquet flexibility determines how much the racquet head will be displaced (translate) when force is applied. The period of oscillation determines the time it takes to "recoil" or "snap back" to its normal position after the applied pressure is removed. These two factors are, in this case, inseparable. As in the tennis racquet, a flexible racquet will "bend" more at contact therefore storing more potential energy than a stiff racquet. However, since the contact time between the strings and the shuttle is so short, it may not have time to transmit this energy back to the
shuttle and is thus "wasted". Finally it should be noted that since no two players have the exact same movement pattern, each player's racquet requirements will be different. It is logical to assume that the player's racquet requirements will change as they improve their level of ability. The beginner usually requires a more flexible racquet than the advanced player because of a lower velocity of the racquet at contact (on strokes requiring maximal velocity). The smash of the beginning player is not as great as that of the advanced player. In this case, the flexible racquet will bend more than the stiff racquet, and at this lower velocity will allow a better transfer of momentum. As it is impractical for players to have custom racquets for particular strokes, they must choose a racquet, string type and tension that is the most appropriate for their ability. The player is then required to adjust the movement pattern slightly in order to accommodate the racquet's characteristics.

Once the above factors have been attended to and the racquet head has acquired the correct angular velocity, it is important that the maximum amount of velocity be transferred to the shuttle. The transfer of momentum is dependent on a number of variables. The mass of the racquet and shuttle will not change in the course of the stroke, thus these two factors are kept constant. However, the transfer of momentum is affected by the velocity of both the racquet head and the shuttle, this will vary from trial to trial. This is true only if the racquet is not accelerating through contact.
Another influencing factor is the racquet angle (both along the horizontal and the frontal plane) at contact. The angle of the racquet about the horizontal plane affects the trajectory (height) of the shuttle. However, the angle about the frontal plane should be perpendicular to the intended trajectory. If the racquet face is not perpendicular at contact, then rotational velocity will be added to the shuttle reducing its linear velocity as well as inducing deviation from the intended flight path. The point of contact on the strings will also affect the transfer of momentum. If contact is made at the center of percussion, then maximum transfer will occur. However, the further away from the center of percussion, the more torque will be applied to the racquet, resulting in a lower amount of velocity transferred to the shuttle.

2.3 Striking Mass

The importance of grip firmness has been the subject of long and numerous debates among certain authors. A number of authors (Gray, 1974; Lendvoy, 1982; Plagenhoef, 1970, 1971), argue that the firmness of grip is the most important factor in hitting a tennis ball. However, these reports are primarily based on Plagenhoef's observation of only two professional tennis players. Plagenhoef stated that the striking mass is dependent on grip firmness and concluded that a high racquet velocity makes it difficult to firmly hold the racquet, possibly resulting in lack of control and
sore muscles. This problem is not as pronounced in badminton because of the lightness of the badminton racquet and shuttle, as compared with the tennis racquet and ball. Since badminton stroke production is more dependent on racquet head velocity, the striking mass does not seem to be as crucial as in tennis.

More recent studies tend to refute the importance of grip firmness in the stroke production (Baker and Putnam, 1979; Grabinger, Groppel, and Campbell, 1983; Liu, 1983; Missavage, Baker, and Putnam, 1984; Plagenhoef, 1982; Van Gheluwe and Hebbelink, 1985; Watanabe, Ikeyami, and Miyashita, 1979). These authors have examined the effect of varying grip firmness and tennis ball rebound velocity off the tennis strings. The conclusions presented in the above studies support the thesis that no difference in rebound velocity is exhibited with differing firmness of the grip.

However, no measures of ball control were made in those studies. Since ball control is of prime importance in the sport of tennis and badminton, the player must control the racquet head as much as possible at the moment of impact. For this reason, grip firmness might be critical. Piscopo and Baley (1981) concluded that a firm grip will help with the control of the placement of the shuttle. As a result of the difference in mass of the equipment of the two sports, the striking mass is not as crucial a factor in the badminton overhead forehand clear as is the racquet head velocity at contact.
2.4 Comparisons of Different Performance Levels

Movement patterns exhibited by the novice or intermediate players are slightly different in the sequencing and timing when compared to those demonstrated by elite players. Since novice player might take the time to "think" about the movement sequence of the stroke, the optimal coordination of the segment movements may be adversely affected. At the beginning ability level, it is also possible that the antagonistic muscle groups may inhibit the free rotation of one segment on the next, thus negating contributions resulting from the kinetic chain link principle (Kreighbaum and Barthels 1981). A novice may have an improper sequencing of the movement; for example all segments may initiate their movement at the same time, thus not taking advantage of the momentum of the preceding segments. Another characteristic of a novice might be the absence of certain segmental movements. For example, the novice may fail to make use of medial rotation of the humerus resulting in a "pushing" action. The point and/or angle of contact may occur too early or too late, affecting the velocity and the trajectory of the shuttle. The main concern of the intermediate player, seems to be inconsistent timing of the sequence of movement. Whereas the novice sometimes demonstrates problems with sequencing the segment movements, the intermediate player may initiate movement of some segments too early, some too late, and some at the appropriate moment. Novice players may have
difficulty in the gross motor movement (movement utilizing the bigger muscles of that particular segment(s)) of the execution of the skill, while the intermediate player has often mastered the motor pattern involving the large muscle mass but experiences difficulty in the control of the finer muscle movement (such as the forearm and wrist) of the skill. The intermediate level player often cannot consistently duplicate the same (correct) movement pattern.

