A STUDY OF AN ANALYTICAL AND KINESIOLOGICAL APPROACH

TO TEACHING BOWLING

by

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CHAPTER I

INTRODUCTION AND STATEMENT OF PROBLEM

The traditional method of teaching, as generally used by physical educators, is based upon teacher explanation, demonstration, and individual correction of errors. Although this is the basis of teaching methodology in physical education, numerous research studies have been conducted to investigate the effect on performance when variations and additions have been incorporated into this method in an effort to make learning more effective.

An analytical approach to teaching, based on kinesiology, has frequently been used in attempts to enhance learning. Kinesiology, the science of human motion, makes an unique contribution to the field of physical education because it makes application from the fields of anatomy, physics, and physiology, the principles that govern human movement. Of foremost importance are the principles of mechanics, which govern all movements, whether of the human body or of inanimate objects. Principles of mechanics, therefore, provide a scientific and objective approach to teaching motor skills, all of which involve movement of the human body and of inanimate objects. This analytical approach, through the medium of principles of mechanics and selected kinesiological principles, is not an end in itself, but a means of understanding movement patterns and improving established patterns.

Although perhaps too little emphasis has been placed on the analytical approach to teaching through the application of mechanical principles, physical educators have long realized the importance of an understanding of the scientific principles upon which effective learning is based. McCloy (50), in a discussion of motor educability, stated that an understanding of the mechanics of an activity is a prerequisite to effective learning. Understanding of the nature of a skill was stated as a definite factor in motor learning. Studies, cited by McCloy, concluded that insight is developed by an understanding of the mechanics of an activity. Other definite factors in motor educability are also amenable to mechanical analysis. These factors are: sensory motor coordination of the eye, hand, foot, and an adaptation to weight and force, the relationship of the performer to external objects, accuracy of direction, arm control, and the function of balance. An understanding of these factors and how to relate them to specific sport's skills is of utmost importance to students as they learn new skills.

Statement of Problem

The purpose of this study was to develop an analytical approach to teaching and to investigate the effect of this approach on learning as compared to the traditional method of teaching. An analytical approach was developed in order to teach skills, not by imitation, but by an understanding of the application of these principles in enhancing improvement and evaluating performance.

Bowling, because it can be measured objectively, does not involve complex coordination, and lends itself well to the application of kinesiological and mechanical principles, was chosen as the motor skill for this investigation.

College women, enrolled in the required physical education program at the Woman's College of the University of North Carolina, were the subjects for the experimental and control classes.

CHAPTER II

REVIEW OF LITERATURE

Mechanical and Kinesiological Principles Related to Movement

In order to choose principles which are applicable to the analysis of bowling, the writer felt it necessary to review the mechanical and kinesiological principles which are basic to the fundamentals of sports activities. An understanding of these basic principles and the results that they produce when applied to the body and to sports implements gave the writer background for the selection of principles relating to bowling and their application to an analysis of bowling skill.

Of significance to the analysis of sports activities are principles of balance. Because sports demand that the body be placed in various positions at different speeds, it is important to the analysis of many sports activities to understand the principles of mechanics and kinesiology which occur when the body adjusts position to maintain balance.

In maintaining balance several principles must be considered and utilized in successful skill performance. Wells (30) and Bunn (4) list the following principles of stability as being fundamental to sports activities:

1. The wider the base of support, the greater will be the body's stability. (30:346)
2. Stability of the body is greatest when the center of gravity is directly over the base of support. (30:346)
3. Lowering the center of gravity will increase the stability of the body. (4:14)

4. Stability in a given direction is directly proportional to the horizontal distance of the center of gravity from the edge of the base of support. (4:14)

5. Stability is directly proportional to the weight of the body. (4:14)

6. A body is in equilibrium when its center of gravity falls within its base of support. (4:19)

In sports activities the teacher is generally, however, more concerned with balance in motion rather than static balance.

Motion, since its principles are applicable to the body as well as sports implements, is a prime consideration in motor performance. Motion of the body is produced by three factors: muscular contraction, gravitational attraction, and external application. According to Rashe and Burke (26:108), this phase of mechanics is often called biomechanics because the mechanical principles are applied to the living organism. These mechanics are both static, concerned with objects in a state of equilibrium, and dynamic, concerned with the body in motion. The dynamic mechanics are divided into two groups according to the end result produced from their application. Kinematics is the study of body motion without regard to the force acting on it; kinetics refers to the study of the forces which cause or change motion.

There are two major classifications of motion: rotary or angular, which is movement around a fixed point; and translatory movement, in which a movement may be either linear, motion in a straight line with all parts of the body moving in the same direction at a uniform rate of speed, or curvilinear, which is defined as motion in a curved path. (30:303)

The human body experiences all of these types of motion. Rotary motion, however, is the most common because most of the body's joints are axial and allow freedom of rotation.

Motion is a function of speed and direction. (4:7) Speed of motion is controlled by two factors: velocity, the rate of change in direction, and acceleration, the rate of change in velocity. When an external force acts, there is a change in velocity which is in direct proportion to the amount of change causing the change. The most important consideration relating to direction is the efficient integration of the movements of the parts of the body.

The laws of kinetics, those stating that forces cause motion or change in motion, were formulated by Sir Isaac Newton. These laws, basic to the science of mechanics, are of utmost importance to the physical educator in fostering an understanding of the basic elements in sports fundamentals.

Newton's first law is often called the law of inertia and is stated as follows: "Any object remains at rest or continues to move at a constant speed in a straight line unless acted upon by some external force." (18:19) This law has important application to sports, especially in the motion of balls. Unless a ball that is moving at a constant speed and in a given direction is resisted by friction, it would continue to roll forever; a ball in the air would continue to move in its established path unless the factors of air resistance and the downward pull of gravity take effect.

The second law states that "the acceleration of the body is directly proportional to the force acting, and is inversely proportional to the mass of the body." (18:10) From this law the relationship between force, mass, and acceleration is evident. A formula can be derived from this relationship and is stated as "Acceleration times the mass equals the force." (26:14)

The third law, the law of reaction, states that "forces always occur in pairs, and the two factors (action and reaction) in a pair are always equal and opposite." (18:10)

Rashe and Burke (26:119) emphasize that the application of this law is of great importance in developing effective and efficient performance in all activities in which the human body is propelled forward or used to throw or strike an object.

When force is sufficient to overcome resistance of an object, motion occurs. There are three aspects of force that must be considered in analysis of human motion: magnitude of the force, direction in which it is acting, and the position of the object on which it is exerting its pull. (30:313) According to Wells (30:313), magnitude is in direct proportion to the number and the size of the muscle fibers which are contracting; direction is determined by the relation of the tendon to the mechanical axis of the segment which is moving; and the point of application of the force is related to the attachment of the muscle to the bone.

The lever, a simple machine for the execution of work, is found in the human body. An important consideration for understanding the use of the lever is the forces that cause it to move and those that create the resistance. A lever is a rigid bar turning around a fixed point or axis. The position of the axis, the points of the application of the force, and the resistance determine the type of lever and its function. Application of mechanical principles to the lever makes it perform useful work for the body.

In the human body the arm is an example of a lever that is commonly used in activities. The bone is a rigid bar, the shoulder joint is the axis of rotation, and the muscles are the operating force. Resistance is the arm itself, or some external force that is operating. The weight that is applied to the lever is usually concentrated at the point of resistance. (30:228)

Any lever may have varying degrees of usefulness for a given purpose, depending upon the location of three points: point of application of force, point of resistance, and the axis around which the lever turns. Levers are divided into three classifications depending upon the location of these three points. The location of these points also determines the length of the lever arm which in turn influences the action of the lever. Arms are measured from the axis. The distance from the axis to the point of force is called the force arm, and the distance from the axis to the resistance is called the resistance arm. The force arm should be long if power is desired and short is speed is the desired action. (4:51) In the body force is generally applied by the short muscles that must overcome a resistance that is some distance away from the force. This arrangement provides for muscular force as well as leverage. This leverage provides both speed and range of movement. (26:127)

In the first class lever the fulcrum is placed between the resistance and the force may, therefore, be placed at a point to balance the two arms or, depending on the relative position of the fulcrum's position, may have a longer force or resistance arm. "Regardless of the position of its fulcrum or of the relative lengths of the two arms, a first class lever is always an arrangement for balance." (30:290)

Second class levers have the resistance between the fulcrum or axis and the force, resulting in a long force arm which produces power with very little range of movement.

Third class levers, with long resistance arms, favor speed and a large range of movement at the expense of force. In this case the force must always be greater than the resistance. (26:128)

Since speed is an important consideration in sports activities, it is important to consider the relation of speed to range of movement. In angular movement these two qualities are interdependent. When two levers of different lengths travel through an angle of identical size at the same velocity, both the longer lever and the shorter will cover the distance in the same amount of time. The longer lever, therefore, must be traveling more rapidly. (30:293)

A discussion of levers would not be complete without an understanding of the moment of force or torque, as it is sometimes referred to by kinesiologists. Torque has been defined as the application of force that causes the object to rotate around its axis of rotation. (4:53) Torque is equal to the product of the force times the perpendicular distance from the point of application of the force to the axis of rotation. In movement of levers, if it is desirable to overcome or minimize the torque, the distance from the axis to the force must be short. In cases when stability or slight rotation is desired, then the torque should be reduced to zero or a small value. (4:53)

<u>Analysis of Bowling Technique</u>

A mechanical analysis of any activity may be made when the basic principles are applied. Bowling is a sport that can easily be analyzed because it employs all the basic principles when the skill is performed correctly.

According to Scott (28), the accuracy that is demanded in bowling is dependent upon the control and coordination of movements of the body in the delivery and release of the ball. The arm swing is the determining factor in the direction of the release, while the method of release determines the direction of rotation on the lane. The rotation, speed, and surface of the alley are factors determining the path that the ball follows.

The arm swing is straight and the movement centers at the shoulder which gives a long lever. With the combined efforts of the shoulder muscles sufficient force to move the long lever is produced. "The backswing puts tension in the anterior muscles and also increases the arc through which the force is applied." (28:222) A backswing that is too long or that follows a circular pattern changes the position of the trunk and thus the position of the arm which in turn affects the line of delivery.

The release of the ball is directly related to the arc that the ball describes. A properly released ball misses the floor on the low part of the arc and is released immediately so that it starts to roll on the lane. If the release of the ball is delayed, the arm starts its upward arc and the ball drops to the alley.

The right leg and the free arm are used to maintain balance. On the forward swing the weight of the ball is balanced over the left foot. Caution should be taken to be sure that the momentum of the ball does not cause the bowler to lose balance. When a bowler leans forward too far and/or too soon, the direction of the arm swing is changed. The result is that the ball is thrown down on the alley rather than being rolled on the alley at the point of release. When the plane of the swing is changed, balance is affected. When the balance is lost earlier, then the ball will hit the right leg as it comes forward in the forward swing.

The slide on the left foot is caused by the forward momentum of the body. In order to utilize this, the bowler should assume a position far enough back on the alley so that she can slide without crossing the foul line.

The method of release of the ball determines the rotation of the ball on the alley. If the ball is released in such a manner that the rotation is clockwise, it will curve to the right. This is caused by supination of the forearm during the swing or at the time of release of the ball. This supination may result also from a forced backswing that causes inward rotation of the arm.

In some cases the bowler attempts to compensate for strong adduction in the movement of the forearm during the forward swing. The effect of the rotation in this case results from the friction on the lane. The curve is to the right, the direction of least resistance.

A counterclockwise rotation may also be caused by the delivery. It is evident that the effect is opposite: the curve is to the left and the cause is pronation of the forearm. This movement does not affect the action of the elbow joint because the action is produced by the pronator teres, and the pronator quadratus. This curve is frequently employed to angle the ball into the one-three pocket.

The angle at which the pins fall is a necessary consideration in aiming. The path of the ball is not affected appreciably by the impact with the pins because inertia of the ball is much greater than that of the pins. The point of contact between the ball and the pins determines the direction of the fall of the pins. If the pin is hit squarely, it is carried directly backward; a pin that is hit on the side will fall diagonally backward. The fall of the pins explains the point of aim in bowling.

Speed of the ball affects the pin fall. A ball that moves with too much speed may knock pins off the alley and leave others standing. On the other hand, a ball with less speed takes out the first pins contacted and they in turn bring the others down.

Essentially bowling is a form of striking and the principles controlling direction are applicable. The difference between bowling and other activities that involve striking is that the striking object, the ball, must be controlled over a distance of about sixty feet.

Physical Education Research Related to Mechanical and Kinesiological Research

McCloy (50) recognized the value of the utilization of mechanical principles in analyzing human movement in a study of the factors that are related to motor educability, a type of motor and athletic intelligence which is characterized by what might be called the "smart player." (50:29)

In a list of ten factors that are prerequisite to effective learning, McCloy listed as a factor the "understanding of the mechanics of the techniques of the activities." (50:32) A second factor was dynamic energy which would be controlled by the proper application of kinetics and kinematics.

