THE EFFECT OF LEARNING AND PRACTICING THE MATURE
OVERARM THROWING PATTERN UPON THE SUBSEQUENT ACQUISITION
OF THE CIRCULAR OVERARM TENNIS
SERVE

by

Julie Ann Wood

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A Thesis

Approved:

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Brenda Lichtman, Chairman

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Coralie A. Emmons

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Mary Ella Montague

Approved:

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Suler E. Ryan
Dean of the College of Education

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by

Julie Ann Wood

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ABSTRACT

Wood, Julie Ann, <u>The Effect of Learning and Practicing the Mature Overarm Throwing Pattern Upon the Subsequent Acquisition of the Circular Overarm Tennis Serve</u>, Master of Arts (Physical Education), May, 1977, Sam Houston State University, Huntsville, Texas.

The purpose of this study was to determine the effects of learning and practicing the overarm throwing pattern upon the subsequent acquisition of the overarm tennis serve. Ss were pre-tested for throwing speed and accuracy, and randomly assigned to the experimental or control group. The pre-test scores were used as covariates. The control group (n=23) practiced the serve for 4 weeks. The experimental group (n=25) practiced the overarm throwing pattern for 1 week and the serve for 3 weeks. Each group practiced 4 days/week, 30 minutes/day. Ss were tested by Hewitt's Tennis Achievement Test and the Wisconsin Wall Test for Serve, for serving accuracy, speed, and a combined score of speed and accuracy. The control group was tested after completing weeks 1, 3 and 4, while the experimental group was tested after completing weeks 2 and 4, of the treatment period. A series of ANCOVA's were computed to analyze the dependent variables of accuracy, speed, and a combined score from both serving tests for each testing session. No significant differences were found between groups at testing period 1 or testing period 2. Significance was found when comparing testing period 3 of the control group with testing period 2 of the experimental group, on Hewitt-accuracy and

Hewitt-combined. The control group had performed significantly better on these 2 dependent variables.

Approved:

Brenda Lichtman
Supervising Professor

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Mr. and Mrs. Paul L. Wood
for their devoted support, encouragement,
and faith which enabled me to
continue my college education.

also

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Chapter I

INTRODUCTION

With the emergence of tennis as one of the major
recreational pastimes of many people from all walks of life,
it is becoming increasingly apparent that a need exists for
new instructional techniques to hasten the learning process.
These instructional techniques must be made available to
all instructional personnel, including the tennis professional,
the physical educator, and the recreation director. In order
to provide for adequate skill instruction, new techniques
are needed which will increase the amount of enjoyment to
be found in the game of tennis.

Many times, however, great frustration is experienced
on the tennis courts, especially at the beginning level of
play. The forehand drive evolves into a high, deep lob. The
backhand drive resembles a quickly executed, downward slapping
motion rather than a smooth, continuous stroke. The serve,
if it may be called that at the beginning level, travels
in all directions with apparently no guidance or control
what so ever.

The focus of this paper is centered around the latter
problem, serving. From previous experience and observation
of beginning level tennis players, the investigator has noted
that there are many problems involved in learning the tennis
serve. Furthermore, this investigator has also noted that

this trend appears to be found more in females than in males.
In actuality however, the serve is less difficult than other
strokes because the individual has control of all the variables.
According to Pasarell,

> "The service motion is, in many
> ways, less difficult to master
> than any of the other strokes
> in tennis, which, after all, de-
> mand that you move to and then
> hit a ball put into play by
> someone other than yourself.
> You control all the variables
> when serving. Yet many players
> make the serve the most diffi-
> cult and frustrating of all the
> strokes," (22:33).

There are many possible reasons for ineffective and
inaccurate serves: a poor ball toss, uncoordinated movements,
ineffectual body rotation, lack of full body extension at
contact, little or no wrist snap, no follow-through, incon-
sistent movement pattern, hitting down on the ball rather
than up and through (4), inadequate shoulder rotation, over-
hitting, and early forward motion (23).

Pasarell considers three problems as most important
in causing an ineffective serve (22:33-35). The first is
dropping the elbow on the wind-up or backswing. This dis-
rupts the rhythm of the entire stroke. Also, the position
of the racket head is altered, making it more difficult to
get on top of the ball with the racket strings. This in
turn contributes to less depth and control.

The second problem is not having the racket cocked
behind the body. This disrupts the tempo of the stroke and
also puts unnecessary strain on the shoulder and elbow.

The final problem is facing the net too soon on the forward swing. Much power is lost by this practice. The shoulders should not be opened until contact has been made with the ball.

It is the common consensus among many authorities that the overarm throwing pattern is essentially the same as the overarm serving pattern in tennis (3,4,5,20,21,22 and 23). Pasarell believes that, ". . . anyone with the ability to throw a ball halfway decently should be able to serve well in tennis," (22:33). No research has been found by the investigator to indicate or support this belief. However, after close scrutiny of the above mentioned errors in serving, it is noted that most of these are also characteristic errors found in the overarm throwing pattern. Consequently, what appears to be a collection of many different, individual errors, may in reality, be related to one overall problem -- an immature overarm throwing pattern.

Since the overarm throwing pattern is one of the major motor patterns learned as a child (6,10,32 and 33), it would seem logical to believe that if an individual has an inadequate or undeveloped overarm throwing pattern, then that same individual might also have an inadequate overarm serving pattern.

Tackling this problem of the tennis serve, should be of interest to many individuals, especially physical educators. It is of great concern that solutions be found which will enhance the teaching process and decrease the learning time

involved in acquiring a new skill.

The ability to serve effectively and accurately is of great importance. Each point is begun by putting the ball in play with a serve. If a player cannot get the ball into the correct service court with the serve, actual play cannot be continued, double faults will occur, and eventually the game will be lost.

The sooner an individual can be put in the game situation and the work on strategy be introduced, the more enjoyment the learner will find in the game of tennis. The overall goal of combining all of the basic strokes to form a fairly solid basis for the player to draw from when playing, will become apparent to the learner more quickly.

Definition of Terms

1. Flexion -- A movement occurring at a joint that decreases the angle at the joint.

2. Extension -- A movement occurring at a joint that increases the angle of the joint.

3. Adduction -- A movement occurring at a joint which permits a body segment to move toward the midline of the body.

4. Horizontal Plane -- The plane which divides the body into upper and lower halves.

5. Horizontal Adduction -- A movement occurring at a joint which permits a body segment to move toward the midline of the body with the movement occurring in the horizontal plane.

6. <u>Inward Rotation</u> -- A movement occurring at a joint which permits a body segment to move or rotate around its longitudinal axis toward the midline of the body.

7. <u>Antero-posterior Plane</u> -- Same as the sagittal plane which divides the body into right and left halves.

8. <u>Oblique Plane</u> -- A plane which is located between any of the fundamental planes (sagittal, frontal, or horizontal) measured in terms of degrees of deviation from said plane.

9. <u>Sagittal Plane</u> -- Same as the antero-posterior plane which divides the body into left and right halves.

10. <u>Block Rotation</u> -- Rotation of the trunk is characterized by the pelvis and spine rotating as one unit about the long axis of the body.

11. <u>Overarm Throwing Pattern</u> -- According to Dauer,

> ". . . The hand is brought back so the hand is well behind the shoulder at about that height. The left side of the body is turned in the direction of the throw, and the left arm is raised and in front of the body. The weight is on the back (right) foot with the left foot advanced with the toe touching the ground. The arm comes forward, and the ball is thrown with a downward snap of the wrist. The weight of the body is brought forward into the throw, with the weight shifting to the front foot. There should be good follow-through," (7:444).

This movement is a unilateral overarm motion. It is distinguished from other movement patterns by the elbow swinging forward ahead of the forearm and the forearm extending just prior to the release of the ball.

12.   Immature Overarm Throwing Pattern -- Characteristic
of an individual who has not yet reached Stage VII of Leme's
10 developmental types (18:31-33).   In Stage VI or below,
the individual is characterized as facing the intended tar-
get with no forward stride taken with the left foot (Stages
I - VI).   There is very little if any weight transfer, and
if it is present, it is from the left (rear) foot forward
to the right (front) foot (Stage V).   There is either exten-
sion and flexion of the spine (Stage II) or spinal rotation
with no pelvic rotation present (Stages III - VI).   Horizon-
tal adduction of the humerus is not present in the forward
swing, nor is full arm extension.   The arm does not cross
the midline of the body on the follow-through, and thus the
follow-through is considerably shortened.   There will be
little, if any, preparatory movements and the entire movement
will appear jerky rather than smooth and continuous.

13.   Mature Overarm Throwing Pattern -- Characteristic
of an individual who has mastered Types VII, VIII, IX, or X
of Leme's 10 developmental types (18:31-33).   The feet may
be front facing, but usually they will be parallel to the
target with the side facing the target.   There will be a
stride taken with the left foot.   The body will either rotate
right with the reverse arm swing (Types VII and VIII) or will
already be right facing (Types IX and X).   The weight transfer
is back to the right foot and then forward onto the left foot.
There may be block rotation of the trunk (Types VII and IX)
or sequential pelvic then spinal rotation of the trunk (Types

VIII and X). The reverse arm movement will be in the horizontal or right oblique plane with a full arm reverse in Types IX and X. Horizontal adduction of the humerus will occur in Types VII and VIII during the forward arm movement. In Types IX and X there will be a sideways forward swing with inward rotation of the humerus and full extension of the arm. On the follow-through the arm will cross the midline of the body and the body will rotate to the left after the release.

14. <u>Circular Overarm Serving Pattern</u> -- The racket head follows a circular path throughout the entire serving motion (23:47-88). The racket movement begins in front of the body at approximately waist level. The racket procedes downward, pointing toward the ground as it moves past the right leg. It continues up behind the body where at shoulder height, the racket is pointing directly backward, with the racket face perpendicular to the ground. The racket continues upward from behind the back on into the forward movement to contact the ball. After contact with the ball, the circular motion is completed with the racket moving down and across the body to the left during the follow-through.

15. <u>Immature Overarm Serving Pattern</u> -- The movement takes place in the antero-posterior plane with the body facing the object to be struck. This enables the server to see the object (ball) throughout the entire motion (32:143-172). The racket arm does not follow a circular movement pattern, but follows a vertical line straight up above the head. There

is little, if any, follow-through. There may or may not be opposition of arm and leg movements depending upon the stage of development. The movement will appear jerky rather than being smooth and continuous.

16. Mature Overarm Serving Pattern -- The movement will occur in the antero-posterior plane with a characteristic mature opposite arm-leg pattern. There is a marked enlargement of the rotatory movements of the hips and trunk with hyperextension of the spine (32:143-172). Preparatory movements will be present allowing for a full backswing preceding the forward swing, continuing into a full follow-through. There will be a continuous flow of movement.

Statement of the Problem

The purpose of this study was to determine the effect of learning and practicing the mature overarm throwing pattern upon the subsequent acquisition of the circular overarm tennis serve as measured by speed, accuracy, and a combined score of both speed and accuracy.

Hypotheses

1. Individuals who learned and practiced the mature overarm throwing pattern before learning the circular overarm tennis serve, will show, when compared to the control group, which did not receive instruction and practice in the overarm throw,

      a. greater accuracy of serve placement as measured by:

          1. Hewitt's Tennis Achievement Test, and

2. the Wisconsin Wall Test for Serve.

b. greater accuracy of serve placement when evaluating:

1. performance at testing period 1,

2. performance at testing period 2, and

3. performance at testing period 2 (throw group) vs. testing period 3 (control group).

2. Individuals who learned and practiced the mature overarm throwing pattern before learning the circular over-arm tennis serve, will show, when compared to the control group, which did not receive instruction and practice in the overarm throw,

a. greater speed of serve as measured by:

1. Hewitt's Tennis Achievement Test, and

2. the Wisconsin Wall Test for Serve.

b. greater speed of serve when evaluating:

1. performance at testing period 1,

2. performance at testing period 2, and

3. performance at testing period 2 (throw group) vs. testing period 3 (control group).

3. Individuals who learned and practiced the mature overarm throwing pattern before learning the circular overarm tennis serve, will show, when compared to the control group, which did not receive instruction and practice in the overarm throw,

a. a greater combined score of speed and accuracy as measured by:

1. Hewitt's Tennis Achievement Test, and

2. the Wisconsin Wall Test for Serve.

b. a greater combined score of speed and accuracy when evaluating:

1. performance at testing period 1,

2. performance at testing period 2, and

3. performance at testing period 2 (throw group) vs. testing period 3 (control group).

Delimitations

The delimitations of this study were as follows:

1. The scope of this study was narrowed to include only the overarm throwing pattern as it related to the circular overarm tennis serve.

2. Forty-eight female volunteers who both threw and served right-handed participated in this study as subjects. Each subject had little or no knowledge of the tennis serve. Each subject was enrolled in a beginning physical education activity class offered at Sam Houston State University during the Spring semester of 1977.

3. The Wisconsin Throw Test measuring both accuracy and velocity was used to evaluate the performance of the subjects on the overarm throw, prior to the beginning of the study.

4. The Wisconsin Wall Test for Serve was used to measure the performance of the subjects on the placement and speed of the tennis serve, through the force and height of the ball.

5. To substantiate the above findings, Hewitt's Tennis Achievement Test for service placement and speed of service was used to measure the performance of the subjects on the tennis serve.

6. The subjects in the control group who learned only the overarm tennis serve had four weeks of practice on the serve. The subjects learning the overarm throwing pattern prior to learning the overarm tennis serve were allowed one week of practice on the throwing pattern and only three weeks of practice on the serve. The first testing session was conducted after both groups had received one week of instruction and practice on the serve. The second testing session was held after both groups had received three weeks of practice on the serve. The third testing period was administered only to the control group after four weeks of practice on the serve.

Limitations

The limitations of this study were as follows:

1. Ball spin was not used as a factor in determining serving ability because of the extreme difficulty in accurately measuring the amount of spin put on a served ball.