In summary, the importance of the appropriate racquet head velocity at contact is apparent from the factors affecting performance described in this chapter. Accuracy, which is the objective of the stroke, is primarily affected by the velocity at release and the direction in which this velocity is applied.
CHAPTER III

METHODOLOGY

This chapter includes the methods and procedures used in this study and is divided into the following sections: 1) subject selection and preparation, 2) the equipment used, 3) the cinematographical procedures, 4) the testing procedures, and finally 5) the treatment of the data.

3.1 Subject Selection and Preparation

Six volunteer male subjects were selected from badminton clubs in the area of Montreal. These subjects were divided equally into three groups corresponding to their ability level. The subjects were categorized on the basis of their playing experience and ranking as provided by the provincial and national federations. The Advanced category was selected in order to represent an efficient and consistent overhead forehand clear. The Novice category reflected a beginning yet not totally novel overhead forehand clear movement. The Intermediate category was chosen to reflect a midpoint between the two previous categories.

Advanced players; players who finished in the top 20 of a national tournament sanctioned by the Canadian Badminton Association and with extensive competition experience.
Intermediate players: with moderate competition experience, at least 10 provincial B tournaments and were at one point ranked provincially in their category (Level B).

Novice players: players having followed a badminton instruction course and having competed in no more than 3 provincial C tournament competitions in badminton or in any other racquet sport.

The subjects were between the ages of 21 to 28 years and of similar height and weight in order to minimize any confounding variables. They were asked to wear only shorts and running shoes. The following anthropometric landmarks were marked on each subject to facilitate digitization:

- One inch below the acromioclavicular joint of the right arm
- Lateral epicondyle of the right humerus
- Lateral and medial styloid process of the right wrist
- Fingers of the right hand
- Top of the racquet head

3.2 Equipment

The shuttles used for the test were six new Yonex Mavis nylon birds approved by the Quebec Badminton Federation for competition. All shuttles qualified in the official speed test as evaluated by a certified badminton referee. The average weight of the shuttles was 5 grams. The racquet used
by all subjects was a Yonex 8500 Carbonex 8 weighing 90 grams, with Vantage synthetic strings strung at a tension of 15 lbs.

3.3 Cinematographical Procedures

3.31 Filming Equipment

Cinematographical data were obtained for each subject using a 16 mm high speed Redlake Locam motion picture camera model 51-003. A 10 mm Schneider Optik Kreoznach lens was mounted on the camera. The Locam camera was loaded with Kodak 4X reversal film type (7277). The frame rate was set at 200 frames/second with a shutter factor of 1/4.8 providing for an exposure time of 1/1200 seconds. Four 1000 watt light banks were positioned in order to optimize subject illumination. A hand held Asahi spotmeter from Pentax was used to measure the luminosity of the filming area and the f/stop was set accordingly. A timing light generator produced a "flash" which was recorded on the film at a rate of one pulse every 0.01 seconds. This was used to calculate the actual filming rate of the camera. Two sets of identification numbers identified the subject and the trial during filming. A 4X4 matrix placed in the plane of motion gave a horizontal and vertical reference as well as a conversion factor to be used during the film analysis.
3.32 Camera Positioning

The camera recorded a sagittal view of the movement and was positioned 4.69 meters away from the plane of action. The filming was done indoors on a regulation badminton court in the Sir Arthur Currie Memorial Gymnasium on the McGill University campus in Montreal. The shuttles were served to the subject by an experienced badminton player. The shuttle was served upward and towards the subject in such a manner that the shuttle would land in the center of the filming area where the subject was standing if it had been allowed to hit the floor (high serve used in singles play). Although tossing the shuttle may have resulted in a more consistent shuttle placement by the researcher, it did not accurately reflect a game situation.

3.4 Testing Procedures

Subjects warmed up for a minimum of fifteen minutes to allow practice with the testing racquet. The subject then had a five minute warm up in the actual filming condition. The task consisted of hitting fifteen overhead forehand clears, seven of which were randomly recorded on film. Any trial in which the investigator deemed that the shuttle was not served accurately was repeated. The subjects stood approximately in the center of the court and were asked to take a few steps back and get into striking position as soon as the shuttle was served. This procedure brought the subject within the confines of a marked area on the floor which delimited the
filming area. If the subject had to leave this area in order to hit the shuttle, the trial was repeated. The subject aimed the shuttle at the baseline of the opposite side of the net hitting the shuttle in as direct a path as possible using the centerline as a guide. The target area was located between the two back service lines of the opponent's court.