Sixteen items were listed as contributing factors to motor educability. Ability to have insight into the nature of the skill by an understanding of the mechanics of the activities was one of these. Some of the research that McCloy made reference to concluded that insight was the direct result of an understanding of the mechanical analysis of the activity. Other studies attributed this merely to "catching on to" the activity. (50:33)

The use of cinematographic analysis as an aid in kinesiological analysis has made it possible to record musculoskeletal movements and to study the performance of athletes. Cinematography has made scientific analysis possible. In addition it has provided an effective means of demonstrating the mechanical principles involved in sports activities.

Cureton (36) has made a notable contribution to the field of athletic research through the development and use of cinematographic research. One of the chief objectives of Cureton's research was to determine the scientific principles of coaching, including an understanding of the mechanics of the skill.

Cureton has pointed out the necessity of interpreting athletic performance in terms of physical principles of the body as a whole supplemented by other considerations which involve the internal body mechanics, physiology of training, and the psychology of competition. He states that while all of these aspects are important, the mechanical analysis is the most basic.

In his exploration of the use of cinematographic analysis to study the external mechanics of the acts involved in skills, Cureton indicated that there is a relation between the analysis and mechanics.

> The fundamental principle is that direction of movement (angles) dimensions, time relations, and the indirect value of force and velocity may be obtained from the film. Since the science of mechanics is an expression of the physical laws of equilibrium or movement in terms of these same fundamentals or derived measures, a mechanical analysis of any movement may be made from measurement made from the screen. (36:5)

Weiss, using elementary school students as his subjects, has conducted some experimental studies that apply to physical education. One of these studies endeavored to test the theory that a person can increase the height of the jump if he applies the fundamental of displacement of the center of gravity. The theory states that the height of a jump may be increased if the center of gravity is displaced when one arm is flung forward prior to the peak of the jump.

To test this theory, Weiss worked with seventh and eighth grade boys. The design of the research was in two parts. In the first phase, the subjects jumped with both arms flung upward. When a plateau was reached by the group, the jumping was terminated. For the second phase of the study, the subjects were divided into experimental and control groups. The control group executed the verticle jump as they had in the past while the experimental group used the modified method of the verticle jump which involved flinging one arm down just before reaching the peak of the jump.

The subjects were tested at two-day intervals throughout the second phase of the study. The best scores from the two phases were used for statistical comparisons.

Weiss concluded from this study that seventh and eighth grade boys do not increase their verticle jump height by using the modified jump.

In a second study done with Ryan (70) the accuracy of the baseball throw was investigated. This study was based on the theory that the pattern of flight follows the law that an object moving in an arc tends, because of centripetal force, to fly off in a straight line at a tangent to the arc of motion when the centripetal force is removed; therefore, the point of aim and timing of the release controls the accuracy of the ball. If the hand follows the path of a flatter arc than the ball, the margin of error is reduced when the ball reaches the target.

The research design was similar to that of the Weiss study previously cited. In the first stages of the research, the subjects were tested for accuracy when they used their "natural throw." Accuracy was based on twenty throws. Following the establishment of an initial accuracy score, the subjects, all elementary school children, were divided into experimental and control groups. The control group practiced their "regular throw" while the experimental group threw the ball in a flatter than normal arc. This latter group was given instruction in this modified throw and allowed to practice it for two class periods. After the instruction, the subjects were tested to establish an initial accuracy score. The subjects' performance in phase two was based on the score for twenty trials.

The analyzed data indicated that the group of students that used the natural throw were more accurate than the experimental group, and that the modified throw caused the students to lose accuracy.

Colville (65) conducted one of the most recent studies involving mechanical principles.

> The purpose of this study was to determine the effect of knowledge of a principle upon immediate learning of a motor skill to which the principle applied, and to determine the effect of knowledge of the same principle upon subsequent learning of a different or more complicated skill to which the same principle was applicable. (65:107)

For the purpose of her study, three principles were chosen that were relevant to motor activities taught in the physical education curriculum and to motor skills that could be objectively measured. In choice of the skills the following factors were considered: illustration by mechanical principles, familiarity of the skill to the mechanical principle, and difficulty of the coordination.

The principles and skills that were chosen were as follows:

Principle I. The angle of incident is approximately equal to the angle of deflection.

Skill I. Rolling a ball against a surface from which it rebounded to a target on an adjacent surface. The more complicated skill was rolling a ball so that it rebounded from two perpendicular backstops to a target placed at right angles to a second backstop.

Principle II. In stopping a moving object, the force opposing the momentum must be equal to the force of the momentum and if the object is to be caught, this momentum must be dissipated by reducing the resistance of the catching surface.

Skill II. Catching a tennis ball in a lacrosse stick. The more complicated skill was to catch a badminton shuttle on a tennis racquet.

Principle III. An object set in forward motion through the air by an external force is acted upon by the momentum and by the gravital acceleration.

Skill III. Archery at twenty yards.
The more complicated skill was archery at thirty and forty yards. (65:108-109)

For the study, two groups were used for each principle. One group was taught without reference to the principle, while the other group was taught to understand and apply the principle. Both groups performed an initial skill and a second more difficult one.

Conclusions drawn from the analysis of the data collected in the skill performance indicated that instruction in principles of mechanics, applicable to the chosen skill, did not result in performance that differed from that of the control group that was not instructed in the principles prior to the performance.

Ragsdale in writing about motor learning, pointed out that a learner may understand the principles applied to inanimate objects, but may not be able to apply them to his movements. Colville's study would appear to support Ragsdale's observations, at least in the early stages of learning an unfamiliar skill.

McKee (51) made a study of mechanical principles that relate to the skill of bowling. The law of inertia was stated as fundamental. To accomplish the objectives of giving the ball sufficient velocity, proper direction, and to efficiently use force, the following aspects of bowling were explained in terms of mechanical principles and their implications for bowling: developing velocity, developing accuracy, maintaining balance, coordinating the arm swing, the approach and aiming.

In a study concerned with the analysis of selected activities in the physical education basic skills program, Smith (68) presented a muscular and physiological analysis of activities from which a basis for teaching was drawn. These principles, selected from the field of physiology, covered the aspects of muscular contraction, muscle tone, respiratory and circulatory systems, fatigue, and effects of training on the body.

The purpose of the kinesiological analysis was to analyze activities in order to study their contribution to development of individual skill, to study improvement of efficiency, and to devise and administer exercises according to the analysis of the skill. These exercises, used as supplementary conditioning exercises,were used to study the effects that they had on the student's subsequent performance in related activities.

For the purpose of analyzing the skills of tennis, swimming, hockey, basketball, rhythmic fundamental principles were selected from authoritarian quotations in the field of physiology and used as they apply to physical education. No effort was made to interpret or apply selected principles. The principles were used by the teacher to plan lessons and exercises scientifically.

An experimental design with experimental and control groups was used to study the effects of the supplementary exercises administered to the classes. These exercises were based on an analysis of the movements involved according to the selected principles. It was concluded that the experimental group showed improvement in abdominal strength and efficiency. However, evidence was not conclusive that the exercises contributed to the accomplishments of the students in the activities selected for this study.

Daughtery, in a study conducted with junior high school boys, stated that "it would be safe to say that kinesiological teaching of skills will develop better performance than pupils will acquire from an elective program." (37:30) His purpose in this research was to show the effects of kinesiological teaching on skill performance and development of strength. This application of kinesiology consisted of systematic use and rotation of squads to facilitate large numbers, systematic practice of proper form based on principles of kinesiology, body building and warm-up exercises, and participation in a game situation.

The four hundred and ninety-seven subjects used in this study were arbitrarily divided into elective and organized groups.

Activity in the organized group was a kinesiologically planned program, while that in the elective group was informal with practice carried on according to the pupil's initiative.

There was conclusive evidence that in the organized group there was general improvement in both skill and strength as discerned from initial and final testing programs. On only two of the eight items on which the students were tested did a comparison of initial and final score reveal that there was no noticeable improvement.

Related Bowling Studies

Prior to a study by Webster in 1949, little scientific research had been directed toward developing new methods of teaching bowling or improving those in current use.

Webster's study endeavored to determine the importance of instructional method to the acquisition of a motor skill and the influence of psychological situations which affect, either favorably or unfavorably, the performance of the bowler. (64:42)

This investigation of a motor skill, as exemplified by bowling, studied bowling fundamentals, methods of instruction, and common practices in skill performance. The data were collected from several sources. The fundamentals of bowling and the methods considered most important were cited as a result of a study of instructional materials and other related publications. A questionnaire was distributed by the American Bowling Congress to participants in bowling tournaments. The results of game scores, collected from the 1939 National Tournament of the American Bowling Congress, were used to determine common habits and practices of bowlers in relation to the pattern of superior skill performance.

From an analysis of the scores of the one hundred bowlers that participated in the tournament, it was found that the following techniques resulted in the best performance:

Right-hand delivery
Two-finger balls
Approach of five or four steps
Straight ball with sharp hook delivery or
Straight ball with wide hook delivery
Upright position with the ball chest high or upright stance with the ball waist high
Sighting at a spot, or pins and spots when shooting for strikes
Sighting at spots, or pins and spots when shooting for spares
Aiming at the three-six or six pin in bowling for strikes when the position of aim is on the pins
Aiming at spot on the alley over ten feet from the foul line
Middle position on the alley for strikes
Right-hand position on alley for number seven spares
Left position on the alley for number ten spares. (64:50)

In addition he concluded that the psychological factors that influenced performance were practice, distraction, diurnal cycle, seasonal change, and superstitions.

Webster's study is helpful to the teacher because it describes the habits, forms, and techniques of superior performers; however, it does not tell how to develop this ability in the most economical way. The studies that follow have been concerned with the attainment of skill in an economical way through the use of efficient methods that are scientifically sound.

Maas (49) developed a rhythmic approach to bowling which taught the relationship of the arm swing to the footwork of the approach according to a rhythmic underlying beat and the influence of the force of gravity.

The arm swing and the approach were practiced without the ball in the first stages of learning in order to develop coordination, the kinesthetic sense, and the strength in the muscle groups involved. These practice sessions were followed by a demonstration of the influences of the body's action on the development of the force of the ball. A ball was thrown from a stationary position at the foul line and the second ball was given additional force through the use of body momentum. This illustrated the importance of the use of the body as a moving force against the stationary forces of ten pins. The four step approach with the ball was presented, therefore, with an emphasis on the body in motion in coordinated form, and on the inertia that can be built within the body as an approach is started from a stationary position and ends with a long stride.

Maas felt that a rhythmic approach to learning a motor skill, predicated on the force of gravity, rhythm, and the body's motions, gave the student a kinesthetic enrichment as well as a specific recreational skill.

In a comparative study of teaching methods, Walters (62) compared the perceptual method with the traditional method of teaching bowling. Perceptual method was defined as "one that attempts to train students to see with perceptual unity and one that makes use of all perceptual cues that are available." (62:14)

The equipment for the experimental group utilized visual aids in various forms. A repetative action motion picture of a softball throw and a softball underhand roll, combined with the four steps, plus four views of the bowling approach, was shown preceding the practice of the skill. The film was shown during the first three days of the learning experience. Practice sessions immediately followed each showing. On the fifth day of instruction a slow motion film of spare bowling was shown and the repetative action film was repeated for the purpose of making an analysis of the arm swing.

Visual aids in the form of charts were also used in this study. Charts, illustrating the theory of spare bowling, were hung from the ceiling so that they could be viewed by all of the students.

In order to force the students to depend on the kinesthetic sense and to utilize environmental cues, they practiced in the dark for the first three lessons. During these three days of practice, the bowlers also viewed the movie. Bowling in the dark was made possible by the use of pins and balls that had been marked with phosphorescent paint.

The students bowled in the light for the first time on the fourth day, during which time they bowled a line and kept score. On the fifth day the experimental classes saw the repetative action movie and the movie of spare bowling.

Throughout the remainder of the learning period, other aids which were used included the charts that were previously mentioned, bowling in front of a mirror, and throwing a softball for improvement of the release and aim.

The control group followed the procedure of demonstration, explanation, and individual help. The softball throw was used with this group analogous to the form of the four step approach.

Although the difference was not statistically significant, the experimental group had fewer plateaus in the learning curves than did the control group. The plateaus in the experimental group occurred when no special devices were used. This was concluded to be indicative of the importance of the devices used and the environmental conditions established for the experimental group.

Bowling is not limited to one specific technique or combination of techniques. Evidence proving the superiority of one technique over the other is not conclusive. Research has been conducted to investigate combinations of techniques in order to determine their effect on final performance.

Summers (56) conducted a study to determine whether instructional techniques of delivery and point of aim affected achievement scores in bowling. Her study involved two variables, type of delivery and point of aim.

The two types of delivery were the hook ball and the straight ball, and the variations in the point of aim were the pin and spot methods.

The significant finding of this study was concerned with the effectiveness of spot bowling. It was concluded by Summers that beginners attain superior results when they are instructed in spot bowling.

In a study by Libba and Sloan (46), experimental and control groups were taught in the same manner with regard to objectives, general instructional procedures, and methods of evaluation. The experimental variable was the hand position. The thumb up position and the V position were the variations used. These led to a straight ball and a hook ball, respectively.

Two performance measures, accuracy and speed, were used as a basis for comparison. Accuracy was measured by an average of the pins that were down on the first ball rolled in each frame. The time measure was an established velocity goal.

The final statistical analysis revealed no conclusive evidence establishing the favorability of either hand position for the beginning bowler.