2. This study did not completely control for the experiences of the subjects between classes. However, the subjects were instructed not to participate in activities involving the overarm throwing pattern and the overarm serving pattern during the study.

3.   During the practice sessions, both groups practiced for the same amount of time each day.   However, a restriction was not established to control the exact number of throws or serves taken by each subject during a practice session.

4.   The temperature of the ball, which influences the height of rebound, was not controlled for in this study.

Chapter II

REVIEW OF RELATED LITERATURE

This chapter is subdivided into four general areas for reviewing the related literature: (1) Overarm Throwing Pattern, (2) Overarm Serving Pattern, (3) Pattern Comparisons, and (4) Serving Tests.

Overarm Throwing Pattern

The overarm throwing pattern is regarded as a unilateral motion. The forearm should follow the elbow as it swings forward and just prior to the release of the ball, the forearm will extend. This general description incompasses both beginning and advanced levels of throwing ability (32: 71-93).

The overarm throwing pattern is one of the basic motor patterns learned as a child. Between the ages of two and four, there appears to be a great deal of variance found in the throwing patterns of children in this age group. During this period, there is a constant searching for a method which will make throwing more efficient.

At approximately six years of age, most boys appear to achieve a mature throwing pattern characterized by a shift in body weight and opposition of leg and arm movements. Girls at this age usually have mastered a transfer of weight, but the tendency is still present to step forward with the foot which is on the same side as the throwing arm (6).

How throwing behavior actually becomes initiated in a child as an infant is still in the realms of speculation. Cratty summarizes two common beliefs which characterize the opinions of present day researchers. One commonly held belief is the role played by heredity. It is postulated that throwing behavior is inherited from early ancestors, being derived from a natural protective mechanism. Other researchers contend that an infant's initial attempt to throw an object is merely an accidental coincidence. ". . . the infant suddenly and accidently swings his hand while holding an object that is dislodged by the resultant centrifugal force," (6:204).

Whatever may cause a child to throw an object for the first time is not a matter of concern in this study. However, the overarm pattern is of concern, and basically, the trend in development appears to be the same in all individuals. This trend progresses from a stiff, jerky movement to a smooth, continuous, flowing movement of the arms, legs and trunk which produces a well coordinated, mature throwing pattern. This mature pattern is developed only after years of experimentation and practice.

Wild conducted a study which resulted in the defining of four distinct types of throws related to the age of the individual (33). Espenschade and Eckert, and Wickstrom have reported results which substantiate Wild's study (10 and 32).

The first type of throw occurs between the ages of two and three. It is the most immature pattern characterized almost exclusively by arm movement. There is some body move-

ment but no body rotation, with all movement occurring in the antero-posterior plane. During the first phase of this throwing pattern, the arm is drawn up either frontally or obliquely. The trunk simultaneously extends until the throwing arm is high above the shoulders. During the delivery phase, the trunk straightens with a forward carry of the shoulders. The corresponding forward arm movement is character- ized by a stiff, downward motion. During the entire throw, the individual remains facing the intended target for the throw and the feet remain firmly in place (10:124).

Basically, the total movement pattern occurs within the same plane, the sequence of movement being backward then forward. Consequently, the development of leverage for an effective and efficient throw is almost impossible.

Between the ages of three and one half to five, the second type of throw develops. Arm and body movements occur mostly in the horizontal plane. The arc which the arm tran- scribes is somewhat flatter. Greater force is attributed to forearm extension prior to release and a forward and downward follow-through. There is a rotation of the body to the right in preparation to throw and then a rotation to the left upon the delivery of the ball with the right hand. The feet remain together and in place during the entire throw. Due to the rotatory motion, greater distance is available in which to apply force. Thus, more leverage may be applied by the trunk and shoulder girdle which provides for a more forceful throw.

The third type of throw is developed between the ages of five and six. Introduced during this stage is a step forward with the right foot as the ball is delivered with the right hand. During the preparatory phase, the weight is kept on the rear foot. ". . . the body is rotated to the right and the arm is brought obliquely upward and over the shoulder so that it is in a flexed and retracted position," (10:125).

During the delivery phase there is a step forward onto the right foot as the body rotates to the left. The arm swing forward is an oblique or lateral movement from the shoulder joint, with the arm extending during release. The shift of the body weight onto the right foot increases the force applied to the ball. However, since the weight is transferred forward onto the right foot and at the same time throwing with the right arm, the backward preparatory movements are limited, thus the timing becomes quite awkward. The follow-through is a forward and downward motion with the body slightly facing left at the completion of the throw.

The fourth and final type of throw generally is developed around the age of six and one half or older, depending upon the individual. This type of throw may be termed a mature pattern. Characteristic of this type is a base of support which provides for opposition of movement which in turn increases power. Weight transfer is accomplished properly, shifting from the back to the forward foot, with marked trunk rotation. The forward arm swing consists of horizontal adduc-

tion of the arm, as the arm is being cocked when the forward step is made on the opposite leg. Maximum use of body leverage is utilized to increase speed at the hand. Most boys usually reach this fourth stage, but many girls don't excel beyond the third stage. According to Wickstrom, "The major obstacle to the achievement of this throwing pattern by girls seems to be the forward elbow swing followed by effective elbow extension," (32:78).

Wild contends that the greatest difference in the four throwing types is the plane in which the movements occur. The most immature throwing pattern occurs in the antero-posterior plane. As the pattern becomes more refined, the movements tend to occur largely in the horizontal plane. The base of support also changes from a stationary base of support to a step forward with the left foot. It appeared to Wild that development of the basic pattern relied heavily upon neuromuscular development, especially the refined development of equilibrium and body orientation (33:22-24).

Wickstrom divided the mature overarm throwing pattern into three parts: (1) Preparatory Movements, (2) Throwing Movements, and (3) the Follow-Through (32). However, even though the pattern is divided into three distinct parts, movement is continuous with some overlapping of the various movements. Quoted below is Wickstrom's outline for the mature overarm throwing pattern (for a right-handed thrower):

Preparatory Movements

1. Pivot, rotating the body to the right
    and shift the weight to the right foot.

2. Swing the throwing arm backward and upward.

Throwing Movements

3. Step forward in the direction of the throw with the left foot.

4. Rotate the hips, the trunk, and the shoulders to the left while retracting the throwing arm to the final position before starting the forward arm action.

5. Swing the right elbow forward horizontally, extend the forearm and snap the wrist just before releasing the ball.

Follow-Through

6. Continue the pattern of movement in the follow-through until the momentum generated in the throwing action can be dissipated, (32:82).

Wickstrom concludes by stating that trunk rotation appeared to be the most important factor in developing a mature over-arm throwing pattern.

Leme conducted a more thorough study on the overarm throwing pattern (18). This study appears to provide for the most conclusive and discriminatory evidence on the development of the overarm throwing pattern at the present time. It was reported that changes in weight transfer and body rotation were the primary factors in the development of the

throwing pattern. Less skilled individuals used block ro-
tation of the trunk where as more highly skilled individuals
used sequential pelvic then spinal rotation of the trunk.

Leme stipulated 10 developmental types of throws in
the development of the overarm throwing pattern. Leme's
study allows for greater discrimination than the stages ad-
vocated by Wild (33). Leme cautioned however, that a pure
type of throw is seldom found.

The 10 developmental types suggested by Leme are in
outline form for a right-handed individual. Types I, II,
III, V, VIII, and X are taken directly from Wild before
the original six types were reduced to the present four (33:
20-24) as discussed in this study. Quoted below are Leme's
10 developmental types:

Type I

Feet are parallel and front facing
with no stride taken. No movement
of the trunk forward is taken and
no rotation is evident. Arm move-
ments are in the antero-posterior
plane and a high degree of elbow
flexion is used.

Type II

Feet remain stationary and are gen-
erally parallel. A slight forward
and upward shift of weight occurs
due to ankle action. No rotation
of the trunk occurs but extension
and flexion of the spine may be
present. Forward arm movements are
primarily in the antero-posterior
plane while the reverse arm move-
ment may be in the horizontal or in
the right oblique plane.

Type III

Feet remain stationary and are generally parallel with no stride taken. Body rotates using primarily spinal rotation which allows for a horizontal shift of weight. Arm movements are in the horizontal or oblique plane.

Type IV

Characteristics are similar to a Type III throw except that the feet are in a stride position with the right foot forward. No stride is taken beyond the original stride length. The weight shifts to the rear foot with the reverse arm swing and then shifts forward with the forward arm swing.

Type V

Feet begin together and a right step forward is taken with the forward arm swing. Spinal rotation is present with a transfer of weight to the rear foot with the reverse arm swing then to the right foot with the forward arm swing. Arm movements are in the horizontal or right oblique plane.

Type VI

Feet are in a stride position with the left foot forward throughout the throw. Spinal rotation is present and the weight shifts to the rear foot then to the forward foot. Arm movement is in the horizontal or right oblique plane.

Type VII

Feet are either front-facing or parallel to the target and a small stride is taken with the left foot. The body faces to the right with the reverse arm swing and the body rotates with the pelvis and spine acting as a unit. The forward arm swing is primarily horizontal adduction of the humerus.

Type VIII

Pattern characteristics are the same as those in Type VII except that sequential pelvic then spinal rotation is utilized.

Type IX

Feet begin parallel to the target with the body right-facing. A long stride with the left foot is taken and rotation with the pelvis and spine rotating as a unit is used. The reverse arm swing is a full arm reverse with the forward arm swing being a sideways forward swing with inward rotation of the humerus and full arm extension. The body rotates to the left after release and the arm crosses the midline of the body in the follow-through.

Type X

Pattern characteristics are the same as those listed in Type IX except that sequential pelvic then spinal rotation is utilized, (18:31-33).

Overarm Serving Pattern

The overarm serving pattern may properly be characterized as an overarm striking pattern. The earliest form of the striking pattern is usually used only by a child. The pattern usually occurs in the antero-posterior plane. This allows the child to face the object which is to be struck, in this case a tennis ball. This also enables the individual to see the ball throughout the entire motion which offers the beginner the most success (32). Consequently, only through experience and practice will an individual progress from an immature overarm serving pattern to a mature pattern.

There are many different methods of serving, but

basically, the fundamentals involved in the serving process are all very nearly the same. Plagenhoef provided the most detailed analysis of the mature overarm tennis serve (23:47-88) which is presented below. Supplementary material is included by Barnaby (1), Broer (3), and Cooper and Glassow (5). This analysis applies to a right-handed individual.

Grip. The most common grip used for the serve is the eastern forehand grip. This grip allows for the palm of the hand to be in the same plane as the face of the racket.

Stance. When the feet are placed correctly in relation to the baseline, an imaginary line passing through the heels of the feet, should point in the direction of the intended flight of the ball. The right foot should be firmly placed against the court surface in order to push the weight of the body into the ball. This will allow the shot to be firm and secure. It is essential that the left foot be positioned so that the knee will bend toward the intended flight of the ball (1:38). The knees must be bent slightly in order to allow for greater mobility and flexibility, and also to allow for a better ball toss.

Racket. In preparation for the serve, the racket should be pointed in the direction of the intended flight of the ball with the racket face perpendicular to the ground. The hitting surface is facing left.

Arm Action and Toss. Arm action at this point consists of a down-together, up-together motion. The hand used to toss the ball for the serve should go down to approximately thigh level before moving upward again in approximately the same plane which characterized the downward movement. At the completion of the upward movement, the fingers should point toward the ball. As the ball reaches the highest point in its flight, the eye, fingertips, and ball should be in a straight line. The tossing hand should be characterized with the wrist layed back and the palm horizontal. The arm should be slightly bent in order to push the ball out in front of the body as the server extends the tossing arm.

Racket Motion. The entire motion of the racket transcribes the path of a circle. The racket begins this circular motion as it is pointing toward the ground by making a half turn. When the racket approaches a height of approximately shoulder level, the racket should be pointing directly backward. At this particular point in the movement, the racket face is perpendicular to the ground. At the beginning of the movement, the striking face was on the left. As the racket progresses to the back position, the striking surface will be on the right.

Forward Swing. The racket continues upward from behind the back, with the elbow in a flexed position. At this time, the spine is in complete hyperextension. As the arm becomes cocked, the forward movement used to transfer the body weight for-

ward is also started. This motion, which is flexion of the spine, starts before the arm is fully cocked. Following this movement is the throwing motion. The elbow is in a high position as it leads the movement through, with the racket following. At this point, the forearm is carrying out most of the movement with the upper arm remaining relatively stable. Flexion of the spine continues to increase. At the moment of impact there is a great deal of movement occurring in the wrist and hand, but very little movement in the forearm.

> "Each body segment moving at the
> proper time, in sequence, produces
> the maximum racket head velocity.
> Because the trunk and legs are the
> heaviest parts of the body, they are
> also the most influential, even though
> the arm gives the greatest range of
> motion," (23:61).

Impact. At the point of impact between the racket and the ball, the player should actually place the racket on the ball. Next, the player should press or push the ball outward in a horizontal direction, aiming toward a point in the air three feet above the net in front of the intended service court to be hit (1:43). After the ball is pressed outward, it should then be pulled downward to give the ball its downward trajectory into the court.

Follow-Through. The follow-through is in a downward direction, across the midline of the body to the left. It is a continuous motion from the point of contact which allows for a gradual deceleration of the swing.

Plagenhoef clearly and most descriptively, explains the overall motion accomplished when the serve is executed correctly by stating that, "The over-all result is that the body is continually attempting to maintain a rhythmic, smooth motion and at the same time exert optimum muscular strength while eliminating unwanted stresses," (23:81).

Pasarell believes that there are three important qualities which are essential for the proper execution of the serve (22:33-35). The first is rhythm which is the ability to coordinate body actions in time with the toss of the ball. The second quality is the ability to maintain balance throughout the entire stroke. The third and final quality is the ability to avoid becoming obsessed with speed. An accurately, well placed serve is more important and necessary to early success in serving ability. Speed will naturally come with time.