The horizontal displacement was recorded for each successful trial as well as the angle of deviation from the straight ahead trajectory. Shuttles landing outside the sides of the court were counted as misstrials and repeated.

The temperature was recorded at different times during the testing period and did not vary significantly.

3.5 Treatment of Data

Seven trials were recorded on film. Of these, the five trials for each subject with the clearest view of the racquet/shuttle contact frames were retained for analysis. The analysis of the film was facilitated by the use of a pin-registered stop action projector, which projected the image on a mounted Summographics digitizing board. The digitizer, which is equipped with a movable cursor and is hooked on-line with the McGill University computer system (MUSIC), was used to digitize the X and Y coordinates of the body landmarks obtained from the film. These coordinates were then saved in the computer's library files.
The digitized coordinates were obtained from each frame starting ten frames prior to the first noticeable backswing movement and terminating at the end of the follow through.

Data were analyzed using a Kinematical Analysis computer program.

The coordinates were used to calculate the following criterion variables; 1) resultant velocity at contact, 2) peak velocity and contact time differences, and 3) transfer of momentum.

The present study is a one-way factorial design. A series of oneway analysis of variances (ANOVA) set at an interval of confidence of \( \alpha = .05 \), was used to compare the different levels of ability for each criterion variable. If the probability of the F ratios obtained from the ANOVA were less then \( \alpha = .05 \), a Scheffé post hoc multiple comparison test was used to identify which levels were significantly different. To further complement the study, descriptive statistics were used to analyze the following variables; 1) angle of projection after contact taken from the horizontal, and 2) the angle of deviation from a parallel trajectory to the center line. These were used to give an indication of the accuracy of each subject in performing the overhead forehand clear.
CHAPTER IV

ANALYSIS AND RESULTS

This chapter includes the results of the investigation and is divided into the following sections: 1) subject profile and characteristics, and 2) descriptive and statistical analysis of the variables.

The statistical analysis is given in order to provide a general description of the physical characteristics and performance of the subjects involved in this study.

4.1 Subject Profile and Characteristics

The individual physical measurements and number of years playing badminton are presented for each subject in Table 4.1. The number of years of experience do not accurately reflect experience or ability level. Although the novice players may have been playing badminton for a number of years, it is the quality of playing or practice they have had that differentiate the players. Novice players do not engage in regular intense badminton playing. As such, the sport is a recreational pastime and participation is occasional. The intensity of the session is usually light and recreational in nature. Intermediate players practice regularly between 2–3 times a week. These practice session are more organized and usually involve a period of stroke practice followed by actual game playing. Advanced players practice at least 3–4
times a week and log in more hours at each practice. It is also likely that the advanced players will supplement their on-court practice with additional physical exercises. The advanced players also have the benefit of continuous quality coaching.

**TABLE 4.1**

Qualitative Characteristics of Subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (yrs)</th>
<th>Height (m)</th>
<th>Weight (Kg)</th>
<th>Ranking</th>
<th>Years Competing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.11</td>
<td>1.81</td>
<td>95.0</td>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>22.63</td>
<td>1.76</td>
<td>75.2</td>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>26.79</td>
<td>1.84</td>
<td>76.0</td>
<td>B</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>28.27</td>
<td>1.70</td>
<td>75.0</td>
<td>B</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>25.31</td>
<td>1.75</td>
<td>66.7</td>
<td>A</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>26.10</td>
<td>1.83</td>
<td>88.4</td>
<td>A</td>
<td>13</td>
</tr>
</tbody>
</table>

**Mean** 25.37  1.79  79.5  A= Elite  
**S.D.**  2.17  .05  10.3  B= Intermediate  
**Range**  5.64  .14  28.3  C= Novice

From Table 4.1 it can be observed that the sample was homogeneous with respect to age and height. There was, however, some differences in the weight of the subjects. The main difference between the groups was provincial ranking.
4.2 Descriptive and Statistical Analysis of the Variables

The displacement of the shuttle was measured from the contact point (in relation to the ground) to the actual touchdown point on the opposite side of the net. The individual score as well as the means of each of the three levels of ability are presented in table 4.2.