Goellner (43), in a study of the effectiveness of head pin, spot, and combination bowling, concluded that head pin bowling was the most successful for the beginning bowler. This conclusion was in direct opposition to that reached by Summers.

The subjects used in this study received traditional instruction in both the straight and the hook ball deliveries for two months. They were then divided into three groups, each of which received instruction in one of the three types of aiming. Each group bowled a ten game series. The recorded scores of these games were analyzed for nine components comprising favorable-unfavorable features of bowling. From this analysis a pattern of desirable features of skill for the average bowler was drawn and the superiority of head pin bowling was established.

Glassow (42) developed a method of teaching based on kinesthetic perception of the movement patterns of the skill. The purpose of this teaching method was to have the bowler visualize kinesthetically before actual performance.

Initially, the bowlers were concerned with adjustment to the ball and delivery. No demonstration of correct form of the delivery was made. The bowler, therefore, used movement patterns that were previously learned, and executed the whole movement of the arm swing with no attention to form.

The first objective in the kinesthetic approach to teaching was to develop a velocity goal after the students had adjusted to the delivery of the ball. This made it necessary to produce a movement pattern that would send the ball down the alley in three seconds. Velocity was chosen as the first goal because force is remembered by the kinesthetic memory and the muscle action for each velocity is different. According to the researcher the development of control would follow the development of the muscular and kinesthetic patterns.

Students practiced to reach the three second velocity goal. No pins were used during this time and the arm swing was developed without the approach because it was considered the primary element in the skill. During this period frequent references were made to the kinesthetic awareness and the kinesthetic memory. When ease of execution and the velocity goal were achieved, the approach was added.

The first four weeks of an eight weeks' bowling course were devoted to developing the velocity goal. The remaining four weeks of the course were spent in bowling.

Glassow concluded that this approach to teaching developed a greater velocity, indicative of an ability to control and develop greater force.

Bowling was chosen by Roloff (67) as an example of a motor skill in her investigation of the relationship of kinesthetics to the motor learning rate of college women. Experimental and control groups were used. The technique that was used with the experimental group was not a drastic change from the traditional method of teaching but had an emphasis on the "feel" of the movement. Two films were shown by Roloff to induce a feeling for the movement involved in bowling. Immediately after the showing of the film, the group practiced. The motion picture was again shown in the sixth and tenth lessons.

Although the experimental group evidenced improvement in scores, there was no statistically significant indication that the method employing the use of the visual aid was the superior method of teaching bowling.

Other techniques used with the experimental group to develop kinesthetic perception included drills with the eyes closed to omit visual stimulus, and short demonstrations.

The classes that were used in this study met for eight weeks. The four step approach was used with variations in the delivery and point of aim.

For the purposes of comparison, an initial score was obtained from each group to measure the status of the student before instruction. This was compared to a mean score of lines recorded on the last four days of classes which was indicative of final performance.

In the analysis of the data, correlations were calculated between gains in bowling scores and initial scores, final performance, and with a measure of kinesthesis. No correlation coefficients were found to be significant between the final performance, motor ability and kinesthesis; nor was there any indication that the method of teaching using kinesthesis affected the learning rate of bowlers.

Subjectively, Roloff concluded that the information that was obtained from this study was not conclusive because the results were affected by three factors: different teachers for the different experimental and control groups, different teaching methods, and difference in initial motor ability scores.

Waterland (63) incorporated kinesthetic perception and mental practice in a study of teaching methods for beginning bowlers. Mental practice was defined as a method by which kinesthetic awareness can be a consciously utilized part of the learning situation. Kinesthetic perception was included in the study to develop "feel" or awareness of the movement involved. "By placing emphasis on kinesthetic awareness it was hoped that the student would be able to recall, through kinesthetic memory, the desired range of movement, and the direction of the overt movement." (63:24) When this sensibility of movement was developed by a student, she imagined the perceived movement before the delivery of the ball. After the pattern of movement was established, direction was established.

The performance level was judged by speed and accuracy. A comparison was made between the mean scores computed for the first four and last four days of the class.

Generally speaking, practice is used to improve bowling skill. Waterman's experimental observations demonstrated that emphasis on kinesthetic perception and mental practice can also raise the level of performance. The results of this study indicated that a combination of three types of learning, kinesthetic perception, mental practice, and overt practice, improved bowling skill.

Bowling norms for individual bowlers were established by Phillips and Summers (53) from game scores that were collected from twenty-two colleges which included bowling in the required physical education program. These norms provide an objective means of evaluating performance according to the ability level of the individual.

From the information collected by Phillips and Summers, a study of learning curves and character of learning at different levels of ability was made. The curves did not overlap, which indicated that the method of classification was good, and a valid means of identification at various levels of ability.

When the learning curves were studied and compared, characteristics of learning were indicated. An initial rise occurred at the lower level of skill and decreased as the skill level increased. Fluctuations were more frequent at higher skill levels. At the middle skill level, and increasing as the skill increased, a decline appeared in the curve at the fifth or the sixth line of bowling.

Lockhart (47) produced a film suitable for beginning bowlers and used it in a study to investigate the use of the motion picture as an instructional device. Four classes were used to form experimental and control groups. The use of the film which was shown to the experimental group in the initial stages of learning was the experimental factor. Continued use of the film was made throughout the instruction period, both in part and in its entirety. Use of the film gave the students an opportunity to perceive superior bowling skill. It was hoped that after observing such skill, the students would be able to evaluate and analyze their own performance more efficiently.

The value of the film as an instructional device was ascertained by statistical analysis of the performance of the experimental and control groups. Game scores and first ball averages were the criteria for comparison. The critical ratios, as well as the graphs of learning, that were obtained indicated that the film was of value as a supplement to instruction.

At the end of a three week period, the experimental group surpassed the control group in performance as determined by the criteria. After five weeks, the mean scores of the experimental group were superior and continued to be superior until the end of the study.

When the learning curves were studied for both of the groups, more consistency was found in the learning rate of the experimental group.

Dean (39), at Stevens College, developed a teaching method that was based on the use of visual aids. Eleven charts, illustrating the theory of spare bowling, were used. The charts were placed so that they could be viewed during every class period. In addition to the charts, a motion picture was used showing the fundamentals of bowling. The picture was shown after the students had been given the opportunity to bowl. This procedure was used so that the students would know what to look for in the film and appreciate the skill involved.

Dean felt that the use of visual aids helped the students enrolled in bowling classes to win the National Intercollegiate Telegraphic Bowling Tournament in 1940.

Speed and accuracy were the variables studied by Roney (54) to determine their relative effects on bowling performance. Among the special devices that were used were adhesive tape lines on the alley, darts for the spot bowlers, and strings placed both on the alley and above it as accuracy guides. In addition, charts were used to give a visual picture of the path of the ball. Ideas for the charts were taken from the study by Dean. Although the purpose of this study was not to determine the value of the visual aid as a teaching device, Roney implied that the special devices were motivational factors for beginning bowlers.

CHAPTER III

PROCEDURE

Selection of Subjects

This study was conducted with the cooperation of the Physical Education Department at the Woman's College of the University of North Carolina. The subjects were sixty-one freshman and sophomore college women enrolled in four bowling classes during the spring semester of the academic year 1959-1960. These classes were a part of the required physical education program at the college.

Organization of Experimental and Control Groups

Four sections of beginning bowling were used in this study: two were designated as experimental groups and two as control groups. In both the experimental and control groups there was an afternoon and a morning section. Control Class I met Monday and Friday at 8:00 a.m.; Control Class II met Tuesday and Thursday at 2:00 p.m.; Experimental Class I met Tuesday and Thursday at 9:00 a.m.; and Experimental Class II met Monday and Wednesday at 3:00 p.m. The same instructor taught all four classes.

A total of sixty-one students participated in the study. There were thirty-one subjects in the two control classes, and thirty subjects in the experimental classes.

Each of the class periods was forty minutes in length. During this time the students alternated bowling and setting pins. Four lanes were available for use with three or four girls assigned to each lane.

Selection and Application of Principles

A review of the mechanics and the laws of kinesiology that govern the movement of the body in all sports activities was made prior to the selection of the principles applicable to the analysis of bowling. A knowledge of this generalized information facilitated the choice of the specific principles that were pertinent to bowling. Preliminary to the selection of the specific principles that relate to bowling, a study was made of the techniques and skills involved in bowling from available instructional materials. (5, 9, 10, 14, 31, 38) The principles were selected on the basis of movement of the body and manipulation of the ball for the specific techniques of the four step approach, straight ball, and head pin bowling.

As in all sports, balance is an essential factor in bowling. Because of changing body position during the execution of the four step approach and the necessity of balancing the weight of the ball while the body is moving and changing positions, the six principles of balance listed below were chosen for analytical purposes.

1. A body is balanced when the center of gravity is balanced over the base of support. The larger the base of support, the greater will be the body's stability.

2. Stability is directly proportional to the area of the base on which the body rests.

3. Stability is increased if the widest part of the base is in the direction of the force which is attempting to disturb the equilibrium.

4. When an object is carried by the body, its weight must be considered as a part of the weight to be balanced over the base of support. This makes a change in the line of gravity and adjustments must be made to try to keep the line of gravity located as centrally as possible.

5. Force may be diminished by increasing the distance over which it is absorbed.

6. Stability is indirectly related to the distance of the center of gravity of the body above its base, and the horizontal distance of the center of gravity from the edge of the base toward the direction of momentum.

7. Newton's Third Law of Motion: For every action there is an equal and opposite reaction.

These principles relate to the balance of the body's segments over the base of support, the relative position of the segments over the base, the direction of the slide on the fourth step, the length of the steps, the position of the ball in relation to the body, the function of the left arm in maintaining balance, and the position of the body in maintaining balance during the release and the follow through.

Principles 1 and 2 as listed explain the relationship of the length of the steps and the position of the body in the four step approach. When these principles are applied to bowling, they explain the desirability of progressively increasing the length of the steps as well as the change of the body position with the steps. They are specifically related to the increase in the body bend and the increase in the height of the backswing.

Application of principle 3 is illustrated by the forward stride on the fourth step. The forward stride or the slide is necessary to balance the body in the impartation of the forward force given to the ball at the time of the release.

The necessity of keeping the ball close to the side during the approach and the adjustment of the arm and the body segments to maintain balance is explained by principle 4. The adjustment of the body to the relative position of the ball compensates for the weight of the ball and keeps the line of gravity and center of gravity in proper relationship to the base of support, the feet.

Because of the increase in force during the release, a follow through is necessary to absorb this force. The control of the body's forces by the follow through is an application of principle 5. The force, or momentum, that is developed as the ball is released is absorbed, partially by the position of the body and the arms that follow the ball as it leaves the hand. The follow through continues until the body is erect in order to maintain balance.

Principle 6, concerning the position of the center of gravity, applies to the height of the body on the release, and the position of the center of gravity as the ball is released. This principle, as explained above, justifies the follow through and the forward lean of the body as the ball is released in order to place the center of gravity in a position to maintain proper balance.

Newton's Third Law was selected to explain why the body bend and forward lean of the trunk are necessary to balance the backswing of the ball during the second and third steps of the approach. This principle also explains the compensation of the force of the push against the floor with the feet by the forward lean of the trunk.

The arm swing, determiner of the general direction which the ball takes, is an important consideration in the development of efficient movement in bowling. The kinesiological principles of levers also apply to and explain the movement of the arm. In the execution of the arm swing, the arm functions as a third class lever. Therefore, the law of the third class lever was selected as a principle for inclusion in this study, with the axis as the shoulder, the lever arm as the straight and extended arm, and the ball as resistance.

The principle that a throw for speed and distance is always made with the longest lever possible when applied to bowling, points out the importance of a straight elbow in order to increase the length of the lever.

Efficiency of the arm swing is necessary because its action is independent of other levers in the body. When a part of the body moves isolated from other parts, then a great deal more efficiency is demanded. The following principle was selected to explain this action:

> The isolated lever moves around its axis which is fixed; and it moves independently of all other parts or levers.

Since in a true third class lever the axis is fixed, stabilization of the shoulder joint during the arm swing is imperative. When there is excessive rotation of the shoulder, the position of the axis is affected and the action of the lever is less efficient.

Bowling is an activity which demands utmost accuracy. "This accuracy is dependent upon the ability of the performer to control and coordinate all movements on the delivery and release of the ball." (28: 220) Four principles which pertain to coordination of the arm swing and the four step approach were selected for inclusion in this study. Due to the importance of the coordination of the pushaway with the first step, the two principles below were selected.

1. The movement of the lever is produced by the force of gravity. This presupposes a starting position in which potential energy is present. The lever must be removed from the resting position before the force of gravity can make it swing downward.

2. The range of the swing of the lever (Amplitude) depends upon the height from which it was initiated.

The forces that act to cause movement of the ball are the weight of the ball itself when it is placed in the correct position so that potential energy can be converted into kinetic energy, and the force of gravity. The pushaway places the ball in such a position that the potential energy of the ball can be utilized. In addition to the energy produced by the ball itself the pushaway places the ball in a position so that gravity can give maximum assistance to the movement.