Pattern Comparisons

According to many authorities (3,4,5,9,20,21,22 and 23), the overarm throwing pattern is essentially the same as the overarm serving pattern. Broer states that the purpose of each motor pattern will cause some adjustments to be made in the basic movements, but the basic mechanics of the two patterns will remain the same (3). Broer further elaborated by reporting that,

"Both leg and arm action were found
to be similar in the overhand throw,
badminton clear and tennis serve.
There were slight differences in the
functioning of the right arm muscles
during the overhand throw, but the
two striking activities were almost
identical," (3:20).

According to Plagenhoef, the only difference between
the throwing pattern and the serving pattern appears to be
in the positioning of the upper arm (23). During the tennis
serve there would be a high elbow position with the upper
arm pointing upward. In the overarm throwing pattern, the
upper arm should be pointing forward.

Cantin (4) believes that a player must use an overhand
throwing motion in order to get the racket head through
the ball on the serve. In this specific throwing motion,
the wrist is permitted to snap the racket head up into the
ball. Mason also believes that a student should learn the
serve by first practicing throwing a ball using the overarm
pattern; the rationale being that the throwing action, weight
transfer, body rotation, and arm and wrist action are almost
identical to that of a mature or good serving motion (20).
Mason outlines a method in which to teach the serve through
the use of the overarm throw (21). The only difference be-
tween the two patterns according to Mason appears to be in
the release of the ball in the throwing pattern versus the
full extension of the body at the point of contact in the
serve.

The investigator devised a chart which is presented
below to depict a motion comparison of the overarm throwing

pattern and the overarm serving pattern. Leme developed the eight categories used for evaluative purposes to differentiate the 10 developmental types of throws (18). Wild also identified the same eight categories (33). The criteria used to compare the two patterns are characteristics found by Leme which describe the 10 developmental types of throwing (18:31-33).

TABLE 1

MOTION COMPARISON OF THE OVERARM THROWING PATTERN

AND THE OVERARM SERVING PATTERN

Qualities of the Overarm Throwing Pattern (18:31-33)	Throwing Pattern		Serving Pattern		
	I	M	I	M	DA
1. Position of the feet					
a. parallel to each other - front facing	X		X		
b. stride position - right foot forward	X		X		
c. stride position - left foot forward	X		X		
d. parallel to target - side facing target		X		X	
2. Stride					
a. none	X		X		
b. with right foot	X		X		
c. small stride with left foot		X	X		
d. long stride with left foot		X	X		
3. Body orientation					
a. facing target	X		X		
b. rotates right with reverse arm swing		X			X
c. right facing		X		X	
4. Weight transfer					
a. none	X		X		
b. slightly forward and upward	X		X		
c. horizontal	X		X		
d. back to left foot - forward to right foot	X		X		
e. back to right foot - forward to left foot		X		X	

Qualities of the Overarm Throwing Pattern (18:31-33) Continued.	Throwing Pattern		Serving Pattern		
	I	M	I	M	DA
5. Trunk action					
a. none	X		X		
b. extension and flexion	X		X	X	
c. spinal rotation	X		X		
d. block rotation		X		X	
e. pelvic then spinal rotation		X		X	
6. Reverse arm movement (backswing)					
a. antero-posterior plane	X			X	
b. horizontal or right oblique plane	X	X	X		
c. full arm reverse (backswing)		X		X	
7. Forward arm movement					
a. antero-posterior plane	X			X	
b. horizontal or right oblique plane	X		X		
c. horizontal adduction of humerus		X	X		
d. sideways forward swing with inward rotation of the humerus		X	X		
e. full arm extension		X		X	
8. Follow-through					
a. does not cross midline of body	X		X		
b. crosses midline of body		X		X	
c. body rotates left after release (or contact)		X		X	

I = Immature   M = Mature   DA = Doesn't Apply

By studying the preceding chart, it is noted that the overarm serving pattern is quite similar to the overarm throwing pattern when using Leme's characteristics for the 10 developmental types of throwing (18:31-33). The following section discusses the similarities and dissimilarities of the two patterns.

Position of the Feet. The first three criteria for the positioning of the feet, (1) parallel to each other - front facing,

(2) stride position - right foot forward, and (3) stride position - left foot forward, are characteristic of an immature pattern for the overarm throw and the overarm tennis serve. A mature pattern for both skills would be with the feet parallel to the target and the side facing the intended target.

Stride. An immature overarm throwing pattern consists of either no stride what so ever or a small stride taken with the right foot. However, for the tennis serve, a stride is not taken when executing a mature pattern. If a stride is taken, it would be with the right foot after contact with the ball in order to advance the player one step closer to the net in anticipation of rushing the net. Characteristic of a mature throwing pattern would be a stride taken with the left foot but this is not appropriate for the mature tennis serve.

Body Orientation. The positioning of the body is basically the same for both the overarm throw and the tennis serve. Facing the target is a characteristic found in both immature patterns. A mature overarm throwing pattern should be characterized by either the body rotating right with the reverse arm swing or by having the body already right facing. The body rotating right with the reverse arm swing (backswing in tennis) is not applicable to the serve. However, for a mature serving pattern, the body should be right facing.

Weight Transfer.   Weight transfer is exactly the same for
both skills.   An immature pattern for either skill would be
characterized by any of the following modes of weight trans-
fer: (1) no weight transfer, (2) a slight forward and upward
weight transfer, (3) a horizontal shift of weight, or (4) a
shifting of weight back to the left foot and forward to the
right foot.   A mature pattern for both skills would be charac-
terized by a transfer of weight back to the right foot and
then forward to the left foot.

Trunk Action.   Trunk action is basically the same for both
skills.   An immature throwing pattern is characterized by,
(1) no trunk action, (2) extension and flexion of the spine,
or (3) spinal rotation without pelvic rotation.   An immature
overarm serving pattern is the same except for the extension
and flexion of the trunk.   If there is extension and flexion
of the trunk without any pelvic and spinal rotation, then
an immature pattern is being performed.   If, on the other hand,
there is hyperextension and then flexion of the spine in con-
junction with pelvic and spinal rotation, then a mature serv-
ing pattern is being performed.   Both block rotation of the
trunk and pelvic, then spinal rotation of the trunk are charac-
terisitc of a mature pattern for both skills.

Reverse Arm Movement.   The reverse arm movement for the overarm
throwing pattern is not the same as for the serve.   The serve
would be characterized by a full circular backswing rather
than a reverse arm swing.   Consequently, at this point, the

two patterns are very much different. An immature overarm throwing pattern would consist of, (1) movement in the antero-posterior plane, or (2) possibly, movement in the horizontal or right oblique plane, depending on the stage of development. A mature overarm throwing pattern should occur in the horizontal or right oblique plane and there should also be a full arm reverse. However, a mature overarm serving pattern should be characterized with a backswing occurring in the antero-posterior plane, not in the horizontal or right oblique plane. There should also be a full circular backswing.

Forward Arm Movement. The two movement patterns differ in many respects during the forward arm motion. A mature throwing pattern should consist of the following depending on the stage of development: (1) horizontal adduction of the humerus, (2) a sideways forward swing with inward rotation of the humerus, and (3) full extension of the arm. In a mature overarm serving pattern there is no horizontal or sideways movement of the arm but there is a full extension of the arm. The movement should take place in the antero-posterior plane.

Follow-Through. The follow-through for both patterns is exactly the same. In an immature pattern for both skills, the arm does not follow-through across the midline of the body. A mature pattern for both skills is characterized by the arm following through across the midline of the body with the body rotating left after the release of the ball in the overarm throw or after contact with the ball in the tennis serve.

Serving Tests

Many authorities (1,4,13,16,21,22 and 23) have attempted to stipulate qualities which may be attributed to a person possessing an efficient and effective serve. Some of the most popular qualities of a good server are: (1) ability to hang the ball toss in the air, (2) ability to serve up and through the ball, (3) possession of more body rotation and backward bend than beginners, (4) arm extension at contact, (5) consistent ball toss with the ability to compensate for an error with the swing, (6) consistent pattern of movement, (7) ability to stretch up to contact the ball at its' highest point, (8) firm wrist snap, (9) complete follow-through, (10) chain reaction of one segment to another, (11) less muscular effort than for a poor server with uncoordinated movement, (12) ability to vary the speed, spin, and placement of the ball, (13) ability to coordinate body actions in time with the toss of the ball, (14) ability to assume a balanced position throughout the stroke, and (15) ability to avoid becoming obsessed with speed.

Speed, spin, and placement appear to be the most essential qualities for an efficient and effective serve. According to Gray, "It (is) generally agreed that there are three components of a good service: speed, spin and placement," (13:23).

Gray (13) discussed in detail, some aspects of speed and spin. When considering speed it should be remembered that the best serve is not always the fastest. It is extremely

difficult for a player to serve continuously hard throughout an entire match and at the same time maintain accuracy. A service velocity of 80-100 feet per second (55-68 MPH) is considered a good serve for intercollegiate women players (11 and 13).

When considering spin, Gray believes that some spin is essential in order to execute a speed service. Without the component of spin, it would be impossible to maintain accuracy when serving the ball into the service court (13:29). Consequently, spin is the primary factor which allows for the ball to drop into the service court on the serve. This will allow for the greatest margin of error. Thus, the true flat serve would not be characteristic of a good server because it possesses no spin.

The problem of what qualities to test at the beginning level of serving ability is a matter of concern to physical educators when evaluating the student on the serve. It is very difficult, if not close to impossible, to find a true solution which would apply to all situations and circumstances. However, for the purposes of this study, of the three general qualities -- speed, spin, and placement -- placement and speed were deemed sufficient for testing the subjects on serving ability.

Placement of the serve was selected as the most important factor involved at the beginning level of serving ability. The player must serve the ball into the correct service court in order to get the game underway. According to Robb:

> "In tennis, the beginner soon learns
> that to score he must be accurate.
> The 'payoff' is getting the ball into
> the proper serving area. If he doesn't
> get the ball into the service area it
> doesn't matter how fast the ball tra-
> velled. A beginner's serve is gener-
> ally slow and accurate because the
> payoff favors accuracy," (25:85).

Speed was considered as the second most important quality at the beginning level of serving ability. As the individual becomes more accurate and the level of play grad-ually improves, the player soon learns that to accomplish the intended goal at an improved level of play, greater speed must be imparted to the served ball. These two quali-ties, placement and speed, used in conjunction with each other, should provide the beginning player with a fairly efficient and effective serve.

Spin was omitted from this study because it is felt by the investigator that the imparting of spin upon the served ball is an unrealistic goal to set for the beginning player. Some individuals will have a natural ability to put spin on the ball when serving. But for the most part, a beginner does not have the ability to consistently put spin on the ball, nor the motivation to work on spin until place-ment and speed are accomplished first. A serve which possesses spin is considered to be an intermediate to advanced skill learned after the basic serve is mastered (1 and 12).

Many attempts have been made to construct reliable and valid tests to evaluate serving ability. DiGennaro proposed a serving test for accuracy without the consideration

of speed (8). The intended target was a series of circles re-
sembling an archery target placed in the inside back corner
of the service court. However, it was found that the coeffi-
cients of reliability and validity were too low to substantiate
the use of this test.

Malinak attempted to construct a serving test to mea-
sure accuracy (19). This test was intended for college women
at the beginning level of achievement. Criteria used for
measurement were: (1) trajectory, (2) angle of rebound,
(3) spin, (4) speed, (5) accuracy, (6) placement, and (7) form.
Form was the only quality measured subjectively by the eval-
uations of three judges. Six different patterns of service
court divisions were used in an attempt to find the most
reliable and valid pattern for determining accuracy.

Reliability was computed using the split half method.
The Pearson product-moment correlation technique was used to
compare the odd-even trials to ascertain the reliability for
one-half of the test (10 trials). The Spearman-Brown Prophecy
formula was used to find the reliability for the full test
(20 trials). This procedure was repeated six times to find
the reliability for each of the six patterns of service court
divisions. The highest product-moment correlation coefficient
for any of the six patterns was r = .57. The highest reliability
coefficient using the Spearman-Brown Prophecy formula was r = .67.
Reliability for the proposed test was not established. ". . . the
proposed test did not consistently measure the ability of the
subjects to execute the tennis serve under the conditions
imposed by the proposed test," (19:34). The validity coefficient

for the evaluation of form was found to be r = .46. Thus, this test was not valid. It was concluded that the proposed test was not reliable nor valid for individual's possessing a beginning level of service ability.

Jones constructed a test to measure the accuracy of the tennis serve (17). Subjects were instructed to serve between restraining ropes which were placed at one foot intervals four to ten feet above the ground. The objective was to serve into the deepest part of the court. The service court was divided into four target areas of varying sizes and possessing different point values. Three groups of high school girls were tested: advanced, intermediates, and beginners.

Reliability was determined through the use of the Spearman-Brown Prophecy formula. From the right service court, the first, third, and fifth trials were correlated with the second, fourth, and sixth trials in the left service court. It was shown, by a correlation of r = .920, that 20 trials taken from both the right and left service courts were reliable for the subjects in this particular study. The validity of the proposed test was found to be fairly high. The coefficient of correlation between the proposed serve accuracy test and the Driver Serve Test was found to be r = .970 The correlation coefficient between the proposed serve accuracy test and subjective rating scales of general playing ability was computed to be r = .760.

It was found that accuracy scores and rating scales distinguished between levels of ability. Jones concluded by emphasizing the fact that the test could be used to predict performance on serving ability. The test could also be used to predict the performance of the skills related to playing a game of tennis.

Sebolt used multiple-image photography to measure velocity (28). Using the analysis of variance technique, the estimate of the intraclass coefficient was found to be $r = .91$. This was significant at the .01 level of significance. However, the results of this study applied to men only.