<table>
<thead>
<tr>
<th>Category</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject Mean</td>
<td>12.20</td>
<td>12.90</td>
<td>12.58</td>
</tr>
<tr>
<td>S.d.</td>
<td>0.32</td>
<td>0.26</td>
<td>0.34</td>
</tr>
<tr>
<td>Grand Mean</td>
<td>12.19</td>
<td>12.83</td>
<td>12.53</td>
</tr>
<tr>
<td>S.d.</td>
<td>0.38</td>
<td>0.43</td>
<td>0.3</td>
</tr>
</tbody>
</table>

A one-way ANOVA was performed on the data and yielded significant differences at the p<.05 level. A Scheffé multiple means comparisons test was subsequently done and significant differences were found between the novice group and the intermediate and advanced group, with the novice group hitting the shuttle a shorter distance. No difference was found between the intermediate and advanced groups.
The subjects were required to hit the shuttle in such a fashion as to follow a parallel trajectory to the center court line. The ability to hit the shuttle in a straight line to the target should demonstrate a certain degree of accuracy. The deviation (in degrees) of the trajectory from a straight line of trajectory is summarized in Table 4.3.

**TABLE 4.3**

Mean Deviation Angle of the Shuttle

(in degrees)

<table>
<thead>
<tr>
<th>Category</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>1 2</td>
<td>3 4</td>
<td>5 6</td>
</tr>
<tr>
<td>Mean</td>
<td>2.89</td>
<td>5.07</td>
<td>3.56</td>
</tr>
<tr>
<td>S.d</td>
<td>0.47</td>
<td>2.16</td>
<td>1.37</td>
</tr>
<tr>
<td>Grand</td>
<td>4.29</td>
<td>4.67</td>
<td>3.82</td>
</tr>
<tr>
<td>Mean</td>
<td>2.76</td>
<td>2.33</td>
<td>1.63</td>
</tr>
</tbody>
</table>

No significant difference was found for the angle of deviation from a trajectory path parallel to the center line among the 3 ability levels.
The time the shuttle spent in flight was recorded from racquet contact to touchdown. These values give an indication of the height to which the shuttle was propelled; the higher the trajectory, the more time the opponent has to set up and return the shuttle. These values are tabulated and presented in Table 4.4.

\[ \text{Table 4.4} \]

Mean Flight Time of Shuttle
(in seconds)

<table>
<thead>
<tr>
<th>Category</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>1 2</td>
<td>3 4</td>
<td>5 6</td>
</tr>
<tr>
<td>Mean</td>
<td>2.20</td>
<td>1.98</td>
<td>1.77</td>
</tr>
<tr>
<td>S.d.</td>
<td>0.19</td>
<td>0.12</td>
<td>0.08</td>
</tr>
</tbody>
</table>


The oneway ANOVA yielded significant differences for the mean flight time of the shuttle. A Scheffé multiple means comparison test indicated that the shuttle hit by the novice group remained airborne for a longer period of time than for the other two groups. No significant difference was found between the intermediate and advanced groups; however, there was an apparent trend across the three levels.
The mean values for the velocity of the shuttle after contact obtained from the digitized data are presented in Table 4.5.

**TABLE 4.5**

Mean Velocity of Shuttle After Contact
(in meters/sec.)

<table>
<thead>
<tr>
<th>Category</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Mean</td>
<td>50.67</td>
<td>42.80</td>
<td>54.86</td>
</tr>
<tr>
<td>S.d.</td>
<td>4.78</td>
<td>6.83</td>
<td>8.44</td>
</tr>
<tr>
<td>Grand</td>
<td>46.74</td>
<td>48.91</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.d.</td>
<td>7.08</td>
<td>10.89</td>
<td></td>
</tr>
</tbody>
</table>

No significant difference was found in post-impact shuttle velocity after contact among the three groups.
The angle at which the shuttle was projected also gives an indication of the height of the shuttle's trajectory. As indicated earlier, the higher the trajectory of the shuttle the more time is given to the opponent to prepare for a return. The mean angle of departure of the shuttle is given in Table 4.6. It should be noted that the departure angle values are not the sole factor contributing to the height of the trajectory. The velocity of the shuttle after contact also affects the trajectory.

**TABLE 4.6**

Mean Angle of Projection of the Shuttle After Contact

(in degrees)

<table>
<thead>
<tr>
<th>Category</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Mean</td>
<td>32.10</td>
<td>33.30</td>
<td>25.10</td>
</tr>
<tr>
<td>S.d.</td>
<td>3.72</td>
<td>2.64</td>
<td>2.11</td>
</tr>
</tbody>
</table>

Grand Mean 32.70 25.90 25.30

Mean S.d. 3.28 1.83 2.32

A oneway ANOVA performed on the shuttle angle of projection data identified significant differences amongst the groups. The Scheffé multiple means comparisons test revealed that the novice group had significantly greater projection angles than the other two groups. No difference was found between the intermediate and advanced groups.
The resultant velocities of the racquet head at contact are given in table 4.7.

**TABLE 4.7**

Mean Racquet Head Resultant Velocity at Contact

(in meters/sec.)