Most bowling authorities agree that the pushaway should be at waist level or slightly higher. The reason for this is explained by the second principle above. The range of movement of the ball, as controlled by the arm swing, is affected by the height of the pushaway. Since the pushaway initiates the movement, both the height and distance of the ball from the body will affect the range of movement.

The coordination of the point of release with the full arm swing is of utmost importance in order to utilize the speed that is produced by the arm swing. In order to release the ball at the proper point in the arc of the swing, the fourth step must be perfectly coordinated with the release. Application of the principles stated below should give the bowler the proper point of release in order to utilize all of the force and speed produced.

> As the lever swings downward its speed increases; as it swings upward its speed diminishes; hence, the lever's speed is greatest at the bottom of the arc.

When this principle is applied to an early release of the ball, it is clear that the ball will not have all the potential speed that it could have. A late release, on the other hand, also results in the loss of speed.

A principle dealing with coordination as related to force is stated below:

> Forces to be summed effectively, must be added at the time of acceleration and the maximum velocity of the preceding force.

Application of this principle indicates the need for perfect coordination in the four step approach in order to utilize all the affecting forces.

Velocity, the rate of change in position in a given direction, also has application in bowling. The selected principles are listed below and are followed by their application to bowling skill and techniques.

> Newton's First Law of Motion: A body remains in a state of rest or of uniform motion unless acted upon by some external force.

The true velocity of the bowling ball is developed by the swing that is propelled by gravity. This makes it necessary for the bowler to place the ball in a position so that forces of gravity can act. This is accomplished by the pushaway in the first step of the approach. From an analytical viewpoint this gives validation to the importance of the pushaway.

> A moment of force is a force tending to produce rotation around an axis times the perpendicular distance from the axis. The direction of gravity's acceleration is always downward.

In order to produce the moment of force that is necessary, the ball must be pushed away from the body on the pushaway. The greater the distance is between the shoulder joint and the ball, the greater the force will be. The performer that pushes the ball away from the body only slightly decreases the moment of force and thus the assistance of gravity in the swing.

> Energy cannot be created or destroyed. Potential energy is energy of position. Kinetic energy is energy of motion. Potential energy can be converted into kinetic energy.

The potential energy of the bowling ball is directly affected by the height of the backswing and the placement of the ball in a position so that there can be a conversion of energy. The initial step in the energy conversion is the pushaway as this affects the height of the backswing which has the most direct effect on the production of kinetic energy. In the execution of the approach, if the backswing is very short, then there is very little energy to be converted.

> Final velocity of an object is determined by the rate of acceleration and the length of time over which the acceleration takes place.

Because the swing of the ball in bowling is gravity propelled, the acceleration is constant; therefore, the velocity that is produced by the swing is of utmost importance in producing efficient movement patterns of the ball because it is gravity propelled. The height of the backswing partially controls the velocity.

> Hyper-extension of the humerus is limited by the structure of the shoulder joint.

Since the shoulder serves as the axis for the arm when classified as a third class lever in bowling, the action of the humerus in the shoulder joint is a controlling factor. The entire action of the arm, as far as range of movement is concerned, is controlled by this axis. Because of the origin and insertion of the muscles, the rotation of the head of the humerus in the glenoid fossa is limited when the body is in an upright position. This is particularly true for individuals with limited flexibility in the shoulder girdle. Due to the fact that it is necessary for the ball to be elevated to shoulder height on the backswing, this principle is applied in order to compensate for the structure of the shoulder joint. For this reason it is necessary in bowling to lean forward with the trunk to facilitate a high backswing. Application of this principle shows the relationship of the forward lean, or the bend of the body, to the height of the backswing.

> In angular movement the maximum linear velocity is at right angles to the radius.

This principle explains the position of the release of the ball in relation to its development of velocity. As has been previously stated, the release of the ball can affect the velocity either positively or negatively. In order for the effect to be positive, the ball must be released at the bottom of the arc and perpendicular to the floor. The forces of gravity carry the ball slightly forward so that the point of release is slightly ahead of this point of the arc. Unless this principle is applied, the performer will release the ball so that gravity has a negative effect on the ball at the point of release.

> Angular and linear forces must be combined. If the forces are to be summed, a second force should be addressed to the first at the point of minimum acceleration and maximum velocity.

This principle relates to the action of the body and its position at the time of release. In order for the velocity of the ball to be correctly produced, the acceleration of the body must be controlled. The arm should swing through from the backswing when the body's acceleration toward the foul line has ceased (on the fourth step) and the body has maximum velocity. The maximum velocity should be attained just prior to the last step and glide; therefore, the slide and the swing through should be simultaneous for effective summation of forces.

> A long lever has greater velocity than a short one. On movement of the arm the hand has greater velocity when the elbow is straight.

Application of this principle to bowling emphasizes the necessity of keeping the elbow straight during the arm swing for an efficient production of force. If the elbow is bent at any time during the arm swing, it reduces the production of velocity.

Accuracy, a factor demanded in bowling skill, depends on the ability of the performer to produce efficient movements and control the forces that affect the ball before it is released and at the point of release. Release, forces which play on the ball, friction, the position of the ball at the point of release, and aim were aspects of bowling skill considered in selection of the principles relating to accuracy. Although the final accuracy is determined by the point at which the ball hits the pins, the factors of the movement in the four step approach cannot be discounted, as they have a direct bearing on final accuracy.

Seven principles of accuracy were chosen to explain the effectors on accuracy produced by the four step approach.

Basic to accuracy is the type of aim that is used by the performer. The advantages of spot bowling are pointed out in the two principles below:

> It is easier to hit a close target than a distant one.
>
> The magnitude of an error is proportional to the distance between the point of release and the target.

Since the distance to the pins is sixty feet and the distance on the alley of the spot is approximately fifteen feet, the bowler who uses spot bowling is aiming at a target that is forty-five feet closer than a bowler who aims for the pins. Because in spot bowling the target is near to the point of release, as contrasted to the aim for the pins, the magnitude of the error is greatly reduced. The less the magnitude of the error, the greater the accuracy.

When using pin aim, the bowler should always focus the eyes on the point of aim. The explanation for this is stated in the principle below.

> Focusing the eyes assists in maintaining balance and a straight line of movement.

Preliminary to the beginning of the approach, the bowler should focus the eyes on the one-three pocket. When the eyes are focused on this point, there is less deviation in the line of movement and better body balance can be maintained. Both the line of movement and balance affect the aim.

The release of the ball is the primary factor in the production of accuracy for the aim. The following principle specifically states the effect of the point of release on accuracy:

> A released object continues to move in the same direction that it is moving at the point of release.
>
> > In angular movement a released object will travel at right angles to the radius of the circle at the moment of the release.

Although there are factors that affect the ball after the release, the most important effect on direction is made at the point of release. In order for this release to be efficient, the backswing and the slide must be in a straight line with the target; any deviation of the body's position causes a negative effect on the ball in relation to accuracy.

> When an object is rotating, more resistance is placed on the side of the object that is turning in the direction of the forward motion. This force is called deflecting force and will result in a change of direction.

From an analytical point of view, it is necessary to prevent the deflecting forces in order that the ball will travel in a straight path. Any side spin that is imparted to the ball will cause a deflecting force and for this reason it is necessary to prevent the spin, unless such spin is utilized in rolling a hook, curve, or back up ball, by assuming the proper hand position during the approach and especially during the release.

Speed of the ball also has considerable influence on accuracy. This is explained by the following principle, selected to show the effect of the forces and speed of the ball on final accuracy in relation to the pins.

> The faster an object travels the less time a deflecting force has to act upon the object in a given distance.

This explains the fact that if there is to be deflection of the ball from its course, it usually occurs when the ball is near the pins or when speed decreases. In addition, this explains the fact that it is important to produce speed and that without speed the bowler sacrifices accuracy.

An unavoidable element which affects bowling is friction. The contact of the ball with the alley produces friction. Friction affects the velocity of the ball and, in turn, accuracy. In the production of speed that is necessary for accuracy, the effect of friction must be considered.

In bowling no matter how large or how small the degree of error, it affects the path of the ball on the alley. This error refers to the angulation of the arm in relationship to the body and the pathway of its arc. The resulting directional errors produced by this type of error are analyzed in the stated principle below:

> A change in the direction of one degree will result in changing the path of the ball by three inches in five feet and by twelve inches in sixty feet.

In bowling, deflection is the most important cause of pin fall. The bowling ball will knock over a limited number of pins; however, the greatest pinfall results from the deflection, which occurs when the pins hit other pins and cause them to fall. Although this is important in both strike and spare bowling, it should be given special consideration in spare bowling. There are two considerations in deflection, the angle that the ball hits the pins, and the speed that the ball is traveling when it contacts the pins. Principles relating to deflection are stated below:

> The sum of the momentum of two colliding objects before a collision is equal to the sum of the momentum of the objects after the collision.
>
> Unless two colliding objects meet squarely, the center of gravity of one hitting the center of gravity of the other at a one hundred and eighty degree angle, both objects will be deflected from the original path. The object with the greatest velocity will be deflected least. The faster an object is traveling the smaller will be the deflection.

When the principle concerning momentum and collision is applied to bowling, it is clear that the mass of the pins and the mass of the ball are constant and, therefore, unchangeable. Analytically speaking, the velocity given to the pins must come from the ball. If the ball has insufficient velocity, then there is little resulting deflection, which narrows the chances for strikes or converting leaves to spares.

In spare bowling the point at which the pin is hit is the important factor. To be successful in the conversion of spare leaves, the bowler must therefore analyze all pins standing and aim for a hit that will cause the greatest or most advantageous deflection.

> Unless two colliding objects meet squarely, the center of gravity of one hitting the center of gravity of the other at a 180 degree angle, both objects will be deflected from their original path. The faster an object is traveling the smaller will be the deflection.

This principle analyzes the path of the ball for bowling tandem leaves. In this case the ball should hit the pin squarely so that the direction of the fall will be straight back; neither ball or pins should be deflected from their course. In cases when deflection is desired, then this principle works in reverse. The angle of impact of two objects will cause pin fall to differ. Relative to this consideration is the speed of the ball. The faster the object is traveling, the less the deflection. Balls that are bowled for tandem leaves should have more speed than those for other leaves.

Teaching Method and Lesson Plans

The traditional method of teaching was used with the control groups. This method follows the procedure of explanation, demonstration, and practice, coupled with individual correction of errors.

A variation of the traditional method of teaching was used to teach bowling to the subjects in the experimental groups. The elements of explanation, demonstration, practice, and individual help were maintained. In addition, an experimental variable was used to supplement this method. In an attempt to develop a greater understanding of the correct execution of the bowling techniques, analysis in terms of mechanical and kinesiological principles was used as the experimental variable. All materials presented to the experimental classes were presented through the medium of principles. To supplement the understanding of the principles, visual aids were used. A complete listing of the principles and illustrations of the visual aids are included in the Appendix.

In the experimental sections the order of presentation of the material was: presentation of principle, explanation of principle, explanation of application to bowling, and relationship to the whole movement pattern. The principles were selected so that they explained to the student the most advantageous execution of the skills and techniques of bowling according to scientific principles.

Recognition and correction of errors were based on an objective and scientific understanding of the movement patterns which form the techniques of bowling. During the entire learning process, the instructor encouraged the students to apply the principles in correction of individual errors.

The principles that were most helpful in explaining the four step approach, the straight ball delivery, and head pin aiming were used to supplement the student's perception of the implications that the principles had for bowling. These principles were reviewed several times during the thirty lessons.

Principles of spare bowling were presented to the classes in the tenth lesson. The supplementary principles that were not used in the first lessons were used during the course of learning when the appearance of certain errors made their use logical and meaningful.

Eleven charts were used which graphically illustrated selected principles. These charts illustrated principles Lever 1; Accuracy 1, 2, and 5; Coordination 3; Balance 3; Deflection 2; and the path of the ball in the four step approach showing the relationship of the pushaway, backswing, and point of release.

In order to be as objective as possible in the use of a method of teaching and its variations, two sets of lesson plans were constructed. The lesson plans for both groups were studied before each class period in order that the two experimental and the two control classes would be taught exactly the same lessons.

A daily record was kept for the four classes. The record included a write-up of the material covered in each lesson, which enabled the instructor to make uniform adjustment in the lesson plans. Outlines of these lesson plans may be found in the Appendix.

Basis of Measurement of Ability (Final and Initial)

Bowling scores were recorded for each game that was bowled in a fifteen-game series by the subjects. A list of the scores for each subject may be found in the Appendix.

Game averages were used as a measure of bowling skill. The mean score of the first five games was used as a measure of initial ability; the mean score of the last five games, games eleven through fifteen, was used as a measure of final performance.

The number of pins down with the first ball rolled in each frame was also recorded and was used as a measure of accuracy. The average of the number of pins down on the first balls in each game was calculated and a mean score of the number down on the first five games and games eleven through fifteen was accepted as the initial and the final measure of accuracy.

Subjects were allowed to bowl outside of class and submit these scores to the instructor; however, since these games were bowled by subjects in each of the four groups throughout the learning period, they were not considered in the statistical analysis of the data.

Treatment of Data

In treating the data for this study, the mean score for each subject was calculated for games one through five and eleven through fifteen as a measure of performance. Average scores for the number of pins down on the first balls in each frame were calculated as an accuracy measure.