Fiereck conducted a study to compare three methods of assessing the velocity of a tennis serve: (1) film analysis, (2) measures of time, distance, and point of contact, and (3) subjective ratings (11). The scores obtained by two subjective raters were averaged together to obtain a subject's velocity score. The component of velocity was scored on a zero to ten point scale with each subjective rater scoring independently.

The objectivity coefficients were (1) between the two timers, $r = .97$, (2) between the two court scorers, $r = .98$, and (3) between the two subjective raters, $r = .85$. The validity coefficients were as follows: (1) between the film velocity and the timer-distance velocity, $r = .92$, (2) between the subjective ratings and the film velocity, $r = .81$, (3) between the subjective ratings and the timer-distance velocity,

r = .78, (4) between the distance scorers and the film dis-
tance, r = .98, and (5) between the timers time and the
film time, r = .98. It was concluded that, "subjective
ratings of velocity are valid measures of the velocity of
tennis serves when timer-distance and film velocity are
used as criterion measures," (11:64).

Hewitt devised a test for the serve to measure place-
ment and speed of the served ball (14). Placement of the
serve was measured according to the target area into which
the served ball landed. The target areas were placed in the
right service court and varied in size. Speed was determined
by measuring the distance the ball bounced after it landed
in the service court.

Reliability, determined through the test-retest
method for the service placement, was found to be r = .94 and
for the speed of service, r = .84. Validity was calculated
by using the Spearman Rho or the rank difference method.
For the beginning level, placement validity was found to be
rho = .72 and speed validity was found to be rho = .89. The
validity for the Dyer Wall Test with a 20 foot restraining
line was found to be rho = .73. The speed of service test
appeared to predict best for beginning ability while the place-
ment test predicted best for the varsity level of play.

Barrow and McGee presented the Wisconsin Wall Test for
Serve (2). The purpose of this test was to determine the
effectiveness of the serve through the measurement of force
and height. This test was designed for use with college women.

A wall target (backboard) was marked off at one foot intervals from the ground up to 12 feet to measure accuracy. Speed was determined through the use of a stop watch. The subjects stood 42 1/2 feet away from the target. A subject's score was determined by the total number of point values for velocity and vertical placement which were made with 10 serves. Velocity measures were made from a total of 10 trials added together and then converted to point values from the specified table. Placement conversions were made from the specified table for each of the 10 serves and then the point values were added together.

Reliability was determined by use of the analysis of variance statistic. Reliability of the velocity scores was found to be $r = .978$ for 20 trials on two days and $r = .942$ for 10 trials on one day. Reliability for the final score, which is a combination of the speed and placement values, was found to be $r = .957$ for 20 trials on two days, and $r = .912$ for 10 trials on one day.

Criteria were established in order to select the tests used to measure speed and accuracy of the tennis serve. Due to the time available in a normal class setting, it was desirable that the tests chosen measured both speed and accuracy simultaneously. More importantly, since the components of speed and accuracy occur simultaneously within a serve, it was important to measure both components simultaneously in order to determine the true effectiveness of a serve. The tests must also be both reliable and valid for beginning level women students. Furthermore, they must be of a practical

nature which would allow them to be used for evaluative pur-
poses in a normal class setting. Also of importance was the
cost and complexity of needed equipment and ease of adminis-
tration.

Many serving tests were reviewed for use in this study.
Most of the serving tests which were considered measured only
one of the two components, speed or accuracy. These tests
did not meet the standards set up for test selection and use
in this study. The following discussion briefly explains
why various serving tests were not selected for use in this
study.

DiGennaro devised a test which only measured accuracy.
The reliability and validity coefficients were too low to
substantiate the use of this test (8). Sebolt used multiple-
image photography to measure only velocity which is unrealistic
for a normal class setting. The equipment needed for this
test is very complex and expensive. This test has been shown
reliable and valid for men only (28). Malinak established
a test to measure accuracy only. However, reliability and
validity were not established for beginning level players (19).
Jones' test measuring accuracy was found to be rather unpractica
for a normal class setting with much time involved in setting
up the proper conditions for administration of the test (17).
Fiereck devised a test to measure only the component of velo-
city. The subjective rating was found to be valid only when
used with film velocity and timer-distance as criterion mea-
sures which is very unpractical for a normal class setting (11).

The two tests utilized within this study for measuring the serving ability of beginning level tennis players were Hewitt's Tennis Achievement Test and the Wisconsin Wall Test for Serve.

Hewitt's Tennis Achievement Test was selected for the following reasons: (1) it measures both placement and speed, (2) reliability and validity coefficients were fairly high, (3) the speed of service test predicted well for beginners, (4) the placement test predicted best for varsity level players but it still is applicable to beginners as indicated by a rho of $r = .72$, and (5) it is very practical for a normal class setting and easy to set up and administer (14).

The Wisconsin Wall Test for Serve was selected to use in conjunction with Hewitt's Tennis Achievement Test. This test was selected for the following reasons: (1) it measures the effectiveness of the serve through force and height, (2) it is applicable to college women, (3) the reliability coefficients are quite high, and (4) it is very practical for a normal class setting and it is easy to set up and administer (2).

The above two tests were used in conjunction with each other to substantiate the results of this study. There were also many strong points and weak points for each of the tests, but the shortcomings of each of the tests appeared to lessen when the two tests were used together. The Wisconsin Wall Test for Serve appears to neglect the placement importance of the

served ball in the service court where as Hewitt's test takes this into account. The Wisconsin test appears to measure speed with a more reliable method, that being the use of a stop watch as opposed to the distance a ball travels between the first and second bounce in Hewitt's test. Thus, Hewitt's test employs an indirect measure to record the speed of the ball while the Wisconsin test uses a direct method to measure the speed of the ball. Lastly, the subjects must serve from a distance of 42 1/2 feet from the wall in the Wisconsin test which is three and one half feet longer than the normal distance from the net. Hewitt's test complies with the normal distance of 39 feet. Thus, it seemed that by using both tests, a bolstering or substantiating of the data could be achieved.

Chapter III

PROCEDURE

Subjects

Forty-eight female volunteer students who were en-
rolled in a beginning activity class at Sam Houston State
University during the Spring semester of 1977 participated
within this study as subjects. Subjects were classified as
beginning tennis players having little, or no, previous ex-
perience or instruction. All subjects both threw and served
right-handed.

Prior to the beginning of the study, the Wisconsin
Throw Test (30) was administered to all subjects to determine
a subject's throwing speed and accuracy. This pre-test was
needed in order to obtain measures of the covariates which
were to be used in the statistical analysis. This controlled
for the possibility that, the initial level of one's throwing
ability might influence the rate of improvement and final
level of skill acquisition in serving (18:31-33). Using a
random selection process, subjects were assigned either to
the experimental group, which practiced the overarm throwing
pattern prior to receiving instruction in serving, or to
the control group.

Measuring Instruments

A. Wisconsin Throw Test for Velocity

Purpose. This test was administered to determine a subject's maturity level in the overarm throw as indicated by the velocity and accuracy of a subject's throw. This test was slightly modified to include an accuracy score which carried equal weighting with the velocity score.

Time Allotment. The pre-test was administered in a gymnasium at specified times during the week prior to the beginning of the study. Each subject was required to come for a scheduled testing time, with each evaluation taking approximately five minutes.

Procedural Organization. Subjects were required to stand behind a restraining line and throw a tennis ball at a wall target 30 feet from the restraining line. The wall target was marked off in one foot intervals from the floor to the height of 11 feet, with the appropriate score appearing on the left side of each target area. Subjects were instructed to aim at the area which was scored as zero. Refer to Figure 1 for an accurate illustration of the wall target areas.

Equipment. The following equipment was needed for this parti-cular test.

1. Tennis Balls -- Six Spalding Extra Duty Champion-ship tennis balls were used for both the pilot test and the main test for throwing speed and accuracy.

2. Stop Watches -- Three Meylan stop watches, model number 233 were used by the timers. Each had a six second sweep, accurate to .001 of a second.

Figure 1

WALL TARGET AREAS FOR THE WISCONSIN THROW

TEST

Wall
Target

| 5 |
| 4 |
| 3 |
| 2 |
| 1 |
| 0 |
| -1 |
| -2 |
| -3 |
| -4 |
| -5 |

11 feet

Floor
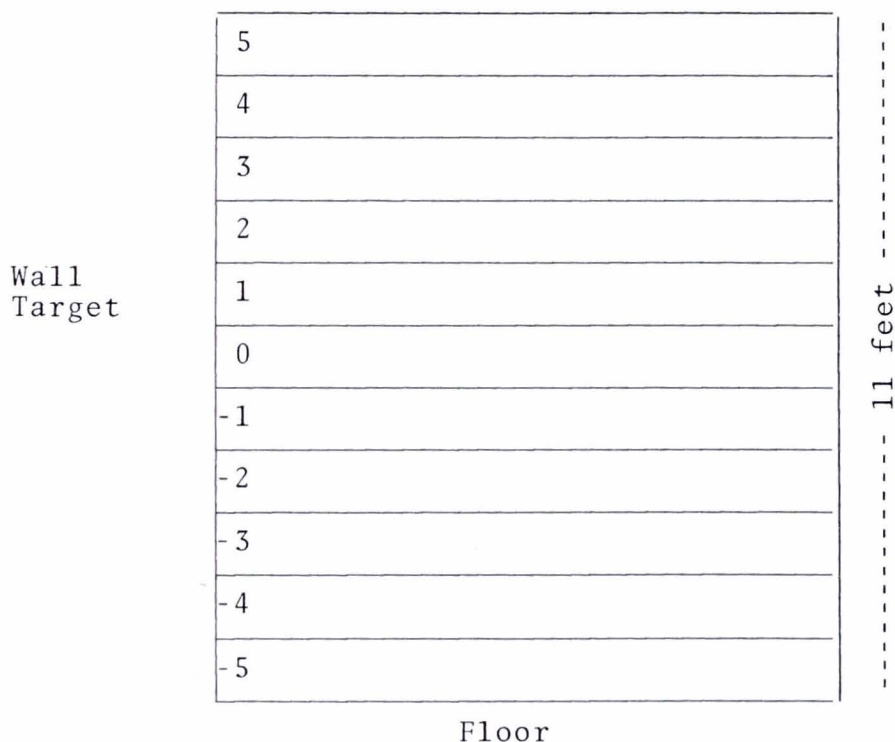
Test Instructions. The following instructions were read to each subject prior to the beginning of the testing period by the investigator.

> You will throw the ball using an
> overhand throwing motion at the
> wall target from behind the line
> 30 feet from the wall. You will
> throw six times. Any throw which
> hits the floor before reaching the

wall shall be repeated. The area
where the ball lands will be re-
corded and the time it takes the
ball to travel from the release
of the ball to wall contact will
also be recorded. You need to
throw the ball as hard as you can
and as accurately as you can,
aiming for the area marked zero.
From these two scores, we will
be able to determine the speed
and accuracy of each of your six
throws. Do you have any questions?

Scoring. The scorer recorded the wall area number corresponding

with where the ball hit in relation to the target. The three

timers independently recorded the time for each of the six

trials per subject. All scores were recorded on a prepared

score sheet (See Appendix A). The watch was started with the

release of the ball and stopped when the ball hit the target.

Any ball hitting a line on the wall target was scored as

hitting in the target area closest to the target area which

was scored as zero (See Figure 1).

Timers and Scorers.

1. Pilot Study -- Ten volunteers were chosen to

   participate in a pilot study which determined

   the interjudge reliability of the timers and

   the scorers. The same procedures were used in

   the pilot and the main study except where noted.

   The F-test for reliability was applied to de-

   termine the consistency among the timers and

   between the scorers (26:125-156). The reliability

   among the three timers was found to be $r = .7464$

Procedural Organization. The wall target was 42 1/2 feet away from the serving line. The wall was marked off in one foot intervals from the floor to the height of 11 feet. The three foot line was designated as the height of the net and was represented by a thicker line. Refer to Figure 3 for an accurate illustration of the wall target areas with the appropriate scoring for each target area labelled on the left side of the wall target.

Figure 3

WALL TARGET AREAS FOR THE WISCONSIN

WALL TEST FOR SERVE
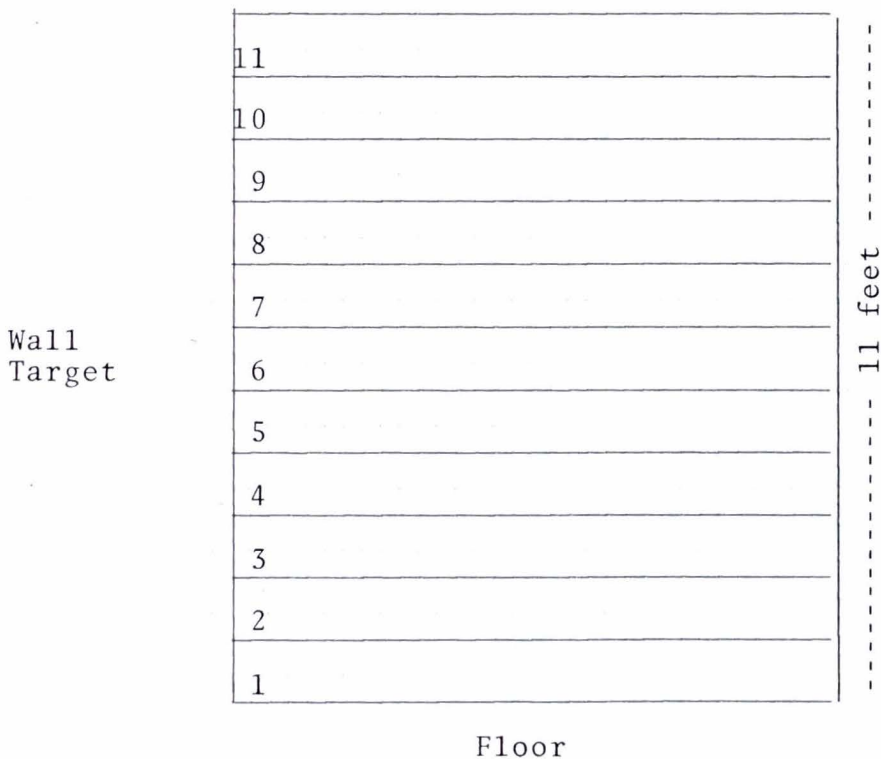
Wall
Target

and a total of six trials were administered.