<table>
<thead>
<tr>
<th>Category</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Mean</td>
<td>99.50</td>
<td>81.61</td>
<td>102.41</td>
</tr>
<tr>
<td>S.d.</td>
<td>10.41</td>
<td>14.15</td>
<td>10.67</td>
</tr>
<tr>
<td>Grand</td>
<td>90.55</td>
<td></td>
<td>87.68</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>20.87</td>
</tr>
</tbody>
</table>

No significant differences were found among the 3 groups for the racquet velocity at contact. However, a distinct trend is apparent reflecting a decrease in racquet head velocity as experience and proficiency increased.
The time difference between peak velocity and contact was calculated and yielded the following results presented in Table 4.8. Note that all peak velocity values occurred before contact.

### Table 4.8

**Peak Velocity and Contact Time Differences**

<table>
<thead>
<tr>
<th>Category</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Mean</td>
<td>.0074</td>
<td>.0050</td>
<td>.0040</td>
</tr>
<tr>
<td>S.d.</td>
<td>.0060</td>
<td>.0070</td>
<td>.0033</td>
</tr>
<tr>
<td>Grand</td>
<td>.0062</td>
<td></td>
<td>.0074</td>
</tr>
<tr>
<td>Mean</td>
<td>.0062</td>
<td>.0073</td>
<td>.0059</td>
</tr>
</tbody>
</table>

* all peak velocity values occurred prior to contact

Results of the oneway ANOVA indicate that there were no significant differences among the groups. However a trend existed indicating that the less experienced players reached a peak velocity closer to contact.
CHAPTER V
DISCUSSION

The purpose of this investigation was to determine, the difference in selected shuttle-racquet head interaction variables for players of different ability levels. These variables included; 1) resultant velocity of the racquet head at contact, and 2) time between peak velocity and contact. This chapter provides a discussion of the results obtained from the investigation and is divided into the following sections; 1) film data, 2) hypotheses and results, 3) discussion of results, and 4) application of results.

5.1 FILM DATA

The validity of the recorded film data was established by comparing the data in this study with those reported in the literature for other post-impact shuttle velocity investigations. Kinematic data for the overhead forehand clear are scarce, so it was necessary to refer to research that was done on the forehand smash. It must be noted that the nature of the smash is that of a more powerful stroke than the clear. The object of the smash, to a certain extent, is to attain maximum velocity. This is not the case for the clear. All of the following reported values were converted to meters/second in order to facilitate comparisons.
Adrian and Enberg (1971) reported a single velocity value of 56 meters/seconds. While Gowitzke and Waddell (1979) obtained linear post-impact shuttle velocity values for elite players ranging from 55.7 meters/seconds to 96.0 meters/seconds with a reported mean of 74.9 meters/seconds. The values obtained in this investigation ranged from 38.62 meters/seconds to 54.86 meters/seconds with a mean of 45.52 meters/seconds. In light of the values reported for the smash, and considering that those were obtained for the most part from elite badminton players, the present values reported fall within an acceptable range.

As mentioned in the delimitations, all the subjects used the same racquet and nylon shuttles. It should be noted at this point that the advanced players are in the habit of using shuttles made out of feather as opposed to synthetic shuttles which were used in this study. Feather shuttles have a more consistent flight path as well as less deformity at contact on high velocity strokes. Although a sufficient amount of time was spent in the warm-up allowing the subject to become accustomed to the equipment, the advanced subjects were not as familiar with the (slightly inferior) nylon shuttles.
5.2 HYPOTHESES AND RESULTS

In this section, each hypothesis is reiterated and followed by the results obtained in the investigation, as well as a discussion pertinent to the hypothesis.

5.2.1 Hypothesis one The racquet resultant velocities at contact will be different for all three skill groups.

There was no significant difference in the resultant racquet head velocity at contact among the three ability levels. There was, however, a trend as indicated by the decrease in racquet head velocity as the player ability increased. When examining the standard deviation of the means, it was found that the advanced group had the smallest standard deviation value (9.28 meters/seconds) reflecting a more consistent stroke. The intermediate group obtained the highest standard deviation score (20.22 meters/seconds).

When comparing the racquet head velocity across the different ability levels, it must be emphasized that the objective of the overhead forehand clear is accuracy, whereas the objective of the smash is to impart the greatest amount of velocity possible. The clear only requires a portion of maximum velocity in order to travel the required distance to the opposite baseline. It is probable that the advanced player is more accurate and therefore a lower racquet head velocity can be used to clear the shuttle. The objective of the overhead forehand clear is to be able to place the
shuttle in a selected area on the court beyond the opponent's reach. Control of the racquet head velocity in the appropriate direction to transfer this velocity to the shuttle in the most efficient manner possible is essential for the success of the stroke.

The fact that no significant differences exist among the three groups for racquet head velocity at contact indicates that for the overhead forehand clear, the subjects of all three levels of ability were capable of generating the required racquet head velocity. A comparison of these data with those of the smash indicates that the overhead forehand clear does not require maximum velocity of the racquet for optimal success.