The analysis of co-variance was applied to determine if there were significant differences between the four groups of subjects. The "t" test, using mean differences and significances of difference, was used to determine the amount of improvement in accuracy and performance made by the groups.

CHAPTER IV

ANALYSIS OF DATA

Presentation of Data

Bowling scores for sixty-one subjects were used for statistical analysis to determine initial and final ability based on game scores and initial and final accuracy based on an average of the first balls bowled in each frame.

The groups for this investigation were not equated since they were four scheduled physical education classes in the required program at the Woman's College of the University of North Carolina. Since the four groups were unequated, the technique of analysis of co-variance was used for the statistical analysis. This technique provides for an adjustment in groups as related to initial and final scores.

The scores of games one through five were averaged for each subject and the mean score was used as a measure of initial ability; games eleven through fifteen were averaged and this mean score was used as the final performance score. The mean of the number of pins down on the first balls in each game was calculated for an accuracy score. The mean score of the number of pins down on the first five games and games eleven through fifteen were used as initial and final accuracy scores. These individual scores and averages may be found in the Appendix.

The average of the mean scores for the four groups of subjects showed that there was no significant difference either between or within groups. An analysis of these mean scores revealed that all subjects belonged to a common population since there was not a significant F.

These data appear in Table I.

The data for the analysis of variance of the mean scores for the final performance appear in Table II, page 51. A significant F was not revealed, and, therefore, it could be assumed that there was no significant difference in performance either between or within groups.

In order to make further adjustments for the unequated groups used in this investigation, the technique of co-variance was used. The sums of the squares and the cross products for four groups of subjects on initial and final performance were calculated prior to the final step in the calculation of the analysis of co-variance. These data appear in Table III, page 52.

In Table IV, page 53, may be found the results of the analysis of co-variance of bowling performance. The minimum level of confidence for rejection of the null hypothesis that there was no difference in bowling performance of the Experimental and Control Groups taught by two methods of instruction, was the 5 per cent level of confidence. The F obtained from this analysis was 1.083. From the F table it was found that with three and fifty-seven degrees of freedom, F must equal or exceed 4.16 for significance at the 5 per cent level of confidence. Since the F obtained failed to meet this criterion, the hypothesis was retained. It can be assumed, therefore, that the four groups were from a common population.

The techniques of variance and co-variance were applied in a similar manner to the mean accuracy scores for the four groups of subjects. The analysis of variance for the initial accuracy scores revealed no significant F. These data appear in Table V, page 54. Nor did the analysis of variance on the basis of final accuracy scores reveal

TABLE I

ANALYSIS OF VARIANCE OF SCORES OF FOUR GROUPS OF SUBJECTS ON THE BASIS OF INITIAL SCORES (AVERAGE OF GAMES 1-5)

Source of Variation	Sum of Squares	df	Mean Squares	F
Between Groups	415.3802	3	138.4600	---
Within Groups	9576.8168	57	168.0143	
Totals	9992.1970	60		

TABLE II

ANALYSIS OF VARIANCE OF FOUR GROUPS OF SUBJECTS
ON THE BASIS OF FINAL SCORES
(AVERAGE OF GAMES 11-15)

Source of Variation	Sum of Squares	df	Mean Squares	F
Between Groups	789.1161	3	263.0387	---
Within Groups	26863.6709	57	471.2925	
Totals	27652.7870	60		

TABLE III

SUMS OF SQUARES AND CROSS PRODUCTS FOR FOUR GROUPS
OF SUBJECTS ON INITIAL PERFORMANCE x
AND FINAL PERFORMANCE y

Source of Variation	df	$\sum x^2$	$\sum xy$	$\sum y^2$
Between Groups	3	415.3802	151.9430	789.1161
Within Groups	57	9576.8168	10109.5000	26863.6709
Totals	60	9992.1970	10261.4430	27652.7870

TABLE IV

ANALYSIS OF CO-VARIANCE OF BOWLING PERFORMANCE FOR FOUR GROUPS OF SUBJECTS

Source of Variation	Sum of Squares of Errors of Estimate	df	Mean Square	F
Total	17114.8431	60		
Within Groups	16191.8588	57	284.0676	1.0831
Adjusted Means	922.9843	3	307.6614	

TABLE V

ANALYSIS OF VARIANCE OF SCORES OF FOUR GROUPS OF SUBJECTS ON THE BASIS OF INITIAL ACCURACY SCORES (AVERAGE OF FIRST BALLS GAMES 1-5)

Source of Variation	Sum of Squares	df	Mean Squares	F
Between Groups	200.0925	3	66.6975	---
Within Groups	5739.3502	57	100.6903	
Totals	5939.4427	60		

an F that was significant. These data appear in Table VI.

The sums of the squares and cross products for the four groups on the basis of initial and final accuracy scores appear in Table VII, page 57.

In Table VIII, page 58, may be found the results of the application of the technique of co-variance to initial and final accuracy scores for four groups of subjects which produced an F that was 9.8561. An F of this value at three and fifty-seven degrees of freedom was found to be significant at the 1 per cent level of confidence. This F indicated that there was significant difference in accuracy between the groups which could not be discounted for by the differences in mean level of initial ability.

The "t" test was applied to the mean scores of final accuracy in order to determine where the difference occurred. The "t" test indicated that there was not a significant difference within the Experimental and Control Groups. However, significant "t"'s were obtained in favor of the Experimental Groups between Control I and Experimental I, Control I and Experimental II, Control II and Experimental I and Experimental II. These "t"'s were all significant at the 1 per cent level of confidence, which indicates that the Experimental Groups made significant improvement over the Control Groups in accuracy. These data appear in Table IX, page 59.

The mean difference, based upon difference between the initial and final scores for each subject in performance and accuracy, for the Experimental and Control Groups was submitted to the "t" test. The results of this analysis are presented in Table X, page 60. Significance

TABLE VI

ANALYSIS OF VARIANCE OF SCORES OF FOUR GROUPS OF SUBJECTS ON THE BASIS OF FINAL ACCURACY SCORES (AVERAGE OF THE FIRST BALLS GAMES 11-15)

Source of Variation	Sum of Squares	df	Mean Squares	F
Between Groups	118.1042	3	39.3680	---
Within Groups	4083.3729	57	71.6443	
Totals	4201.4771	60		

TABLE VII

SUMS OF SQUARES AND CROSS PRODUCTS FOR FOUR GROUPS OF SUBJECTS ON INITIAL ACCURACY x AND FINAL ACCURACY y

Source of Variation	df	$\sum x^2$	$\sum xy$	$\sum y^2$
Between Groups	3	200.0925	111.7849	118.1042
Within Groups	57	5739.3502	3071.1004	4083.3729
Totals	60	5939.4427	3182.8853	4201.4771

TABLE VIII

ANALYSIS OF CO-VARIANCE OF BOWLING ACCURACY
FOR FOUR GROUPS OF SUBJECTS

Source of variation	Sum of Squares of Errors of Estimate	df	Mean Square	F
Total	2495.8022	60		
Within Groups	1643.3319	57	28.8304	9.8561*
Adjusted Means	852.4703	3	284.1568	

*Significant at the 1% level of confidence.

TABLE IX

SIGNIFICANCE OF DIFFERENCE OF MEAN DIFFERENCE
ACCURACY SCORES IN BOWLING
FOR CONTROL AND EXPERIMENTAL GROUPS

	Mean	"t"		
		Control I	Experimental I	Experimental II
Control I	60.73	.69	3.67*	4.38*
Control II	61.25		2.97*	3.68*
Experimental I	63.47		.71	
Experimental II	64.00			

*Significant at the 1% level of confidence.

TABLE X

MEAN DIFFERENCE AND SIGNIFICANCE OF DIFFERENCE BETWEEN INITIAL AND FINAL AVERAGE AND ACCURACY SCORES FOR EXPERIMENTAL AND CONTROL GROUPS

	Mean Difference	"t"
EXPERIMENTAL GROUP		
Average Scores	19.2666	3.5777*
Accuracy Scores	13.9333	10.8093*
CONTROL GROUP		
Average Scores	19.7419	3.6044*
Accuracy Scores	13.7741	9.5507*

*Significant at the 1% level of confidence.

was found at the 1 per cent level of confidence, thus indicating that all groups showed significant improvement in both performance and accuracy as a result of instruction in bowling by two methods.

Interpretation of Data

Although statistical analysis of the bowling scores for four groups of subjects in the initial stages of learning showed no significant difference in performance, it was evident that subjects in this investigation increased their scores. In the writer's opinion, this was due to individual differences which could be accounted for by different levels of ability, and variations in individual learning rates. This is substantiated by Phillips and Summers (53) who point out that in the initial stages of learning there is an initial rise in skill and that improvement differs with the level of skill.

Since the "t" test revealed that there was significant improvement in all four groups in both performance and accuracy, this would appear to indicate that practice of correct form is more important than the method of instruction. This conclusion is drawn from the fact that four groups taught by two teaching methods with the same amount of instruction time each showed significant improvement. This is backed up by Glassow (42) who states that students in bowling improve during instruction regardless of the instruction, and that practice without instruction also results in improvement. Walter's study further substantiates this conclusion.

According to Goellner (43) a definite pattern of skill performance does not seem to emerge as far as beginning bowlers are concerned.

Phillips and Summers (53) point out that among beginning bowlers there is inconsistency of performance because of limited practice in performance. In the writer's opinion, both of these factors affected the outcome of this investigation. During the fifteen-game series, there was not enough time to establish a pattern of performance and to reach a level of consistent performance.

The writer agrees with Sloan (55) that the function of the effective teacher in bowling instruction is to assist the learner in clarifying her goals and making needed adjustments in her motor performance. This belief is upheld by the outcomes of this investigation. Apparently, regardless of the method of instruction, as long as the learner is able to understand the goals and adjust her movement patterns, she will show successful skill improvement. This seems to occur no matter what method of teaching is used.

Although no significance of difference in performance, as measured by game scores, was evident, the analysis of co-variance did reveal that the Experimental Groups were superior in accuracy. In the writer's opinion, this seems to indicate that emphasis in this specific area of bowling technique is more beneficial by application and understanding of principles than by their application to the skill itself. A great deal of emphasis was placed on principles of accuracy throughout the instruction of the Experimental Group. It may be assumed that it was as a result of this emphasis that the accuracy improvement in the Experimental Groups was larger than that in the Control Groups.

The results of this study seem to indicate that knowledge and understanding of the mechanical and kinesiological principles that apply to the execution of bowling technique do not enhance individual improvement in skill. The investigator feels that the students in the Experimental Groups had a better understanding of the principles governing the movements of the body and manipulations of the ball, but were unable to apply them. This conclusion is backed up by Ragsdale's theory that "a learner may understand the principle applied to inanimate objects, but he may not be able to apply it to his own movements." (65:105)

Conclusions in this study also support Colville's conclusions that students' performance in Experimental Groups that received instruction in principles of mechanics did not differ in performance from Control Groups that received no instruction in principles prior to participation in a selected activity.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to develop an analytical approach to teaching, based on selected principles of kinesiology and mechanics, and to investigate the effects of this approach on learning to bowl as compared to the traditional method of teaching.

Sixty-one college women enrolled in the required physical education program at the Woman's College of the University of North Carolina were subjects for this study. The subjects made up four classes of beginning bowling; two were designated as experimental groups and two as control groups. The classes met twice weekly for forty minute periods for a total of thirty lessons. Lesson plans for the experimental and control groups, constructed prior to the beginning of instruction, were identical with the exception of the inclusion of the principles and use of visual aids for the experimental groups.

Bowling scores for each subject were recorded for each game that was bowled in a fifteen-game series. Game averages were used as a measure of bowling skill. The mean score for the first five games was used as a measure of initial ability; the mean score of the last five games, games eleven through fifteen, was used as a measure of final ability.

The number of pins down with the first ball rolled in each frame was recorded and used as a measure of accuracy. The average of the number of pins down on the first balls in each game was calculated and a mean score of the number down on the first five games and games eleven through fifteen were used as initial and final measures of accuracy.

The mean scores calculated for the initial and final ability and accuracy were subjected to statistical comparison using analysis of co-variance to identify any significant difference between them. The mean score was compared on two levels: initial performance and accuracy based on games 1-5, and final performance and accuracy based on games 11-15.

Difference scores between initial and final performance and accuracy were calculated. The mean difference was submitted to the "t" test to determine the significance of difference for both the experimental and control groups.

On the basis of the data collected and statistically analyzed on the basis of initial and final performance and accuracy scores in bowling, the following conclusions were drawn:

1. For the four groups of subjects used in this study there was no significant difference in game scores based upon initial and final performance.

2. For the four groups of subjects in this study there was superior performance in accuracy in the experimental groups.

3. Instruction in mechanical and kinesiological principles did not appear to enhance learning and improve performance as measured by bowling scores of the beginning bowlers in this study.

4. The traditional method of teaching bowling was as effective as the analytical approach developed and used in this investigation for improving over-all performance.

5. There was significant improvement in bowling skill in both the experimental and control groups of subjects. For both groups this improvement was statistically significant at better than the 1 per cent level of confidence.