Figure 2

POSITIONING OF THE TIMERS AND THE SCORER

FOR THE WISCONSIN THROW TEST FOR

VELOCITY
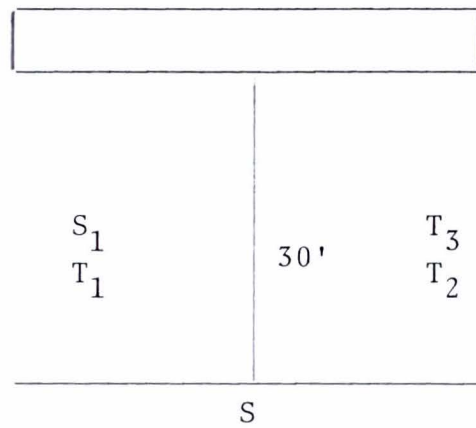
B.   Wisconsin Wall Test for Serve

Purpose.   The purpose of this test was to determine the
effectiveness of the overarm tennis serve as reflected by
the force and height of the served ball.

Time Allotment.   This test was administered to the control
group at the end of weeks one, three and four of the treat-
ment period, and at the end of weeks two and four of the
treatment period for the experimental group.   The test was
set up and administered in a gymnasium.   Each testing period
for the main study was conducted on a Thursday night or on a
Friday afternoon.   Subjects took approximately five minutes
to complete this test.

and between the two scorers, an r = .9962 was obtained in the first pilot study. Since the reliability among the timers was rather low, a second pilot test was conducted. Prior to the second pilot test, the timers had been retrained in a second instruction and practice session. A reliability coefficient was computed again for the timers and was found to be r = .9886.

2. Main Study -- The three timers and the scorer were placed along one of the sidelines of the testing area in order to obtain a clear view of both the subject and the wall target, as shown in Figure 2. Timer one (T_1) was placed to the left of the subject and 14 feet from the restraining line. Timers two and three $(T_2$ and $T_3)$ were placed to the right of the subject, 14 feet and 16 feet from the restraining line respectively. The scorer (S_1) was placed to the left of the subject and 16 feet from the restraining line. S indicated the position of the subject.

Two students who were not participating in the study retrieved balls. The balls were returned to the testing area after each subject had been evaluated. Subjects were tested separately. The timers and scorer rated each subject independently, recording scores on separate score sheets (See Appendix A). Subjects had approximately 10 seconds between trials,

Equipment. The following equipment was needed for this serving test.

1. Tennis Balls -- Six Wilson Extra Duty Felt Championship tennis balls were used. New balls were provided for each of the three testing sessions conducted during the treatment period.

2. Stop Watches -- Three Meylan Stop Watches, model number 233 were used by the timers. Each watch had a six second sweep, accurate to .001 of a second.

Test Instructions. Standardized test instructions were read to each group (control and experimental) before the first testing session by the investigator. The original set of instructions (2:235-236) were modified somewhat by the investigator to accommodate the time allotment and needs of this study.

> You will serve at the wall target
> from behind this line 42 1/2 feet
> from the wall. You will serve 10
> times. Your point of aim is area
> four on the wall. (Refer to Figure
> 3). Any serve which hits the floor
> before reaching the wall shall be
> repeated. You must hold two balls
> in your tossing hand for each serve.
> You may have two practice serves
> and then we will begin. The area
> where the ball lands will be re-
> corded and the time it takes the
> ball to travel from the racket to
> the target will also be recorded.
> Do you have any questions?

Scoring. The scorer noted the wall area number, and the three timers noted the time for each serve. All of the

evaluators gathered the data independently and recorded this information on separate score sheets (See Appendix B). Any serve hitting the floor before reaching the wall target was repeated. Any serve which hit a line on the wall target was scored as landing in the target area closest to area four (See Figure 3). Foot faults were not accounted for because the subject served from a distance of 42 1/2 feet from the wall target which is three and one half feet longer than the normal distance of 39 feet from the net. The velocity measures for the total of 10 trials were added and then converted to the point values indicated on the Wisconsin Wall Conversion Tables (See Appendix C). Placement conversions were made from the Conversion Tables (See Appendix C) for each of the 10 serves and then added. The converted point values for both velocity and placement were also added together to obtain a final composite score for each subject.

Timers and Scorers.

1. Pilot Study -- Fourteen volunteers were chosen to participate in a pilot study which was conducted to determine the interjudge reliability of the timers and the scores. The same procedures were used in the pilot study and in the main study except where noted. The reliability among the three timers was found to be r = .9917 (26:125-156). The reliability of the scores, determined on a percentage basis, was found to be 70%. Since the reliability was found to be quite low for

the scorers, a second pilot study was conducted.
Prior to the second pilot study, one scorer was
found to be unsatisfactory. Three scorers were
obtained and instructed in the responsibilities of
keeping score. The F-test for reliability was applied
and the reliability coefficient was found to be
$r = .99367$.

2. Main Study -- The three timers and the scorer
were seated along one of the sidelines of the
testing area in order to obtain a clear view of
the subject and the wall target, as shown below
in Figure 4. Timer one (T_1) was seated to the
left of the subject and 21 feet from the restrain-
ing line. Timers two and three $(T_2$ and $T_3)$ were
seated to the right of the subject, 21 feet and
23 feet from the restraining line respectively.
The scorer (S_1) was seated to the left of the
subject and 23 feet from the restraining line.
S indicates where the subject was positioned.

Figure 4

POSITIONING OF THE TIMERS AND THE SCORER FOR

THE WISCONSIN WALL TEST FOR SERVE
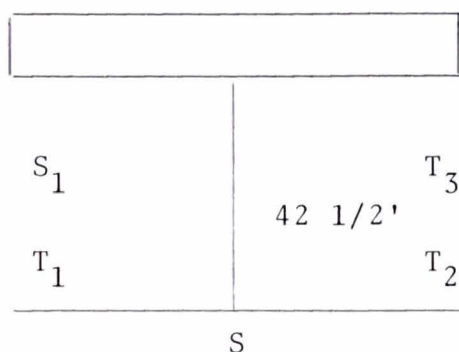
Subjects were allowed two practice trials before being tested. Each subject was tested on 10 trials (2:335). Two students not participating in the study retrieved balls. The balls were returned to the testing area after a subject had served. Subjects were tested separately. The timers and scorer rated each subject independently, recording scores on separate score sheets (See Appendix B). Subjects had approximately 10 seconds between trials.

C.   Hewitt's Tennis Achievement Test

Purpose. This test was administered to determine the effectiveness of the tennis serve through the measurement of accuracy and speed. It also served to substantiate the findings of the Wisconsin Wall Test for Serve.

Time Allotment. This test was administered to the control group at the end of weeks one, three, and four of the treatment period, and at the end of weeks two and four of the treatment period for the experimental group. The test was set up and administered in a gymnasium. Each testing period for the main study was conducted on a Thursday night or on a Friday afternoon and took approximately five mintues to complete.

Procedural Organization. The right service court was prepared and marked off according to the requirements necessitated by this test. Zone areas were marked off in front of and behind the baseline in order to indirectly measure the speed of the

served ball. A total court diagram is presented in Figure 5. Instructions for preparation of the testing area follow the diagram.

Figure 5

PREPARATION OF THE TESTING AREA FOR HEWITT'S

TENNIS ACHIEVEMENT TEST
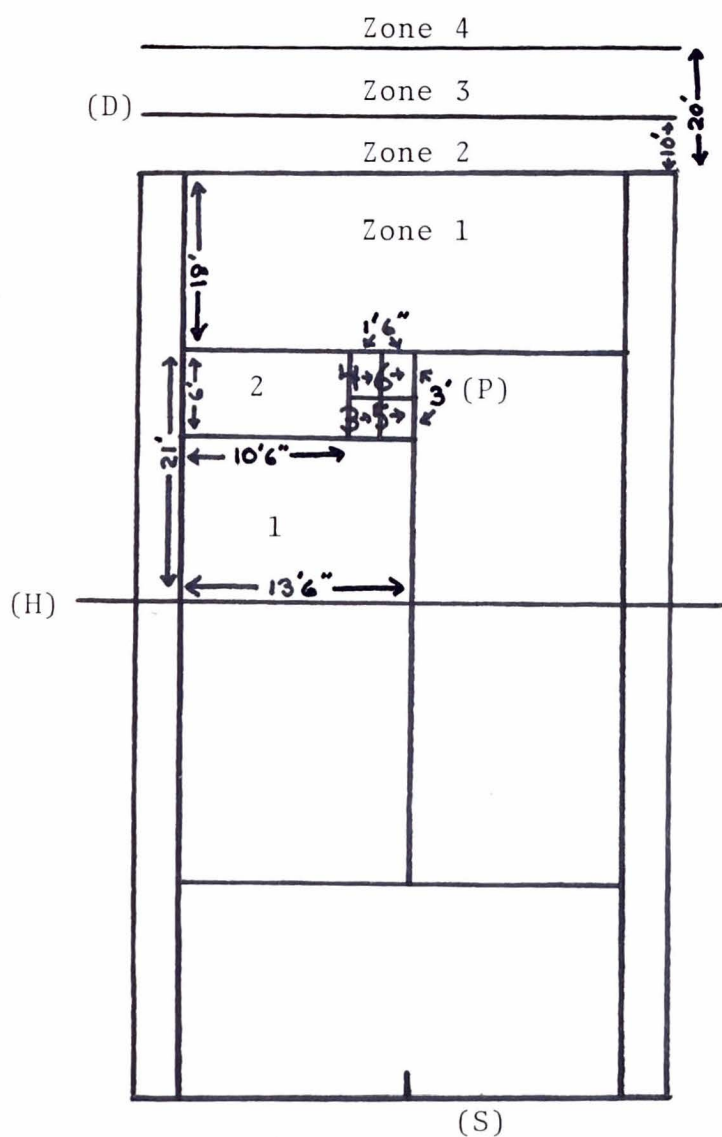
1. The right service court was measured as 21 feet long and 13 feet 6 inches wide. A distance of six feet was measured down each sideline from the service line and a line marked by masking tape was extended between the two points. The larger of the two areas was labelled area one.

2. In the right hand corner of the box above area one, a box was constructed with tape three feet wide and six feet long. The area just to the left was labelled area two, measuring ten feet six inches wide and six feet long.

3. The box which was constructed in step two was further divided into four equal boxes, each three feet long and one foot six inches wide with specific area numbers placed on the lines to the left of each box.

4. A restraining line was constructed by installing a pole as an extension of each net post. A rope was strung between the poles at the seven foot height above the net.

5. The entire backcourt area was labelled as zone one and a number one was placed in the backcourt area to indicate zone one.

6. A line was constructed with masking tape 10 feet behind the baseline and a number two was placed in this area to indicate zone two.

7. A second line was constructed with tape 20 feet

behind the baseline and a number three was placed in this area to indicate zone three.

8. The area beyond zone three was designed as zone four and was labelled as such.

Equipment. The following equipment was needed for this serving test.

1. Tennis Balls -- Six Wilson Extra Duty Felt Championship tennis balls were used. New balls were provided for each of the three testing sessions conducted during the treatment period.

Test Instructions. The following instructions were read to each group (control and experimental) prior to the first testing session by the investigator.

> This is a test to measure the accuracy and the speed of your serve. You are allowed two practice serves before the actual testing begins. You are to stand just to the right of the center mark and behind the baseline. You will serve ten balls into the right service court target area to measure your accuracy on the serve. The ball must travel underneath the restraining rope. Speed will be measured by the distance the ball travels after it has bounced in the service court as indicated by the zone in which the ball lands on the second bounce. All let serves will be repeated. Balls landing outside the right service court or balls served into the net will be scored as zero for both placement and speed. Do you have any questions?

Scoring the Serve.

1. Placement -- For every ball hit over the net and under the seven foot restraining line, the serve

was scored on the basis of the target area hit. Since the numbers were placed on the lines, all hits were scored for their appropriate lines and their adjacent spaces to the right of each number (Refer to Figure 5).

a. Placement for each of the 10 serves was scored as six, five, four, three, two or one.

b. Balls which landed out of the service court either long or wide were scored as zero.

c. All balls served into the net were scored as zero.

d. All let serves were repeated.

e. Balls which travelled over the restraining rope were scored as zero.

2. Speed -- The speed of service was determined by measuring the distance the served ball bounced from the first to the second bounce. This distance was determined by the zone in which the ball landed on its second bounce. (Refer to Figure 5).

a. Zone 1: Backcourt area to the baseline - scored as one point.

b. Zone 2: The area ten feet beyond the baseline - scored as two points.

c. Zone 3: The area which is between 10 and 20 feet beyond the baseline - scored as three points.

d.   Zone 4:   The area 20 feet beyond the
baseline - scored as four points.

Scorers.

1.   Pilot Study -- Fourteen volunteers were chosen
to participate in a pilot study to determine the
interjudge reliability of the accuracy scorers,
the speed scorers and the height scorers.   The
procedures in the pilot and the main study were
the same except as noted.   The Pearson product-
moment correlation statistic was applied to deter-
mine the consistency between the accuracy scorers
and the speed scorers.   The reliability between
the two accuracy scorers was found to be r = .97905,
and between the two speed scorers, r = .99894.
For the height scorers, a phi correlational tech-
nique was applied and found to be r_p = 1.00,
which indicated that the raters were in perfect
agreement regarding these assessments.