5.2.2 Hypothesis two There will be significant differences among the three levels of ability in the time between peak racquet head velocity and shuttle contact.

Theoretically an effective swing is characterized by a smaller difference between peak racquet velocity and contact time. This ensures that the racquet head is moving at its maximal velocity when contact with the shuttle is made. If maximal velocity is reached before or after contact, the player is not making efficient use of the momentum developed during the swing. When maximum velocity coincides with racquet-shuttle contact, effective stroke production is accomplished. The second hypothesis was based on this principle.
Horizontal and vertical velocity values were computed in order to obtain the resultant velocity of the racquet head. In the present hypothesis, only the positive values (upward (Y) and forward (X)) were computed for the analysis. These two positive values represented the desired direction of the racquet head in the execution phase of the stroke.

The time difference between peak velocity and contact among the three ability groups resulted in no significant differences. There was however a trend reflecting an increase in the time difference as ability increased, with advanced players having the greatest time difference. This may have occurred as a result of the unfamiliarity with the slightly different flight path of the nylon shuttle.

When examining the consistency values across the three levels of ability for this variable, the trend for the standard deviation values indicated that variance decreased as the ability level increased. Although the novice group obtained a lower peak velocity and contact time difference, the advanced group had a smaller standard deviation (0.0059 meters/seconds) than that of the novice group (0.0062 meters/seconds) which in turn had a lower standard deviation than the intermediate group (0.0073 meters/seconds). This is indicative of the more consistent performance of the advanced players followed by the novice group. The intermediate group was the least consistent of all.
5.2.3 Hypothesis three There will be no significant differences among the three levels of ability in the angle of projection of the shuttle after contact.

In order for a clear to be effective, the shuttle must travel as deep as possible, as well as high enough to prevent the opponent from intercepting the projectile before it reaches the back of the court. However, it was noted in this study, that the novice player had a significantly smaller shuttle displacement than the other two groups. In conjunction with the racquet head velocity, the other major factor affecting the outcome of the shuttle's trajectory is the angle of projection of the shuttle after contact. As has already been established in this study, the racquet head velocity for the three levels of ability is similar. However, the angle of projection obtained by the novice group (32.70 degrees) is significantly higher that those obtained by the intermediate (25.90 degrees) and advanced (25.30 degrees) players.

Such results suggest that the novice player executed more of a defensive type clear, while the intermediate and advanced players executed more of an offensive clear.

5.3 Discussion of results

Shuttle post-impact velocity yielded no significance difference among the three ability levels, which is consistent with the non significant values obtained for the
racquet head velocity at contact. These post-impact velocity values were respectively, 46.74 meters/seconds for the novice group, 48.91 meters/seconds for the intermediate group, and 40.91 meters/seconds for the advanced players.

Significant differences between groups were obtained for shuttle displacement, shuttle angle of projection, and shuttle flight time. It was found that the subjects in the novice group had a significantly smaller horizontal shuttle displacement value as measured from the contact point to the touchdown point of the shuttle on the opposite side of the net. Shuttle displacement for the novice group was 12.19 meters, as compared to 12.83 meters and 12.53 meters for the intermediate and advanced groups respectively. No significant difference for horizontal shuttle displacement was found between the intermediate and advanced players.

The above differences in performances amongst the groups may be attributed to the differences in the angle at which the shuttle is projected by the racquet head after contact. Data obtained from the film exhibited significant differences in the angle of projection of the shuttle between the novice group (32.70 degrees) and the other two groups (intermediate (25.90 degrees) and advanced group (25.30 degrees)). No significant difference was found between the latter two groups. Examining the standard deviation, the intermediate subjects had the smallest value (1.83 degrees) of the three groups indicating a higher degree of consistency in the angle of projection of the shuttle. The advanced group did obtain a
smaller deviation (2.32 degrees) than the novice group (3.28 degrees), indicating that the intermediate and advanced groups were more consistent than the novice group for this variable.

Time measured from when the racquet contacted the shuttle to touchdown revealed that the shuttle spent significantly more time in flight (2.09 seconds), when cleared by the novice group than either the intermediate group (1.85 seconds) or the advanced group (1.76 seconds). These factors indicate that the subjects of the novice group hit the shuttle with a highest trajectory. This had several effects on the shuttle: a higher peak vertical displacement, a longer flight time, and a smaller horizontal displacement than that of either the intermediate or advanced groups. The objective of the overhead forehand stroke, from a strategical point of view, is to clear the opponent and spend as little time, in the air as possible. The longer flight time, as well as the higher vertical displacement, allows more time for opponents to get in the proper position and set up their return. In addition, if the shuttle is not "deep" enough into the backcourt, the opponent will have more strategic options as well as a better probability of success. On the other hand, the intermediate and advanced players projected the shuttle at a much lower angle. This resulted in a shorter flight time as well as a longer horizontal shuttle displacement allowing less time for the opponent to set up. In addition, it forces the opponent to "hurry" the movement which could affect the
intended return stroke. Although there was no significant difference between the intermediate and advanced groups, the latter group did obtain slightly lower scores than the former for shuttle flight time.