6. Conclusions in this study support Colville's conclusions that students' performance in experimental groups instructed in mechanical principles did not differ from performance in control groups that received no instruction in principles.

7. Conclusions in this study further support Ragsdale's theory of motor learning "that a learner may understand the principles applied to inanimate objects, but he may not be able to apply it to his own movements." (65:101)

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APPENDIX

LESSON PLANS FOR EXPERIMENTAL AND CONTROL GROUPS

EXPERIMENTAL GROUPS
(Experimental-analytical Method)

LESSON 1

I. Introduce to bowling
II. The arm as a third class lever as used in bowling skill.
  Principle:
    Lever: 1
    Visual Aid: 1
    Velocity: 9
III. The action of the lever as it executes the arm swing.
  Principle:
    Lever: 3
IV. The arm swing
  A. Explanation
  B. Demonstration
  C. Practice

LESSON 2

I. Review the lever: Ball, force and range.
  Principle:
    Lever: 1,2,3
II. One step Approach
  A. Principles:
    Velocity: 1 and 5
  B. Application of principle
  C. Demonstration
  D. Practice
III. Four step Approach (Without ball)
  A. Approach defined
  B. Explanation
  C. Demonstration
  D. Practice of steps
  E. The path of the arm swing
    Visual Aids: 2 and 3
  F. Practice

CONTROL GROUPS
(Traditional Method)

LESSON 1

I. Same as for experimental
II. The arm swing
  A. Explanation
  B. Demonstration
  C. Practice

LESSON 2

I. Review swing with emphasis on:
  A. Pattern of the swing
  B. Release of ball
  C. Stance
  D. Backswing
II. One step Approach
  A. Explanation
  B. Demonstration
  C. Practice
  D. Individual Help
III. Four step Approach (Without ball)
  A. Explanation
  B. Demonstration
  C. Practice

EXPERIMENTAL GROUPS

LESSON 3

- I. Review
    - A. Principles in Lessons 1 and 2
    - B. Review Four step Approach (without ball)
- II. Four step Approach (with ball)
    - A. Stress pushaway and backswing and corresponding principles in Lesson 2
    - B. Practice
- III. Balance
    - A. Principles:
        - Balance: 1,2,3,4
        - Visual Aid: 7
- IV. Aim: Headpin Bowling
    - A. Explanation
    - B. Principle Accuracy: 7
    - C. Application
- V. Accuracy
    - A. Visual Aid: 5
    - B. Principles corresponding
        - Accuracy: 1 and 5
    - C. Application
- VI. Practice aim for 1-3 pocket with attention to:
    - A. Four step Approach
    - B. Aim
    - C. Accuracy

LESSON 4

- I. Scoring
- II. Simple Rules
- III. Review of safety procedures
- IV. Point of Release
    - A. Explanation
    - B. Principle:
        - Coordination: 3
        - Velocity: 7
        - Visual Aids: 5 and 6

CONTROL GROUPS

LESSON 3

- I. Review, verbally, Four step Approach
- II. Four step Approach (with ball)
    - A. Explanation
    - B. Demonstration
    - C. Practice
    - D. Stress
        1. Pushaway
        2. Backswing
        3. Balance
- III. Aim: Headpin Bowling
    - A. Explanation
    - B. Demonstration
- IV. Accuracy
    - A. Thumb position
    - B. Point of release
    - C. Path of the arm
    - D. Cross alley ball
- V. Same as VI.

LESSON 4

- I. Same
- II. Same
- III. Same
- IV. Point of release
    - A. Explanation
    - B. Demonstration
- V. Explanation of effect of speed on the ball
- VI. Begin first game

EXPERIMENTAL GROUPS

LESSON 4 (continued)

C. Application
IV. Speed
  A. Visual Aid: 8
  B. Principle:
    Accuracy: 2 and 3
  C. Application
V. Begin first game

LESSON 5

I. Review and Emphasis
  A. Follow through
  B. Balance with review of principles
    1. feet; position at release
      Visual Aid: 7
    2. left arm; position for balance
  C. Demonstration of above
  D. Demonstration of the swing of lever and incorrect arm position
  E. Games continued

LESSON 6

I. Review points of emphasis in Lesson 5
II. Height of backswing
  A. Principle:
    Velocity: 3,5 and 6
III. Review principles of balance
IV. Games continued

LESSON 7

I. Review principles of:
  A. Levers
  B. Velocity:
    Principles: 1,3,5,9
  C. Visual Aids: 1,2 and 3

CONTROL GROUPS

LESSON 5

I. Review
  A. Follow through
  B. Balance
  C. Arm swing
II. Games continued

LESSON 6

I. Brief review of form of Four step Approach
II. Games continued

LESSON 7

I. Review and Emphasis
  A. Speed
  B. Backswing
  C. Pushaway
II. Games continued

EXPERIMENTAL GROUPS

LESSON 7 (continued)

D. Pushaway:
    Principles:
        Velocity: 1, 2
        Coordination: 1,2

II. Games continued

LESSON 8

I. Review terms
II. Simple theory of spare bowling
III. Review principles
    A. Accuracy
    B. Velocity
IV. Deflection
    A. Explanation
    B. Relation to spare bowling
V. Games continued

LESSON 9

I. Review of principles
    A. Accuracy:
        Principles: 1, 5
            1. Application
            2. Demonstration
    B. Speed of ball:
        Principles:
            Accuracy: 2 and 3
                1. Application
                2. Demonstration
                3. Visual Aid: 8
II. Games continued

LESSON 10 (Spare Bowling)

I. Discussion
    A. Importance of picking up spares to high scores
    B. Causes of spare leaves

CONTROL GROUPS

LESSON 8

I. Same
II. Same
III. Emphasis
    A. Straight arm in the swing
    B. Pushaway
IV. Same
V. Same

LESSON 9

I. Emphasis
    A. Looking at point of aim
    B. Balance
    C. Height of backswing
    D. Speed
II. Same

LESSON 10 (Spare Bowling)

I. Same
II. Points to consider
    A. Angle
    B. Stance, approach and arm swing

EXPERIMENTAL GROUPS

LESSON 10 (continued)

C. Types of spares
1. right
2. center
3. left

II. Principles of Spare bowling
A. Visual Aids: 4,9,10,11
B. Review in relation to application to Spare bowling
1. Accuracy:
Principle: 5
C. Application of review as to arm swing and body position
D. Principle:
Deflection: 1
1. Application
2. Demonstration
E. Principle:
Deflection: 2
1. Application
2. Demonstration
F. Application and demonstration of principles to specific leaves
1. right side leaves
2. left side leaves
3. center leaves

III. Practice bowling at specific leaves, A, B, and C above

LESSON 11

I. Review principles and Visual Aids of Spare bowling presented in Lesson 10
II. Practice
III. Games continued

LESSON 12

I. Application of principles to correction of errors. Teacher demonstration of errors.

CONTROL GROUPS

LESSON 10 (continued)

C. Shoulder position
D. Position on alley for right, left, and center spares
E. Point of aim
F. Effect of pin action

III. Illustration of above points by application to:
A. Right leaves
B. Left leaves
C. Center leaves

IV. Practice bowling at specific leaves, A, B, and C above

LESSON 11

I. Review Spare bowling
II. Practice
III. Games continued

LESSON 12

I. Discussion of errors. Teacher demonstration of errors and their correction.
A. Balance

EXPERIMENTAL GROUPS	CONTROL GROUPS
LESSON 12 (continued) A. Balance B. Backswing C. Degree of error as related to arm swing D. Speed of ball II. Application of principles to individual student's errors. Correction. III. Games continued	LESSON 12 (continued) B. Backswing C. Degree of error as related to arm swing D. Speed of ball II. Same III. Same
LESSON 13 I. Review of principles relating to release of the ball A. Principle: Coordination: 3 B. Principle: Accuracy: 1 C. Principle: Velocity: 7 and 8 D. Visual Aids: 5 and 6 II. Correction of individual errors III. Games continued	LESSON 13 I. Explanation of cause of error with release of ball II. Same III. Games continued
LESSON 14 I. Student's analysis of own errors according to principles II. Correction of errors III. Games continued	LESSON 14 I. Correction of individual errors II. Games continued
LESSON 15 I. Same as above II. Same as above III. Same as above IV. Presentation of principles that are needed to correct individual student's errors V. Games continued	LESSON 15 Same as above

EXPERIMENTAL GROUPS	CONTROL GROUPS
LESSONS 16 thru 18 Same as above	**LESSONS 16 thru 18** Same as above
LESSON 19 I. Spot bowling II. Principles: A. Principle B. Principle III. Application IV. Practice with 1-3 pocket V. Games continued	**LESSON 19** I. Explanation of Spot bowling II. Practice with 1-3 pocket III. Games continued
LESSON 20 I. Review Spare bowling A. Principles B. Visual Aids II. Practice of specific leaves III. Games continued	**LESSON 20** I. Review Spare bowling II. Practice of specific leaves III. Games continued
LESSON 21 I. Application and review of principles according to individual student's errors II. Games continued	**LESSON 21** I. Correction of individual errors II. Games continued
LESSONS 22 thru 27 Same as above	**LESSONS 22 thru 27** Same as above
LESSON 28 I. Review of principles and Visual Aids II. Games continued	**LESSON 28** I. Review of form for the Four step Approach II. Games continued

EXPERIMENTAL GROUPS	CONTROL GROUPS
LESSON 29	LESSON 29
I. Review of rules and terms II. Games continued	I. Review of rules and terms II. Games continued
LESSON 30	LESSON 30
Finish games	Finish games

PRINCIPLES OF ACCURACY

PRINCIPLE	APPLICATION	SOURCE
1. A released object continues to move in the same direction that it was moving at the point of release. In angular motion a released object will travel at right angles to the radius of the circle at the moment of release.	1. The backswing and the slide must be in a straight line with the target. The time of release of the ball is important. It should be opposite the radius of the circle.	1. (51:16)
2. When an object is rotating, more resistance is placed on the side of the object that is turning in the direction of the forward motion. This force is called the deflecting force and will result in a change of direction.	2. The ball rolls on the alley and therefore top spin has no effect on the ball. Side spin will give rise to the deflecting forces which will cause a change of direction.	2. (51:16)
3. The faster an object is traveling the less time a deflecting force has to act upon the object in a specified distance.	3. Speed is an important factor in maintaining the roll of the ball. Speed in this case prevents the effect of the deflecting force. This explains why spin does not affect the ball until there is some loss of speed as the ball approaches the pins.	3. (51:17)

PRINCIPLE	APPLICATION	SOURCE
4. Friction is a force working to stop motion and is determined by: a. nature of the touching of two surfaces b. force with which the objects are pressed together c. speed of the object.	4. The contact of the ball on the alley introduces the effect of friction. Friction affects the forward velocity and thus accuracy.	4. (51:17)
5. A change in the direction of one degree will result in a change in the path of the ball by three inches in fifteen feet.	5. The alley is forty-two inches wide. The center of the number seven pin is eighteen inches to the left of the center of the head pin. A small change in the angle of the body or the arm during the swing will result in a change in the path of the ball, and thus accuracy will be affected. All other things being equal, a very small change in the angle of the body will pick up a spare.	5. (51:20)

PRINCIPLE	APPLICATION	SOURCE
6. The magnitude of an error is proportional to the distance between the point of release and the target.	6. Advantage of spot bowling.	6. (51:20)
7. Focusing the eyes assists in maintaining balance and a straight line of movement.	7. The eyes, in pin bowling, should be focused on the point of aim.	7. (51:20)

PRINCIPLES OF BALANCE

PRINCIPLE	APPLICATION	SOURCE
1. A body is balanced when the center of gravity is balanced over the base of support. The larger the base of support the greater will be the body's stability.	1. In the four steps of the approach the segments of the body must be balanced over the base of support.	1. (30:351) (51:17)
2. Stability is directly proportional to the area of the base on which the body rests.	2. The length of the steps in the approach are related to the stability of the body.	2. (4:13)
3. Stability is increased if the widest part of the base is in the direction of the force which is attempting to disturb the equilibrium.	3. A forward stride on the fourth step is more effective than a side stride in enhancing stability.	3. (51:18)
4. When an object is carried by the body its weight must be considered as a part of the weight to be balanced over the base of support. This makes a change in the line of gravity and adjustments must be made to try to keep the	4. The closer the ball is to the body the easier it is to balance. A lowered center of gravity aids balance. The free arm should be out to the side of the body to balance the weight of the	4. (28:123) (51:19)

PRINCIPLE	APPLICATION	SOURCE
line of gravity located as centrally as possible.	ball in the other hand. The forward lean of the trunk during the backswing helps to maintain balance. As the ball is released the body must be brought back into an erect position to be balanced over the base of support, the feet.	
5. Force may be diminished by increasing the distance over which it is absorbed.	5. The follow through continues until the body is erect. This increases the distance in which the body's forward momentum can be absorbed.	5. (51:18)
6. Stability is indirectly related to the distance of the center of gravity of the body above its base; and the horizontal distance of the center of gravity from the edge of the base that is toward the direction of the momentum.	6. The position of the body during the release and the follow through.	6. (4:114) (28:119)