2.   Main Study -- One subject was tested at a time.
The subjects were allowed two practice trials
before being tested.   For each serve, the subject
stood just to the right of the center mark and
behind the baseline (See Figure 5).   Each subject
served 10 balls into the right service court
target area to measure accuracy of placement.
Due to the time available for testing, balls served
into the net were not repeated, but were scored

as zero for both accuracy and speed. Foot
faults were not accounted for, which is in com-
pliance with the original test (14). Two students
not participating in the study retrieved balls.
The balls were returned to the testing area
when a subject was not serving.

Three scorers were needed for this test. Each scorer
was positioned in order to best observe the placement area,
the zone area for speed or the height of the served ball (See
Figure 5). The placement scorer (P) was positioned in the
back left corner of the left service court, three feet from
the center service line and three feet from the service line.
The placement scorer was responsible for noting the placement
area of the served ball. The speed scorer (D) was placed on
the line representing the 10 foot mark behind the baseline
and directly in line with the right doubles court sideline.
This scorer was responsible for noting the number of the
zone in which the ball landed on its second bounce for the
speed measurement. The height scorer (H) was positioned at
the net post to the left of the subject. The height scorer
noted whether the ball went under the seven foot restraining
rope or over it. This scorer was also responsible for calling
out serves which hit the net and bounced into the correct
service court in which case, the serve was repeated. (S)
represented the positioning of the subjects. Refer to Figure 5
for the positioning of the scorers. Each scorer worked
independently and recorded the data on separate score sheets

(See Appendix B).   Balls landing out of the service court
long or wide, or those that travelled over the seven foot
restraining rope were scored as zero.   All balls landing on
a zone area line for speed were recorded as landing in the
area farthest from the net.

Administrative Procedures

Prior to the beginning of the study all subjects were
given the throwing pre-test to determine their speed and accur-
acy on the overarm throw.   Through random assignment, the sub-
jects were divided into two groups, an experimental group and
a control group.   Both groups practiced four days a week, 30
minutes a day, for the entire four weeks.   Subjects provided
their own rackets and balls for each practice session.

Experimental Group.   The first week of the treatment period for
the experimental group was devoted totally to learning and prac-
ticing the overarm throwing pattern.   During week two of the
treatment period, the serve was introduced and the basic motions
were practiced.   At the end of week two, the first testing session
was conducted to determine each subject's serving ability as
measured by the Wisconsin Wall Test for Serve and Hewitt's
Tennis Achievement Test.

Weeks three and four were spent with continued practice
on the overarm tennis serve.   At the end of the fourth week,
a second testing session was conducted.   Again serving ability
was tested by administering the Wisconsin Wall Test for Serve

and Hewitt's Tennis Achievement Test.

Control Group.   The subjects in the control group began the
first week of the treatment period with the overarm serving
pattern.   Subjects were introduced to the serve and practiced
the basic motions.   At the end of week one, the first testing
session was conducted to determine the subject's serving ability
as measured by the Wisconsin Wall Test for Serve and Hewitt's
Tennis Achievement Test.

        During the second and third weeks, subjects practiced
the overarm serving pattern, working on general problems
involved in learning the serve.   At the end of the third week,
the Wisconsin Wall Test for Serve and Hewitt's Tennis Achieve-
ment Test were administered to determine the serving ability
of the subjects.

        After the second testing session (after week three),
subjects again practiced on the serve, working on specific
details to improve the placement and speed of the served ball.
At the end of week four, a third testing session was provided.
Refer to Appendix D for detailed lesson plans of the practice
sessions for the experimental group and Appendix E for the
control group.

        Table 2 presents a summarization of the paradigm utilized
within this study.   The following abbreviations were used
within Table 2:   M = Monday, T = Tuesday, W = Wednesday,
Th = Thursday, and F = Friday.

TABLE 2

PRACTICE AND TESTING SCHEDULE OF THE

CONTROL AND EXPERIMENTAL GROUPS

Week	1	2	3	4
Control Group	M,T,W,Th <u>Practice</u> Th,F Test 1	M,T,W,Th <u>Practice</u>	M,T,W,Th <u>Practice</u> Th,F Test 2	M,T,W,Th <u>Practice</u> Th Test 3
Experimental Group	M,T,W,Th <u>Practice</u> <u>Throwing</u>	M,T,W,Th <u>Practice</u> Th,F Test 1	M,T,W,Th <u>Practice</u>	M,T,W,Th <u>Practice</u> Th Test 2

The subjects were randomly counterbalanced across
groups during each of the testing periods for the order of
serving test completion.

Testing Purposes. The first testing session was administered
to both groups to determine the effects of learning and prac-
ticing the overarm throwing pattern before a great deal of
instruction was given on the overarm tennis serve. The se-
cond testing session was administered to both groups after
three weeks of practice on the serve. This testing session
was used to determine the effects of learning and practicing
the overarm throwing pattern during the later stages of learn-
ing and practicing the overarm tennis serve. Testing session
three was administered to the control group after four weeks
of practice on the serve. This test was compared with test
two of the experimental group, which was given after four weeks
of treatment -- one week of practice on the overarm throwing

pattern and three weeks of practice on the tennis serve. This comparison determined the overall effect of learning the overarm throwing pattern before learning the tennis serve. In essense, these comparisons answered the question of whether it was worth taking a week to practice and learn the overarm throwing pattern rather than beginning directly with the overarm tennis serve.

Statistical Procedures

In order to ascertain the effect of learning and practicing the mature overarm throwing pattern on serving ability in tennis, the analysis of covariance (ANCOVA) statistical procedure for multiple covariates was adopted. Two covariates were used in each analysis, the speed and accuracy of the overarm throw. A series of ANCOVA's were computed for each of the following dependent variables:

1. speed scores obtained from each of the serve tests,

2. accuracy scores obtained from each of the serve tests, and

3. combined scores of speed and accuracy obtained from each of the serve tests.

Analyses were conducted using data which was obtained at testing period one and two. An additional series of ANCOVA's were performed comparing the data from test period two for the group receiving a week's practice of overhand throwing with the scores of the control group at test period three.

Prior to using the analysis of covariance procedure,

a basic assumption must be met. A condition of homogeneity of regression must be present. This assures that the regression of the covariates on the dependent variable will be consistent for both the experimental and control groups. This assumption was tested by an F-test procedure. All analyses conducted within this study adopted the .05 level of significance (34:809-812).

Chapter IV

RESULTS

The data which are presented in this study were collected during three testing sessions over a period of four weeks. The analyses of the data presented in this chapter were computed in an attempt to determine what effect learning and practicing the overarm throwing pattern had upon the subsequent acquisition of the overarm serving pattern.

Group Differences for Testing Period One

Testing session one was administered to both the experimental group and the control group after each had participated in one week of practice on the overarm tennis serve. By using the ANCOVA statistical procedure for multiple covariates from the scores on throwing speed and throwing accuracy, it was found that there were no significant differences in serving ability between the experimental group and the control group at testing period one. The hypotheses predicting that the experimental group would show a greater degree of serving ability at testing period one than the control group was rejected for the dependent variables of accuracy, speed, and a combined score of speed and accuracy on both the Wisconsin and the Hewitt serve tests. These results may be seen in Table 3 as each of the F-tests for differences between the group means was not significant at the .05 alpha level.

TABLE 3

HOMOGENEITY OF REGRESSION AND ANCOVA TESTS FOR THE DIFFERENCE

BETWEEN THE GROUPS DURING TESTING PERIOD ONE

Dependent Measure	Unadjusted Mean Control Group (n=23)	Unadjusted Mean Experimental Group (n=25)	Adjusted SS Treatment	Adjusted SS Error	F-test Group Differences	F-test Homogeneity of Regression
Wisconsin-Accuracy	72.826	52.000	834.941	12801.901	2.870	9.707*
Wisconsin-Speed	22.237	18.811	30.696	1544.343	0.875	37.542*
Wisconsin-Combined	553.956	589.440	31809.962	1566933.835	0.893	1.115
Hewitt-Accuracy	5.609	6.120	33.180	901.956	1.525	2.675
Hewitt-Speed	4.870	6.240	27.400	1056.273	1.141	4.430*
Hewitt-Combined	10.478	12.360	201.751	3614.733	2.456	3.059

Group Difference Critical Value $F_{.05}, (1,44) = 4.06$

Homogeneity of Regression Critical Value $F_{.05}, (2,42) = 3.22$

* $p < .05$

Due to the fact that significance was not reached on any of the dependent variables, these results were interpreted to signify that the learning and practicing of the overarm throwing pattern prior to learning the overarm serving pattern had neither a facilitory affect nor an inhibitory affect on a subject's serving ability at testing period one.

Three of the serving tests in Table 3 met the basic assumption of homogeneity of regression at the .05 level of significance: (1) Wisconsin - combined, $F(2,42) = 1.115$, (2) Hewitt - accuracy, $F(2,42) = 2.675$, and (3) Hewitt - combined, $F(2,42) = 3.059$. The remaining three tests in Table 3 indicated the presence of heterogeneity of regression. Although three of the six analyses indicated the presence of heterogeneity of regression, a decision was made not to utilize the Neyman-Johnson technique (24:241-256). This decision was predicated upon the fact that each omnibus F-test was not significant.

Group Differences for Testing Period Two

Testing session two was administered to both the experimental group and the control group after each had completed three weeks of practice on the overarm tennis serve. At testing period two, it was found, through the use of the ANCOVA statistical technique for the multiple covariates of speed and accuracy of the overarm throw, that no significant differences in serving ability existed between the experimental group and the control group. This may be noted in Table 4.

TABLE 4

HOMOGENEITY OF REGRESSION AND ANCOVA TESTS FOR THE DIFFERENCE

BETWEEN THE GROUPS DURING TESTING PERIOD TWO

Dependent Measure	Unadjusted Mean Control Group (n=23)	Unadjusted Mean Experimental Group (n=25)	Adjusted SS Treatment	Adjusted SS Error	F-test Group Differences	F-test Homogeneity of Regression
Wisconsin-Accuracy	60.783	51.240	742.893	12044.895	2.714	4.221*
Wisconsin-Speed	21.566	18.386	70.175	1208.378	2.555	39.556*
Wisconsin-Combined	578.478	600.880	4527.921	1550625.438	0.128	5.703*
Hewitt-Accuracy	6.826	5.440	12.777	680.384	0.826	1.001
Hewitt-Speed	5.130	5.360	32.643	652.504	2.317	1.116
Hewitt-Combined	11.957	10.800	12.235	2443.515	0.220	0.784

Group Difference Critical Value $F_{.05, (1,44)} = 4.06$

Homogeneity of Regression Critical Value $F_{.05, (2,42)} = 3.22$

* $p < .05$

In light of these results, the hypotheses predicting that the experimental group would show a greater degree of serving ability at testing period two when compared to the control group was rejected for the dependent variables of accuracy, speed, and a combined score of speed and accuracy on both the Wisconsin serve test and the Hewitt serve test. Collectively, these results indicated that, at testing period two, the learning and practicing of the overarm throwing pattern prior to learning the overarm serving pattern, neither positively nor negatively affected a subject's serving ability.

Of the above mentioned serving tests, in Table 4, three met the basic assumption of homogeneity of regression: (1) Hewitt - accuracy, $F(2,42) = 1.001$, (2) Hewitt - speed, $F(2,42) = 1.116$, and (3) Hewitt - combined, $F(2,42) = 0.784$. The three analyses computed for the Wisconsin serving test indicated the presence of heterogeneity of regression. A decision was made not to utilize the Neyman-Johnson technique (24:241-256), despite the fact that three of the six analyses suggested the presence of heterogeneity of regression. The fact that each omnibus F-test was not significant provided the basis for this decision.

Group Differences for Testing Period Three of the Control Group and Testing Period Two of the Experimental Group

Testing session three was administered to the control group after four weeks of practice on the tennis serve. These scores were compared with testing session two of the experimental group, which was conducted at the completion of the

four week treatment period, after one week of practice on the overarm throwing pattern followed by three weeks of practice on the overarm tennis serve. The ANCOVA statistical technique for multiple covariates was again used to analyze the results. The statistical results indicated that the differences in means between the groups for Hewitt's accuracy test and a combined score on Hewitt's serving test were significant. Refer to Table 5, for a total composite of these results.

The hypothesis that the experimental group at testing period two would show greater accuracy of serve placement scores when compared to the control group at testing period three, on the Wisconsin serve test, was rejected. The differences in scores between groups did not reach significance, $F(1,44) = 3.151$.

The hypothesis that the experimental group at testing period two would show greater accuracy of serve placement scores when compared with the control group at testing period three, on Hewitt's serve test, was also rejected. A significant difference of $F(1,44) = 7.602$ was found for the comparison of the group means. However, by comparing the adjusted mean of the control group ($M = 8.802$) with the adjusted mean of the experimental group ($M = 6.750$), it was found that the control group performed significantly better on the Hewitt accuracy test than did the experimental group.

The hypotheses that the experimental group at testing period two would show greater speed of serve scores than the

TABLE 5

HOMOGENEITY OF REGRESSION AND ANCOVA TESTS FOR THE DIFFERENCE

BETWEEN THE CONTROL GROUP AT TESTING PERIOD

THREE AND THE EXPERIMENTAL GROUP AT TESTING PERIOD TWO

Dependent Measure	Unadjusted Mean Control Group (n=23)	Unadjusted Mean Experimental Group (n=25)	Adjusted SS Treatment	Adjusted SS Error	F-test Group Differences	F-test Homogeneity of Regression
Wisconsin-Accuracy	59.304	51.24	759.574	10608.123	3.151	16.911*
Wisconsin-Speed	21.521	18.386	49.364	1193.197	1.820	42.425*
Wisconsin-Combined	584.826	600.880	114123.300	1306347.200	3.303	2.464
Hewitt-Accuracy	8.783	5.440	113.120	651.751	7.602*	0.969
Hewitt-Speed	7.522	5.360	45.316	542.531	3.675	0.796
Hewitt-Combined	16.304	10.800	329.484	2152.118	6.786*	0.768

Group Difference Critical Value $F_{.05, (1,44)} = 4.06$

Homogeneity of Regression Critical Value $F_{.05, (2,42)} = 3.22$

* $p < .05$

control group at testing period three, on the Wisconsin serve test and Hewitt's serve test, was rejected. This was evident by the fact that the difference in scores between groups did not reach significance, $F(1,44) = 1.820$ for the Wisconsin speed test and $F(1,44) = 3.675$ for Hewitt's speed test.