The decrease in performance variance as the ability level increased was reflected by a decrease in standard deviation for the performance variables. Advanced subjects obtained a standard deviation score for mean flight time of the shuttle of (0.11 seconds), followed by the intermediate group (0.14 seconds), and finally the novice group (0.19 seconds) reflecting increased consistency in the time of flight with increased ability.

In order to obtain a measure of accuracy, the subjects were asked to hit the shuttle so that the trajectory would be parallel to the center line. The amount of deviation from the parallel path was recorded for each trial and yielded no significant difference among groups. This suggests a similar degree of lateral accuracy by all subjects. However, when examining the standard deviation values, it was found that the advanced group had a smaller deviation value (1.63 degrees) than the intermediate group (2.33 degrees) which in turn had a smaller value than the novice group (2.76 degrees). This suggests that although a similar degree of accuracy is present among the three groups, there is an increase in the consistency of shuttle placement (hitting in a straight line) with ability.
5.4 Application of the results

There are several implications regarding the instruction of the overhead forehand clear based on the results of this investigation. It would appear that there is not much difference between the intermediate and advanced groups based on the variables in the present investigation. The fact that no significant difference existed among the three groups with respect to the racquet head velocity at contact is of particular interest. These findings suggest that the novice and intermediate groups are indeed capable of generating an adequate amount of racquet head velocity at contact for the overhead forehand clear. Thus, other factors must be held accountable for the different outcome of each group.

Differences existed, more specifically between the novice group and the intermediate and advanced groups. The principal difference was the angle of projection of the shuttle after contact, resulting in an increased flight time for the novice group. The angle of projection is dependent upon the oncoming trajectory of the shuttle prior to contact, but it is mainly influenced by the racquet head trajectory and angle at contact. The racquet angle is primarily controlled by the hand/forearm interaction. It is possible that novice players were slightly late in initializing the striking movement which resulted in a greater angle of departure of the shuttle after contact. This is reflected by the observation that the novice subjects reaching peak velocity after contact more
often than the other two groups. From a coaching point of view, it is imperative that the instructor stresses early preparation of the stroke in order to reach the appropriate racquet head velocity at contact, as well as the appropriate angle of projection of the shuttle after contact. For novice players, this would mean decreasing the angle of projection of the shuttle so that the trajectory of the shuttle is less vertical. Finally, the coach should emphasize the importance of consistency in the stroke.
CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to examine differences in selected kinematic variables among male badminton players of three varying ability levels executing the overhead forehand clear. It was hypothesized that no differences would be found in racquet head resultant velocity at contact, time difference between peak velocity and contact time, and angle of projection of the shuttle after contact.

The following chapter provides a summary and conclusions of the information obtained in this investigation and is divided into the following sections: 1) findings, 2) conclusions, 3) implementation of the results, and 4) recommendations for further research.

6.1 Findings

The following cinematographical data obtained and analyzed in this investigation provided the following information;

1. Flight time of the shuttle from contact to touchdown decreased with ability.

2. Angle of projection of the shuttle after contact decreased with ability.

3. Racquet head resultant velocity at contact decreased with ability.
4. The horizontal displacement of the shuttle from contact to touchdown point was significantly lower for the novice than for the intermediate or advanced groups.

5. No significant difference was found among the three groups with respect to the mean shuttle velocity after contact.

6. No significant difference was found among the three groups with respect to the mean angle of deviation as measured from the center line.

7. No significant difference was found among the three groups with respect to time difference between peak racquet head velocity and shuttle contact time.

8. Standard deviation was examined in order to establish the consistency of the groups. The smaller the value, the more it reflected consistency. The following calculated standard deviations of two performance and related cinematographical variables decreased with increased ability:

   (1) No significant difference was found between the three groups in regards to the mean angle of deviation as measured from the center line.

   (2) The novice group had a significantly higher discrepancy between the trials for the flight time of the shuttle from contact to touchdown point than the two other groups.
9. The following calculated standard deviations of performance and related cinematographical variables indicated a smaller variability for the advanced group than for either the intermediate or novice groups:

(1) Horizontal shuttle displacement after contact.
(2) Racquet head resultant velocity at contact.
(3) Peak velocity and contact time difference.

10. Mean angle of projection exhibited a smaller variability in the intermediate group than for either the novice or advanced groups.

6.2 Conclusions

Based upon the findings of this investigation and within the limitations, delimitations and assumptions of this study, the following conclusions appear justified.

1. The racquet head resultant velocity at contact is not significantly different for the varying ability levels, and therefore should not be considered a critical performance variable for this sample.