PRINCIPLE	APPLICATION	SOURCE
7. Newton's Third Law of Motion: For every action there is an equal and opposite reaction.	7. The body must lean forward to balance the forces in the opposite direction when accelerating. The force created by leaning forward balances the force of the push against the floor by the feet.	7. (26:118-119)

PRINCIPLES OF CO-ORDINATION

PRINCIPLE	APPLICATION	SOURCE
1. The movement of a lever is produced by the force of gravity. This presupposes a starting position in which potential energy is present. The lever must be moved from the resting position before the forces of gravity can make it swing downward.	1. The pushaway places the ball in a position so that gravity can affect the swing of the ball. The pushaway makes the conversion of the potential energy to kinetic energy possible.	1. (30:387)
2. The range of the swing of the lever depends on the height from which the movement was initiated.	2. The pushaway of the ball is important as it determines the height that initiates the movement and affects the range of the movement.	2. (30:387)
3. As the lever swings downward its speed increases; as it swings upward its speed diminishes. Hence the greatest speed occurs at the bottom of the arc.	3. Unless the ball is released at the proper time speed is affected. In order to release the ball at the bottom of the arc the release must be times with the fourth step.	3. (30:388)
4. Forces, to be summed effectively, must be added at the time of least acceleration and maximum velocity of the proceeding force.	4. Since the acceleration of gravity is constant the speed of the steps must be adjusted to the arm swing; therefore, the necessity for the perfect coordination of the arms and the legs.	4. (51:19)

PRINCIPLES OF DEFLECTION

PRINCIPLE	APPLICATION	SOURCE
1. The sum of the momentum of two colliding objects before a collision is equal to the sum of the momentum of the objects after the collision.	1. The mass of the pins and the ball is constant. The velocity given to the pins must come from the ball.	1. (51:20)
2. Unless two colliding objects meet squarely, the center of gravity of one hitting the center of gravity of the other at a one hundred and eighty degree angle, both objects will be deflected from the original path. The object with the greatest velocity will be deflected least. The faster an object is traveling the smaller will be the deflection.	2. In tandem bowling the front pin should be hit squarely with the ball so that the ball will not be deflected from its course and miss the second pin. The regulation of the speed of the ball according to the type of spare leave is important.	2. (51:20)

PRINCIPLES OF THE THIRD CLASS LEVER

PRINCIPLE	APPLICATION	SOURCE
1. Levers of the third class have the force applied between the fulcrum and resistance; force and resistance operate in opposite directions and the force must always be greater than the resistance.	1. The shoulder is the axis, the ball is the resistance and the muscles make the power that operates the resistance arm.	1. (26:128)
2. A throw for speed and distance is always made with the longest lever possible.	2. The arm swinging the ball is a long lever. The elbow should be straight during the entire swing of the arm.	2. (28:146)
3. An isolated lever moves around its axis, which is fixed; and it moves independently of other levers. The levers of the human body do not move in this way. Because the end of the lever is attached to other body segments it necessitates shift of the body position.	3. In bowling, the position of the body must be shifted to allow an efficient arm swing.	3. (28:133)

PRINCIPLES RELATING TO THE DEVELOPMENT OF VELOCITY

PRINCIPLE	APPLICATION	SOURCE
1. Newton's First Law of Motion: A body remains in a state of rest or uniform motion unless acted upon by some external force.	1. In order for the force of gravity to act upon the ball it must be placed in a position so that this action can take place. This position is made possible by the pushaway. The velocity is developed by a gravity produced swing, and therefore the forces of gravity are necessary.	1. (26:28-9) (51:14)
2. A moment of force is a force that tends to produce rotation around an axis, times the perpendicular distance from the axis. The direction of gravity's acceleration is always downward.	2. The pushaway develops the moment of force. The greater the perpendicular distance between the ball and the shoulder joint the greater the forces amount to.	2. (18:32)
3. Energy cannot be created or destroyed. Potential energy is energy of position. Kinetic energy is energy of motion.	3. The ball at the top of the backswing has potential energy which may be converted into kinetic energy. The potential energy that can be converted is related to the height of the backswing. The potential energy of the bowling ball is increased directly according to the height of the backswing.	3. (18:32)

PRINCIPLE	APPLICATION	SOURCE
4. Potential energy can be converted into kinetic energy.	4. Same as above	4. (51:15)
5. Final velocity of an object is determined by the rate of acceleration and the length of time over which the acceleration takes place; or final velocity is determined by the distance over which the acceleration takes place.	5. Acceleration of gravity is constant in a gravity propelled swing. The velocity is determined by the height of the backswing.	5. (51:15)
6. Hyper-extension of the humerous is limited by the structure of the shoulder joint.	6. Hyper-extension of the arm is required for a high backswing. A higher backswing is facilitated by leaning forward with a bend of the body.	6. (51:15)
7. In angular movement the maximum linear velocity is at right angles to the radius.	7. If the ball is released when the ball is perpendicular to the floor, due to the force of gravity, the ball will strike the alley ahead of this point.	7. (51:15) (4:37)
8. Angular and linear forces may be combined. If the	8. The swing through of the arm should come when the body's	8. (51:15) (26:400-408)

PRINCIPLE	APPLICATION	SOURCE
forces are to be summed a second force should be addressed to the first at the minimum acceleration and maximum velocity of the first.	acceleration toward the foul line has ceased and the body has maximum velocity. Maximum velocity should be attained just before the last step and the slide; therefore, the slide and the swing through should be simultaneous for effective summation of forces.	
9. A long lever has greatest velocity than a short one. In movement of the arm the hand has greater velocity when the elbow is straight.	9. For greatest velocity the arm swing should be made with a straight arm avoiding any bend of the elbow.	9. (30:381-382)

BOWLING SCORES FOR SUBJECTS IN EXPERIMENTAL GROUP I

Subject	Game Scores														
Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	73	61	121	88	76	106	135	120	97	86	135	99	138	121	113
2	90	92	167	104	106	140	104	105	101	107	113	101	143	95	160
3	80	76	105	73	115	96	109	92	101	103	115	96	86	71	95
4	84	107	101	87	70	96	98	116	103	105	143	111	102	109	102
5	60	73	48	49	76	89	93	78	75	131	74	90	93	121	98
6	97	125	99	117	104	95	105	98	122	147	105	137	81	123	92
7	71	67	73	93	88	39	79	96	66	85	116	100	102	125	91
8	73	64	152	86	100	81	96	117	73	56	82	126	118	103	102
9	93	103	108	90	128	116	79	66	91	137	117	101	93	123	100
10	57	79	78	71	87	97	72	83	93	99	74	140	96	115	108
11	102	90	93	80	104	146	114	104	114	133	116	138	119	160	178
12	87	58	38	120	106	125	86	90	84	87	110	89	67	90	85
13	108	82	76	151	156	128	121	87	106	93	134	99	95	100	130
14	71	94	59	68	69	90	65	71	87	87	111	79	79	66	94
15	50	40	14	47	53	46	100	52	51	30	54	61	70	88	89

AVERAGES FOR GAME SCORES AND ACCURACY SCORES

EXPERIMENTAL GROUP I

Subject	Games 1-5	Games 11-15	Accuracy 1-5	Accuracy 11-15
1	83	101	51	70
2	111	122	62	92
3	89	92	58	65
4	89	113	53	67
5	61	95	40	56
6	108	107	66	63
7	68	106	47	67
8	95	106	49	57
9	104	106	58	64
10	74	85	48	56
11	93	122	56	77
12	81	104	48	53
13	114	111	68	67
14	72	85	47	55
15	40	72	24	43

BOWLING SCORES FOR SUBJECTS IN EXPERIMENTAL GROUP II

Subject	Game Scores														
Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	109	107	94	82	119	119	133	145	142	131	127	163	131	146	142
2	112	147	115	199	104	110	99	93	155	105	134	130	140	152	122
3	83	93	85	91	117	87	58	112	75	98	122	99	115	80	89
4	110	89	128	107	129	139	121	116	123	97	120	115	87	104	100
5	70	60	69	107	61	109	63	91	108	106	72	118	83	98	104
6	68	60	116	117	108	103	117	82	88	54	98	93	85	71	111
7	36	68	59	74	85	103	98	115	100	70	148	84	131	95	96
8	85	66	76	71	77	85	95	130	90	93	82	114	82	118	113
9	113	86	104	114	102	121	100	85	119	127	137	123	110	138	136
10	83	106	116	56	97	79	100	101	108	138	95	114	89	118	145
11	46	48	62	74	67	115	75	74	70	89	86	85	98	66	89
12	66	120	57	81	76	102	92	125	132	97	107	141	86	70	131
13	42	61	59	70	58	32	85	80	66	81	72	74	70	105	106
14	106	95	92	94	85	95	94	98	65	117	131	137	106	140	123
15	67	57	40	46	90	76	90	76	97	107	79	127	120	93	106

AVERAGES FOR GAME SCORES AND ACCURACY SCORES

EXPERIMENTAL GROUP II

Subject	Games 1-5	Games 11-15	Accuracy 1-5	Accuracy 11-15
1	102	141	57	79
2	125	135	66	73
3	93	101	151	60
4	112	105	57	65
5	73	95	43	60
6	93	91	51	61
7	64	110	41	60
8	75	101	46	58
9	103	128	62	74
10	91	112	49	70
11	59	84	34	54
12	80	107	50	66
13	58	85	33	49
14	94	127	50	73
15	60	105	32	58

BOWLING SCORES FOR SUBJECTS IN CONTROL GROUP I

Subject	Game Scores														
Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	46	69	69	85	72	93	124	107	139	126	116	130	101	91	84
2	73	62	83	97	85	100	101	95	116	110	81	97	123	116	99
3	76	86	114	95	74	102	109	112	119	96	114	72	102	107	100
4	103	117	143	142	99	114	126	111	81	115	90	107	148	152	116
5	70	97	57	62	79	69	93	123	99	81	95	53	75	82	125
6	67	55	67	92	80	85	80	67	67	54	96	93	79	82	78
7	69	100	69	105	79	72	62	62	88	75	91	87	84	96	87
8	65	96	100	84	95	93	105	101	152	134	100	121	99	95	106
9	18	96	78	56	73	60	55	71	162	76	75	96	86	61	100
10	33	47	83	46	63	57	105	66	85	108	96	94	122	106	105
11	68	103	91	81	112	61	57	81	93	76	92	97	101	104	90
12	78	83	57	82	45	62	86	67	62	81	55	96	69	84	84
13	69	101	99	69	104	89	80	106	100	111	85	108	136	112	139
14	84	116	83	115	93	116	106	125	116	73	102	119	89	130	113
15	59	89	95	97	83	76	99	68	122	95	102	95	118	65	108

AVERAGES FOR GAME SCORES AND ACCURACY SCORES

CONTROL GROUP I

Subject	Games 1-5	Games 11-15	Accuracy 1-5	Accuracy 11-15
1	68	104	32	63
2	80	103	50	69
3	89	99	58	55
4	120	122	69	71
5	73	86	44	50
6	72	85	42	50
7	84	89	50	56
8	88	105	48	69
9	50	83	31	61
10	54	104	33	61
11	91	96	51	64
12	69	77	40	46
13	88	116	53	69
14	98	106	51	67
15	84	97	54	60