The hypothesis that the experimental group at testing period two would show a greater combined score of speed and accuracy than the control group at testing period three, on the Wisconsin serve test, was rejected. The difference in scores between groups for a combined score of speed and accuracy did not reach significance, $F(1,44) = 3.303$.

The hypothesis that the experimental group at testing period two would show a greater combined score of speed and accuracy when compared to the control group at testing period three, on Hewitt's serve test, was rejected. A significant difference of $F(1,44) = 6.736$ was found for the comparison of the means. However, when comparing the adjusted mean of the control group ($M = 15.675$) with the adjusted mean of the experimental group ($M = 9.480$), it was found that the control group performed better than the experimental group.

As previously indicated, significance was reached at the .05 level for two dependent variables: (1) Hewitt - accuracy, $F(1,44) = 7.602$ and (2) Hewitt - combined, $F(1,44) = 6.736$. These significant results indicated that the four weeks of practice on the serve by the control group was more beneficial to serving ability than the experimental group's one week of practice on the overarm throwing pattern followed

by three weeks of practice on the serve, when measured by the Hewitt accuracy score and the Hewitt combined score. It appeared that in these two dependent variables, serving ability was facilitated by the additional week of physical practice on the serve which the control group was exposed to. Significance was not reached for the remaining four dependent variables appearing in Table 5, indicating that learning and practicing the overarm throwing pattern prior to learning the overarm tennis serve, neither facilitated nor inhibited a subject's serving ability, at the completion of the fourth week of this study.

As shown in Table 5, the homogeneity of regression assumptions were violated for the speed and accuracy scores on the Wisconsin serve test. A decision was made not to utilize the Neyman-Johnson technique (24:241-256) as the omnibus F-test for each of these variables was not significant.

Discussion

The intent of this study was to determine how prior practice on the overarm throwing pattern affected a beginner's serving ability during a four week treatment period. From the overall results, it appeared that, earlier practice on the overarm throwing pattern neither facilitated nor inhibited a subject's serving ability, except at testing period three of the control group versus testing period two of the experimental group on the Hewitt accuracy test and on a combined score of speed and accuracy on the Hewitt test.

As mentioned in the review of literature, Mason advocates that a student should learn the serve by first practicing throwing a ball using the overarm pattern. The rationale supporting this method is the belief that the throwing action, weight transfer, body rotation, and arm and wrist action are almost identical to that of the overarm serving pattern (20). Many other authorities (3,4,5,21,22 and 23) also believe that the overarm throwing pattern is essentially the same as the overarm serving pattern. If this contention is true, it would seem reasonable to hypothesize that, individuals who had prior practice on the overarm throwing pattern, would overall, demonstrate a higher level of serving ability as opposed to subjects who did not receive prior practice on the overarm throwing pattern. However, the results of this study indicated that, prior practice on the overarm throwing pattern did not significantly yield better performance scores on the serve tests employed in this study. One possible reason for this finding involves the learning of the overarm throwing pattern. It is possible, that subjects who were characterized by an immature overarm throwing pattern, were not given ample time to practice the pattern, or to "learn" the movement pattern. Learning requires that a movement pattern be habitual in nature, without the involvement of higher symbolic thought processes to execute the specific movement pattern. If this be the case, subjects would possess a great deal of variance in the movement pattern, allowing little, if any, positive transfer between the over-

arm throwing pattern and the overarm serving pattern. However, if most of the subjects were mature throwers, little benefit may have been gained from prior practice on the overarm throwing pattern before instruction was given on the tennis serve. From the above mentioned rationale, it is probable that Mason's advise in particular, may be more beneficial to the lower skilled throwers.

When comparing testing session three of the control group with testing session two of the experimental group, it was found that the control group performed significantly better with respect to two of the six dependent variables utilized in this study: (1) Hewitt - accuracy and (2) Hewitt - combined. This finding raises the question of why these significant differences did not appear on the Wisconsin serve test also. There are two possible reasons for this discrepancy. First, when considering the accuracy measures for both of the serve tests, it appears that Hewitt's test places more emphasis on the actual placement of the ball into the correct service court, where as the Wisconsin test measures accuracy by recording the height of the served ball when it comes in contact with the wall target. The Hewitt test allows feedback related to an actual game situation, where as the Wisconsin test does not. In light of this visual feedback, it is possible that subjects were motivated to a greater extent on the Hewitt test because it was possible to see the end result of each serve, which could account for the better accuracy scores on the Hewitt test for the control group.

Second, when considering a combined score of speed and accuracy, the method of measuring the component of speed becomes very important. The Hewitt test employs an indirect method to measure speed, that being the measurement of the zone in which the served ball hits on the second bounce. This method does not precisely differentiate between subjects as to the speed each subject imparted to the served ball. The Wisconsin test employs a direct method of measuring speed by utilizing a stop watch. This method discriminates quite precisely the differences in speed scores between subjects. When accounting for the method used in Hewitt's test to measure speed, compounded with the feedback provided in Hewitt's accuracy test, it is possible to comprehend why subjects performed significantly better on these two dependent variables for Hewitt's test when compared to the Wisconsin accuracy score and the Wisconsin combined score.

A third factor which influenced the difference between the control group and the experimental group, is that the control group had an additional week of serving practice. Accuracy may take more time to develop, especially in light of how the two serving tests measure the components of speed and accuracy. Some support is given in the analysis, for the control and experimental groups did not differ in their speed scores on either serving test.

Concerning the violations of the homogeneity of regression assumption, it would appear that a more sensitive paradigm would involve the use of a randomized block design.

In this procedure, subjects would be grouped according to their initial throwing ability and then randomly assigned to either the experimental group or the control group. This would further serve as an aid in reducing the amount of within group error variability, which appeared quite large in this study. In turn, this would improve the power of the study in rejecting a null hypothesis. One consideration must be pointed out. A person's combined score would have to be used as the variable upon which to classify subjects. This becomes necessary, as a trade off of throwing speed for greater accuracy is a possible strategy which a subject could adopt.

Chapter V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The intent of this study was to determine the
effects of learning and practicing the overarm throwing
pattern upon the subsequent acquisition of the overarm
tennis serve.

Summary

Forty-eight subjects selected from various beginning
activity classes at Sam Houston State University volunteered
to participate in this study. The Wisconsin Throw Test was
administered as a pre-test during the week prior to the be-
ginning of the study to evaluate a subject's throwing speed
and throwing accuracy. This pre-test determined the covari-
ates to be used in the statistical analysis.

Subjects were then randomly assigned to one of two
groups -- an experimental group or a control group. The
control group (n = 23) practiced the overarm serve for four
weeks. The experimental group (n = 25) practiced the over-
arm throwing pattern for one week and the overarm serve for
three weeks. Both groups were tested on serving speed, accur-
acy, and a combined score of speed and accuracy by Hewitt's
Tennis Achievement Test and the Wisconsin Wall Test for Serve.

Three different comparisons were computed using the
ANCOVA statistical procedure for multiple covariates. Testing
session one was administered after both groups had received

one week of practice on the serve. This comparison deter-

mined the effects of learning and practicing the overarm

throwing pattern, before a great deal of instruction on

the overarm tennis serve was given. Testing session two

was administered to both groups after three weeks of prac-

tice on the serve. This comparison determined the effects

of learning and practicing the overarm throwing pattern

during the later stages of learning and practicing the over-

arm tennis serve. Testing session three was administered

to the control group after four weeks of practice on the

serve, and was compared with test two of the experimental

group. This comparison determined the overall effect of

learning the overarm throwing pattern before learning the

overarm tennis serve.

A series of ANCOVA's were computed for each of the

following dependent variables:

1. speed scores obtained from each of the serve

tests,

2. accuracy scores obtained from each of the serve

tests, and

3. combined scores of speed and accuracy obtained

from each of the serve tests.

The results of the analyses suggested the following:

1. When analyzing the effect of learning and practicing

the overarm throwing pattern upon the subsequent acquisition

of the overarm tennis serve at testing period one, it was

found that:

a. there were no significant differences

between the groups on accuracy scores obtained from either the Wisconsin accuracy test or from Hewitt's accuracy test.

b. there were no significant differences between groups on speed scores obtained from either the Wisconsin speed test or from Hewitt's speed test.

c. there were no significant differences between the groups on a combined score of speed and accuracy obtained from either the Wisconsin serve test or from Hewitt's serve test.

2. When analyzing the effect of learning and practicing the overarm throwing pattern upon the subsequent acquisition of the overarm tennis serve at testing period two, it was found that:

a. there were no significant differences between groups on accuracy scores obtained from either the Wisconsin accuracy test or from Hewitt's accuracy test.

b. there were no significant differences between groups on speed scores obtained from either the Wisconsin speed test or from Hewitt's speed test.

c. there were no significant differences between groups on a combined score of speed

and accuracy obtained from either
the Wisconsin serve test or from
Hewitt's serve test.

3. When analyzing the effect of learning and prac-
    ticing the overarm throwing pattern upon the
    subsequent acquisition of the overarm tennis
    serve at testing period three of the control
    group with testing period two of the experimental
    group, it was found that:

    a. there was not a significant difference
        between groups on accuracy scores obtained
        from the Wisconsin accuracy test.

    b. there was a significant difference between
        groups on accuracy scores obtained from
        Hewitt's accuracy test, with the control
        group performing significantly better than
        the experimental group.

    c. there were no significant differences between
        groups on speed scores obtained from either
        the Wisconsin speed test or from Hewitt's
        speed test.

    d. there was not a significant difference between
        groups on the combined scores of speed and
        accuracy obtained from the Wisconsin serve
        test.

    e. there was a significant difference between
        groups on the combined scores of speed and

accuracy obtained from Hewitt's serve
test, with the control group performing
significantly better than the experi-
mental group.

Conclusions

The following conclusions may be drawn from the
results yielded by this study.

1. Learning and practicing the overarm throwing
pattern prior to receiving instruction on the overarm serving
pattern, does not facilitate or inhibit the acquisition of
the overarm serve, except when comparing testing period three
of the control group with testing period two of the experi-
mental group. At this comparison, the control group per-
formed significantly better when analyzing the dependent
variables of accuracy scores and combined scores of speed
and accuracy on the Hewitt serve test.

2. After one week of practice on the serve, or during
the early stages of learning the serve, it is apparent that
serving ability is neither enhanced nor inhibited by previous
instruction on the overarm throwing pattern.

3. At the completion of three weeks of practice on
the serve, or during the later stages of learning the serve,
serving ability is not significantly affected by prior in-
struction on the overarm throwing pattern.

4. When comparing testing period three of the control
group with testing period two of the experimental group, in
determining the overall effect of prior instruction on the
overarm throwing pattern upon the acquisition of the overarm

tennis serve, it was found that, the only significant differences between the groups occurred for the dependent variables of Hewitt - accuracy and Hewitt - combined, in which case the control group performed significantly better than the experimental group.

5. Practicing the overarm throwing pattern in preparation for learning the serve could provide for an excellent indoor activity during inclement weather, as no inhibitory effects are suggested at the present time.

6. It appears that either teaching methodology advocated in this study would be appropriate, depending upon an individual's personal philosophy, time allotment, available equipment, and the availability of facilities.

Recommendations

After reviewing the results of this study, the following recommendations were appropriate:

1. A study should be conducted to look at the same problem as was researched in this study, utilizing a randomized block design, which would allow subjects to be blocked or grouped according to throwing ability. This would help decrease the amount of variability among subjects within groups.

2. It would be interesting to conduct a study to determine the amount of transfer which is inherent between the overarm throwing pattern and the overarm tennis serve.

3. A study needs to be conducted to determine exactly, which aspects or components of the overarm throwing pattern

are detrimental to the acquisition of the overarm serving pattern. For example, does the forward arm movement of the serve follow the same path as the forward arm movement of the overarm throwing pattern? If not, then would the overarm throwing method be detrimental to the cognitive and associative stages of the learning process?

4. Further research is needed to determine the optimum amount of practice needed on the overarm throwing pattern, in order for this practice to be beneficial to learning the overarm tennis serve.

5. It would be interesting to find out if individuals who possess an excellent serve as demonstrated by speed and accuracy scores, also demonstrate excellent throwing ability. Pasarell believes that, those who can throw a ball with some observable degree of skill, should be able to serve a tennis ball (22:33).

APPENDIX A

APPENDIX A

SCORE SHEET - WISCONSIN THROW TEST

SCORERS OR TIMERS

SUBJECT   TRIALS   SUBJECT   TRIALS

	1	2	3	4	5	6

	1	2	3	4	5	6

APPENDIX B

APPENDIX B

SCORE SHEET - SERVING TESTS

S s #	1	2	3	4	5	6	7	8	9	10

APPENDIX C

APPENDIX C

WISCONSIN WALL CONVERSION TABLES (2:336)

Vertical Placement		Velocity	
Wall Area	Point Values	Time	Point Values
11'	1	4.00	300
10'	2	4.25	290
9'	4	4.50	280
8'	6	4.75	270
7'	7	5.00	260
6'	8	5.25	250
5'	9	5.50	240
4' Net	10	5.75	230
		6.00	220
3'	6	6.25	210
2'	4	6.50	200
1'	2	6.75	190
		7.00	180
		7.25	170
		7.50	160
		7.75	150
		8.00	140
		8.25	130
		8.50	120
		8.75	110
		9.00	100
		9.50	90
		10.00	80
		10.50	70
		11.00	60
		11.50	50
		12.00	40
		12.50	30
		13.00	20
		13.50	10
		13.51+	0

*Velocity Scores treated in terms of 10 serves, not in terms of individual serves.