2. The time difference between peak velocity and contact time values are not significantly different among the three ability levels. While it may affect performance, such differences are not a critical element in the badminton overhead forehand clear.
6.3 Implications of the Results

There are several implications regarding the instruction of a striking skill like the overhead forehand clear. First of all, it would appear that there is not a great deal of difference in the velocity variables at contact of the overhead forehand clear among the three levels of ability when receiving the shuttle in a stationary position. It then appears that maximal racquet head velocity is not a factor contributing to the difference in the performance of the overhead forehand clear among the three groups. This result is of importance as it indicates that coaches would not need to spend an inordinate amount of time trying to increase the racquet head velocity at contact of the novice, but rather should concentrate their efforts on other factors such as the angle of projection of the shuttle. The preferable method would be to emphasize controlling the amount of racquet head velocity in conjunction with the angle of projection of the shuttle in order to produce a clear that just passes the opponent as well as having the necessary depth. It must be noted that although no instructions were given to the subjects regarding the type of clear (i.e. offensive or defensive), the novice player did show a propensity towards the defensive clear, while the flight path of the shuttle of the other two groups resembled that of the offensive clear. The novice must attempt to project the shuttle at a lower angle, thus decreasing the flight time of the shuttle. A
decreased flight time will result in less time for the opponent to set up for a retaliatory stroke return. Furthermore it was found that the novice group had a smaller horizontal shuttle displacement. This was the result of a high angle of projection of the shuttle after contact. In order to lower the trajectory, the racquet angle must be increased from the horizontal. To accomplish this, the coach or teacher must emphasize an early preparation of the stroke execution and an earlier movement initiation that would allow the racquet head to be in the proper position without having to change the arm position at contact, only the racquet head.

The intermediate group yielded surprisingly similar results to the advanced group. Although differences were not significant, the advanced group usually obtained slightly better results in the different variables. More discriminating variables are warranted to determine the differences between these two groups.

6.4 Recommendation for Further Research

This study was designed to identify the interaction of selected kinematic variables as they apply to the interaction between the shuttle and the racquet head in the striking performance of the overhead forehand clear of male badminton players of three different ability levels.

The findings of this study have suggested several areas of improvement for further research. Future investigation
should; (1) include the use of more subjects in each of the ability levels, (2) have the subject in movement (starting from the center of the court) before striking the shuttle, (3) breakdown the percentage of contribution to the final velocity derived from each body part (segment) involved, including the trunk and legs, (4) use three-dimensional cinematography and analysis in order to investigate forearm pronation and humeral medial rotation, (5) investigate beginning players with very little racquet sport experience, (6) identify the effect of striking mass at contact, and (7) compare velocity and acceleration curves of the complete movement in order to denote movement replication consistency. This would indicate the ability of the player to accurately reproduce a movement, thus enhancing the accuracy of the stroke.
LIST OF REFERENCES


Shambes, G.M., and Campbell, S.K., (1973) Inherent Movements in Man, Kinesiology III, Published by the Committee on Kinesiology of the Physical Education Division, AAHPER, Washington, pp. 58.


Appendix A

Informed Consent Form

Name: (print) ____________________________

The study you will participate in is designed to compare certain characteristics of the movement pattern of the Badminton Overhead Forehand Clear of players of different ability levels. You will be asked to execute fifteen (15) overhead clears, seven (7) of which will be recorded on high speed film, this will allow me to analyze your striking technique and compare it to Badminton players of different ability levels.

You may discontinue your participation in the study at any time, simply by asking to do so. That is, you can refuse to complete one or all the trials, can ask to have your filmed trials destroyed before analysis, or you can have the results withdrawn from the comparisons.

It will be possible for you to see the filmed recording of your trials, and to receive an analysis of your striking technique once the study is completed. AFTER THE STUDY IS COMPLETED, THE FILMED RECORDINGS OF YOUR TRIALS WILL BE MAINTAINED IN THE FILM LIBRARY OF THE BIOMECHANICS LABORATORY OF THE MCGILL UNIVERSITY DEPARTMENT OF PHYSICAL EDUCATION, TO BE USED FOR RESEARCH AND INSTRUCTIONAL PURPOSES. (IF YOU DO NOT WANT YOUR TRIALS TO BE USED FOR PURPOSES OTHER THAN THE PRESENT STUDY, DRAW A LINE THROUGH ALL CAPITALIZED LINES).

By signing below, you are indicating that you consent to participate in the study, that you have read and understood this informed consent form, and that all your questions concerning the study have been answered, and that the researchers and University are not responsible for any injuries that might occur in the course of this filming session.

Signature: ____________________________

Date: _________________________________

Address: _____________________________

Telephone: __________________________
Appendix B

Cinematographic Setup

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CAMERA

LIGHTS
SERVER
SUBJECT
VALID TARGET AREA

67
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