APPENDIX D

APPENDIX D

TREATMENT PERIOD - EXPERIMENTAL GROUP

I. Week 1

    A. Monday, February 7, 1977 -- General Body Orientation

        1. Demonstrate and explain motions of overarm throwing pattern (no ball)

            a. body position

            b. leg action, arm action, trunk action

            c. practice motions

        2. Wall drills

            a. forward arm movement with finger touch against wall

            b. emphasize follow-through

        3. Demonstrate throw against wall

        4. Subjects practice throwing against wall

    B. Tuesday, February 8, 1977 -- Leg Movement, Arm Movement, and Trunk Movement

        1. General review and warm-up (no ball)

            a. explain and demonstrate overarm throwing pattern

            b. subjects practice motions with no ball

            c. subjects practice throwing against wall

        2. Leg movement (weight transfer back and forward)

            a. demonstrate and explain

            b. subjects practice

        3. Trunk action

            a. demonstrate and explain

      b.   subjects practice

4.   Leg and Trunk movement together

5.   Arm movement (back and forward)

      a.   demonstrate and explain

      b.   subjects practice

6.   Put all the movements together, practicing the motion without a ball

7.   Wall practice

      a.   draw a box approximately 2' by 2'

      b.   get as many balls in as possible out of 10

C. Wednesday, February 9, 1977 -- Accuracy Work

1.   Warm-up

      a.   motion drill against the wall

      b.   throwing against the wall

      c.   partner work - one person throw and the other observe and correct the movement pattern

2.   With a partner, practice throwing the width of the gym

3.   Target work on the wall

      a.   aim for a 2' by 2' box, trying for 8 out of 10 hits

      b.   place an X in the middle of the above box, and try for 5 out of 10 hits

D. Thursday, February 10, 1977 -- Movement Pattern, Accuracy, and Speed

1.   Warm-up

      a.   throwing against wall, concentrating on the movement pattern itself

          b.   throwing to a partner

     2.   Accuracy

          a.   aim for a 2' by 2' box

          b.   aim for an X placed in the above box

     3.   Speed - add speed work to the above practice on accuracy

II.   Week 2

   A.   Monday, February 14, 1977 -- General Stroking Motions and Ball Toss

     1.   General stroking motion

          a.   demonstrate and explain

          b.   subjects practice with no racket

          c.   put subjects on court and have them throw from a half court position to get general concept of serve and flight of ball

          d.   practice stroking motion with racket

     2.   Ball toss

          a.   demonstrate and explain

          b.   subjects practice toss, letting ball drop to racket face on floor as a target area

     3.   Put racket motion together with ball toss

          a.   practice coordinating the 2 motions together without contacting the ball

          b.   practice serving against the wall

   B.   Tuesday, February 15, 1977 -- General Stroking Motions and Ball Toss

     1.   General stroking motion (review)

        a. demonstrate and explain

        b. subjects practice with racket

    2. Ball toss (review)

        a. demonstrate and explain

        b. subjects practice

    3. Stroking motion with ball toss

        a. demonstrate and explain

        b. subjects practice without contacting ball

    4. Practice serving against the wall

C. Wednesday, February 16, 1977 -- Specific Problems and General Placement (same as for Tuesday, February 15, 1977)

D. Thursday, February 17, 1977 -- Specific Problems and General Placement

    1. subjects were divided into 2 groups

    2. group 1 practiced serving against the wall

    3. group 2 practiced serving on the court

    4. groups switch after 15 minutes

E. Thursday, February 17, 1977 and Friday, February 18, 1977 -- Test 1

III. Week 3

A. Monday, February 21, 1977 -- Court Placement, Areas 1 and 2

    1. Group 1 (wall practice)

        a. keep ball within net line and upper line on wall

        b. try for 8 out of 10 in a row

      2. Group 2 (court practice)

        a. aim for areas 1 and 2 in the right or left service court (opponents forehand side)

      3. Groups switch after 15 minutes

B. Tuesday, February 22, 1977 -- Court Placement, Areas 1 and 2 (same as for Monday, February 21, 1977)

C. Wednesday, February 23, 1977 -- Court Placement, Areas 3 through 6 (same as for Monday, February 21, 1977 aiming for areas 3 through 6)

D. Thursday, February 24, 1977 -- Court Placement, Areas 3 through 6 (same as for Monday, February 21, 1977 aiming for areas 3 through 6)

IV. Week 4

A. Monday, February 28, 1977 -- Speed Work and Accuracy

      1. Group 1 - wall work

      2. Group 2 - court work

      3. groups switch after 15 minutes

B. Tuesday, March 1, 1977 -- Speed Work and Accuracy (same as for Monday, February 28, 1977)

C. Wednesday, March 2, 1977 -- Confidence Work (same as for Monday, February 28, 1977)

D. Thursday, March 3, 1977

      1. Individual practice

      2. Test 2

APPENDIX E

APPENDIX E

TREATMENT PERIOD - CONTROL GROUP

I. Week 1

A. Monday, February 7, 1977 -- General Body Orientation
    and Movement Pattern of Serve and Ball Toss

    1. Demonstrate and explain general stroking motions

        a. body position

        b. leg, arm, and trunk action

        c. practice motion with no racket

        d. emphasize forward arm movement with follow-
            through

    2. Ball toss

        a. explain and demonstrate

        b. subjects practice

        c. use racket face as target on floor

    3. Arm motion with ball toss

        a. explain and demonstrate against wall

        b. subjects practice against wall using hand as
            a racket

        c. subjects practice against wall using racket

B. Tuesday, February 8, 1977 -- Leg Movement, Arm Movement,
    and Trunk Movement

    1. General review and warm-up

        a. explain and demonstrate

        b. subjects practice without racket

    2. Leg movement (weight transfer)

a. explain and demonstrate

b. subjects practice

3. Trunk movement

a. explain and demonstrate

b. subjects practice

4. Combine leg movement with trunk movement

5. Arm movement (backswing and forward swing)

a. explain and demonstrate

b. subjects practice

6. Put all the movements together

7. Review ball toss

a. subjects practice

b. racket on floor for aiming purposes

8. Wall practice using hand

9. Ball toss with racket motion

a. practice coordination without ball contact

b. practice against the wall

C. Wednesday, February 9, 1977 -- Ball Toss and Stroking

1. Warm-up

a. review the stroke

b. stroking with racket (no ball)

c. review ball toss and practice

2. Put toss and racket motion together without contacting ball

3. Practice stroking against the wall

D. Thursday, February 10, 1977 -- Stroking Motion and Ball Toss

      1. Warm-up serving against the wall

      2. Divide subjects into 2 groups

         a. group 1 - wall work

         b. group 2 - court work

         c. groups switch after 10 minutes

E. Thursday, February 10, 1977 and Friday, February 11, 1977 -- Test 1

II. Week 2

A. Monday, February 14, 1977 -- General Stroking Motions

      1. Divide into 5 groups

         a. group 1 - court work

         b. group 2 - serving motion with ball toss

         c. groups 3, 4, and 5 - wall work

      2. Groups rotate every 5 minutes

B. Tuesday, February 15, 1977 -- General Stroking Motions

      1. Subjects divided into 2 permanent groups

      2. Group 1 - court work

      3. Group 2 - wall work

      4. Groups switch after 15 minutes

C. Wednesday, February 16, 1977 -- Specific Stroking Problems and General Placement (same as for Tuesday, February 15, 1977)

D. Thursday, February 17, 1977 -- Specific Stroking Problems and General Placement (same as for Tuesday, February 15, 1977)

III.   Week 3

    A.   Monday, February 21, 1977 -- Court Placement,
        Areas 1 and 2

        1.   Group 1 - wall work

            a.   keep ball within net line and upper line on
                wall

            b.   try for 8 out of 10 in a row

        2.   Group 2 - court work

            a.   aim for areas 1 and 2 in the right or left
                service court (opponents forehand side)

        3.   Groups switch after 15 minutes

    B.   Tuesday, February 22, 1977 -- Court Placement,
        Areas 1 and 2 (same as for Monday, February 21, 1977)

    C.   Wednesday, February 23, 1977 -- Court Placement,
        Areas 3 through 6 (same as for Monday, February 21, 1977
        aiming for areas 3 through 6)

    D.   Thursday, February 24, 1977 -- Court Placement Areas
        3 through 6 (same as for Monday, February 21, 1977
        aiming for areas 3 through 6)

    E.   Thursday, February 24, 1977 and Friday, February 25,
        1977 -- Test 2

IV. Week 4

    A.   Monday, February 28, 1977 -- Accuracy and Speed Work

        1.   Group 1 - wall work

        2.   Group 2 - court work

        3.   Groups switch after 15 minutes

    B.   Tuesday, March 1, 1977 -- Accuracy and Speed Work
        (same as for Monday, February 28, 1977)

C. Wednesday, March 2, 1977 -- Confidence Work (same
    as for Monday, February 28, 1977)

D. Thursday, March 3, 1977

    1. Individual practice

    2. Test 3

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Barnaby, Jack. Advantage Tennis. Boston: Allyn and Bacon, Inc., 1975.

2. Barrow, Harold M. and Rosemary McGee. A Practical Approach To Measurement in Physical Education, 2nd ed. Philadelphia: Lea and Febiger, 1971.

3. Broer, Marion. Efficiency of Human Movement, 3rd ed. Philadelphia: W. B. Saunders Company, 1973.

4. Cantin, Eugene. "You Do Not Serve Down At the Court," World Tennis, 22, (January, 1974), 52-53.

5. Cooper, John and Ruth Glassow. Kinesiology. St. Louis: Mosby, 1968.

6. Cratty, Bryant J. Perceptual and Motor Development in Infants and Children. New York: The Macmillan Company, 1970.

7. Dauer, Victor P. Dynamic Physical Education for Elementary School Children, 4th ed. Minneapolis, Minnesota: Burgess Publishing Company, 1971.

8. DiGennaro, Joseph. "Construction of Forehand Drive, Backhand Drive, and Serve Tennis Tests," Research Quarterly, 40 (October, 1969), 496-501.

9. Edwards, Janet. "A Study of Three Measures of the Tennis Serve." Unpublished Master's Thesis, University of Wisconsin, 1965.

10. Espenschade, Anna S. and Helen M. Eckert. Motor Development. Columbus, Ohio: Charles E. Merrill Publishing Co., 1967.

11. Fiereck, Lavonne M. "Assessments of Velocity of the Tennis Serve of College Women." Unpublished Master's Thesis, Southern Illinois University, 1969.

12. Gould, Dick. Tennis, Anyone? 2nd ed. Palo Alto, California: National Press Books, 1971.

13. Gray, Marvin R. What Research Tells the Coach About Tennis. Washington, D.C.: American Association of Health, Physical Education, and Recreation, 1974.

14. Hewitt, Jack. "Hewitt's Tennis Achievement Test," Research Quarterly, 37, (May, 1966), 231-240.

15. Jensen, Clayne R. and Gordon W. Schultz. Applied Kinesiology. New York: McGraw-Hill Book Company, 1970.

16. Johnson, Joan. "Tennis Serve of Advanced Women Players," Research Quarterly, 28 (May, 1957), 123.

17. Jones, Shirley Kathryne. "A Measure of Tennis Serving Ability." Unpublished Master's Thesis, University of California at Los Angeles, 1967.

18. Leme, Sally A. "Developmental Throwing Patterns in Adult Female Performers Within a Selected Velocity Range." Unpublished Master's Thesis, University of Wisconsin, 1973.

19. Malinak, Nina R. "The Construction of an Objective Measure of Accuracy in the Performance of the Tennis Serve." Unpublished Master's Thesis, University of Illinois at Urbana, 1961.

20. Mason, R. Elaine. "New Tennis Progressions," Journal of Health, Physical Education and Recreation, 39, (April, 1968), 24-28.

21. Mason, R. Elaine. Tennis. Boston: Allyn and Bacon, Inc., 1974.

22. Pasarell, Charlie. "How To Make Your Serve an Effective Weapon," World Tennis, 24, (December, 1976), 33-35.

23. Plagenhoef, Stanley. Fundamentals of Tennis. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1970.

24. Pottloff, R. F. "On the Johnson-Neyman Technique and Some Extension Thereof," Psychometrika, 29, (1964), 241-256.

25. Robb, Margaret D. The Dynamics of Motor Skill Acquisition. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1973.

26. Safrit, Margaret J. Evaluation in Physical Education. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1973.

27. Scott, M. Gladys. Analysis of Human Motion, 2nd ed. New York: Appleton-Century-Crofts, 1963.

28. Sebolt, Don R. "A Stroboscopic Study of the Relationship of Ball Velocity and Tennis Performance," Research Quarterly, 41, (May, 1970), 182-188.

29. Singer, Francine. "Comparison of the Development of the Overarm Throwing Patterns of Good and Poor Performers (Girls)." Unpublished Master's Thesis, University of Wisconsin, 1961.

30. University of Wisconsin - Madison. Personal correspondence
        between Dr. Marie Liba and Dr. Doris Horton. Date
        unknown.

31. Wells, Katharine F. Kinesiology, 5th ed. Philadelphia:
        W. B. Saunders Company, 1971.

32. Wickstrom, Ralph. Fundamental Motor Patterns. Philadelphia:
        Lea and Febiger, 1970.

33. Wild, Monica R. "The Behavior Pattern of Throwing and Some
        Observations Concerning its Course of Development in
        Children," Research Quarterly, 9, (October, 1938), 20-24.

34. Winer, B. J. Statistical Principles in Experimental Design.
        New York: McGraw-Hill Book Company, 1971.

35. Women's Softball. Chicago: The Athletic Institute, 1971.