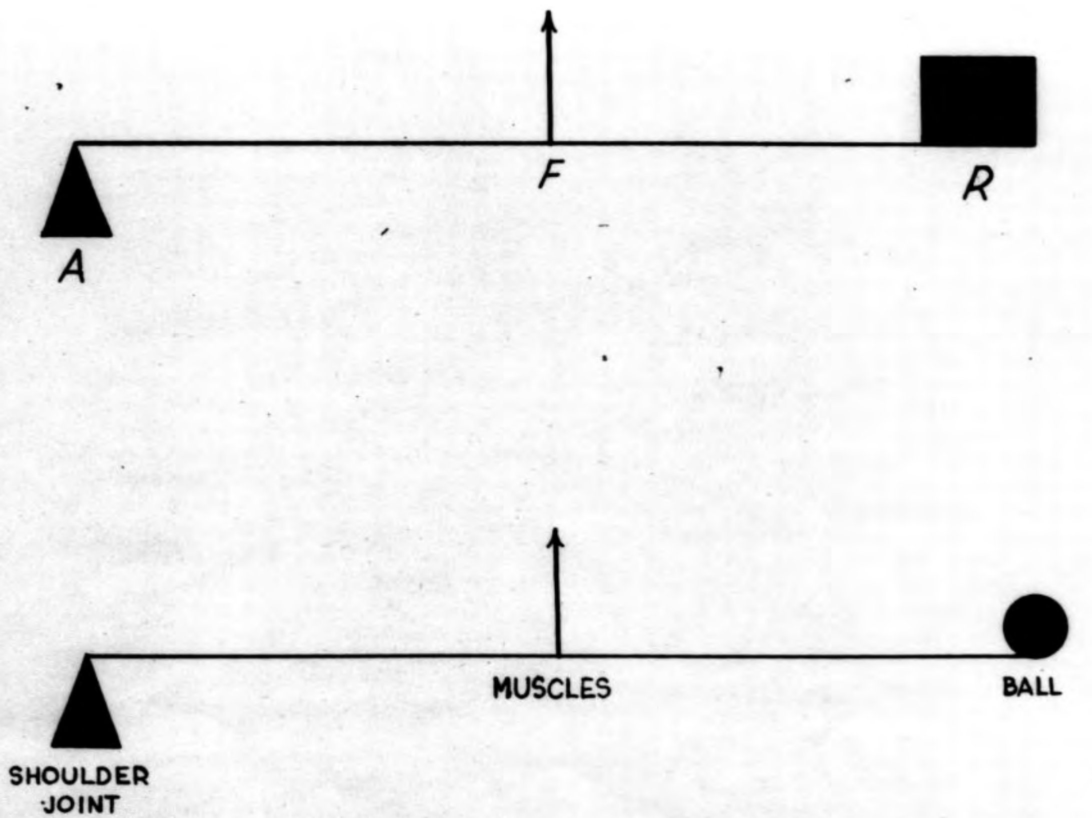
BOWLING SCORES FOR SUBJECTS IN CONTROL GROUP II

Subject	Game Scores														
Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	44	75	120	79	60	73	69	125	89	85	97	101	91	137	156
2	49	55	68	67	127	58	60	63	82	103	72	83	90	135	130
3	117	121	102	57	91	63	105	106	116	107	88	93	117	121	129
4	102	64	97	96	67	54	85	56	108	81	76	91	117	98	101
5	60	64	88	65	95	82	82	90	80	76	107	99	89	102	81
6	116	91	92	104	93	80	77	93	113	96	146	143	110	144	116
7	81	96	68	69	91	70	101	64	55	114	102	92	81	105	107
8	96	126	67	101	81	107	113	129	113	108	111	102	147	110	100
9	95	72	66	98	97	71	163	98	132	107	80	114	132	110	121
10	80	52	86	59	73	89	75	107	102	80	89	62	90	129	103
11	47	60	63	33	54	92	52	75	143	65	64	47	118	115	63
12	91	71	84	96	86	100	99	72	99	112	79	93	99	120	127
13	45	84	65	82	73	51	76	76	58	64	98	119	90	78	72
14	111	81	106	110	95	120	137	136	112	156	120	116	127	93	127
15	83	66	68	77	104	99	104	85	72	82	122	62	97	90	96
16	48	55	85	73	88	82	94	85	85	106	97	116	81	76	94

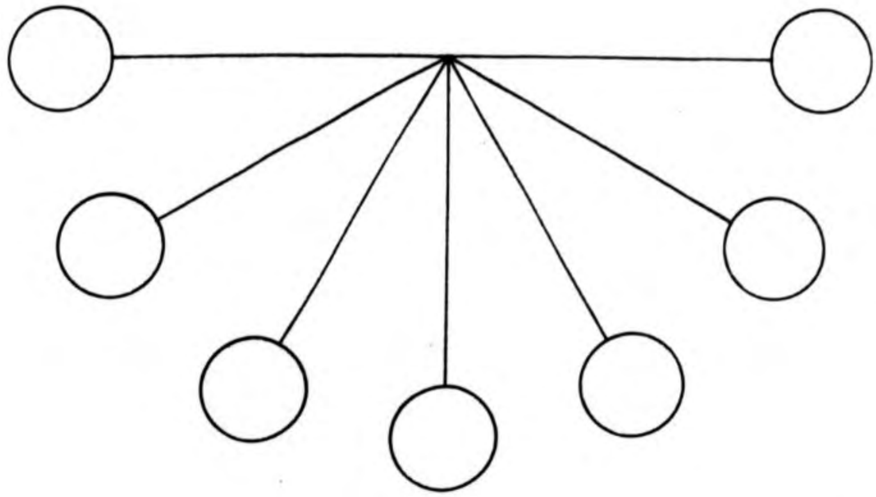
AVERAGES FOR GAME SCORES AND ACCURACY SCORES

CONTROL GROUP II

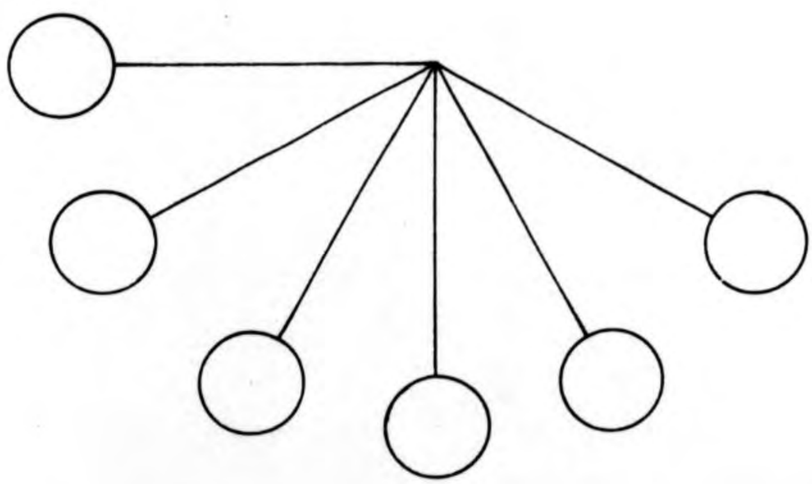
Subject	Games 1-5	Games 11-15	Accuracy 1-5	Accuracy 11-15
1	75	116	45	62
2	73	102	38	62
3	97	109	47	68
4	85	96	47	57
5	74	97	46	59
6	99	131	57	63
7	77	97	54	62
8	94	114	62	69
9	85	111	50	64
10	70	94	50	56
11	51	81	33	54
12	85	103	54	64
13	69	87	35	57
14	100	116	57	70
15	79	93	41	53
16	69	92	42	59



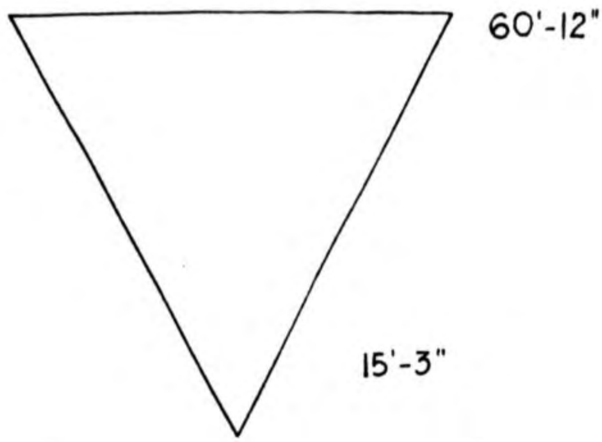
VISUAL AID I: THE ARM AS A THIRD CLASS LEVER



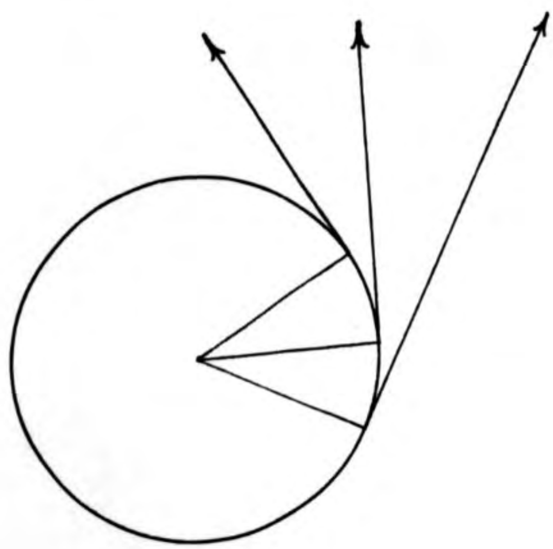
VISUAL AID 2: THE PATH OF THE BOWLING BALL IN A FOUR STEP APPROACH



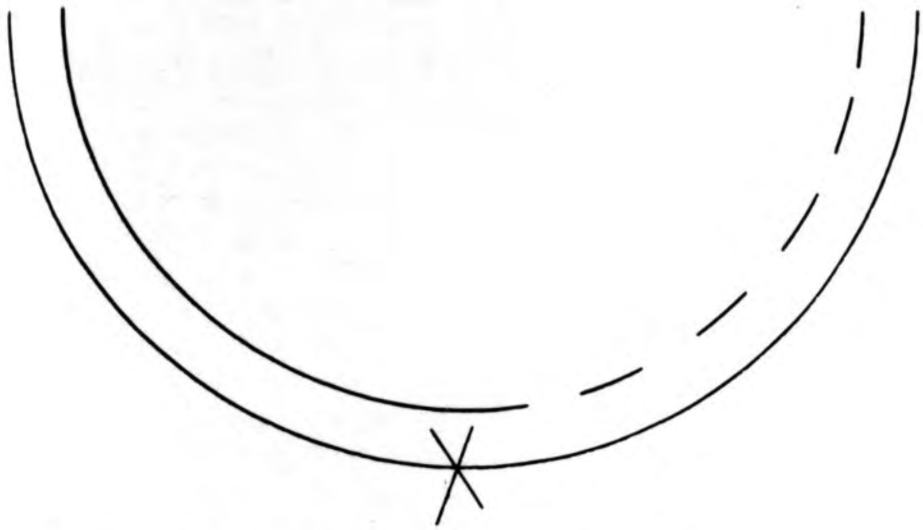
VISUAL AID 3: THE PATH OF THE BOWLING BALL IN THE DOWNSWING AND THE POINT OF RELEASE



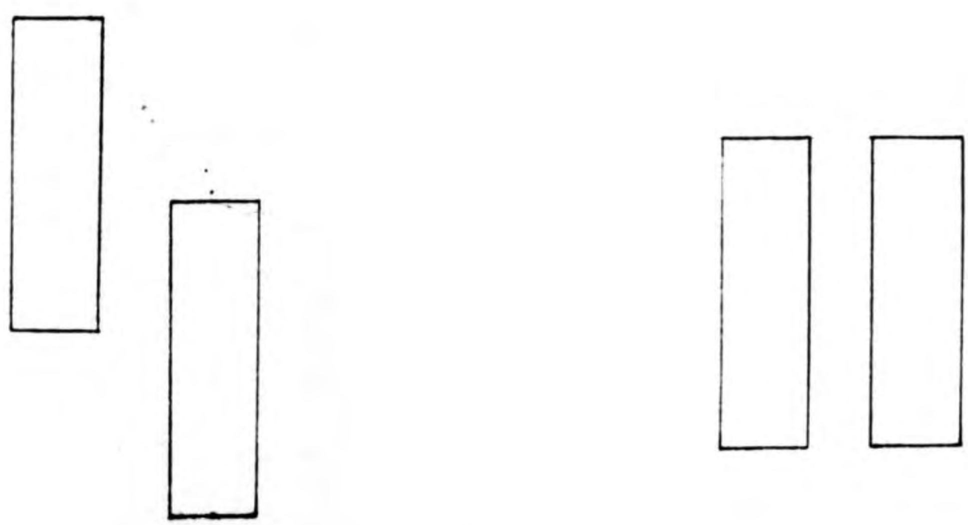
VISUAL AID 4: THE EFFECT OF DEGREES OF ERROR ON THE DIRECTION THAT THE BALL TRAVELS



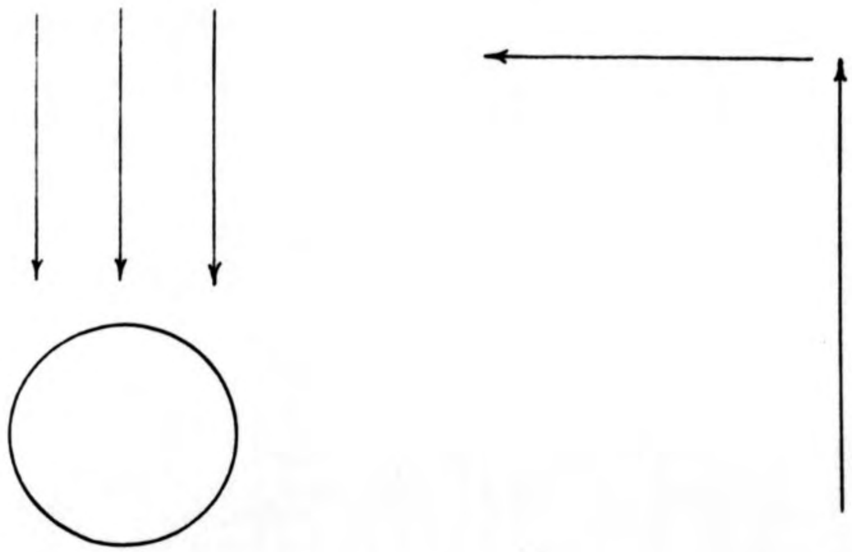
VISUAL AID 5: DIRECTION OF THE BALL AS EFFECTED BY THE POINT OF RELEASE



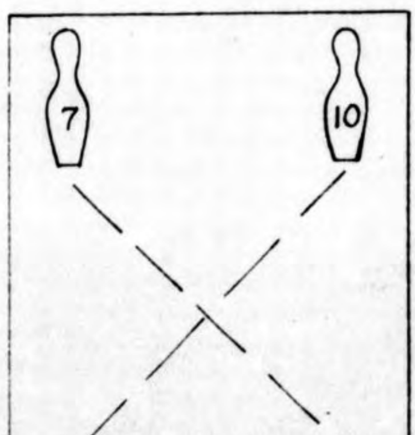
VISUAL AID 6: POINT OF RELEASE



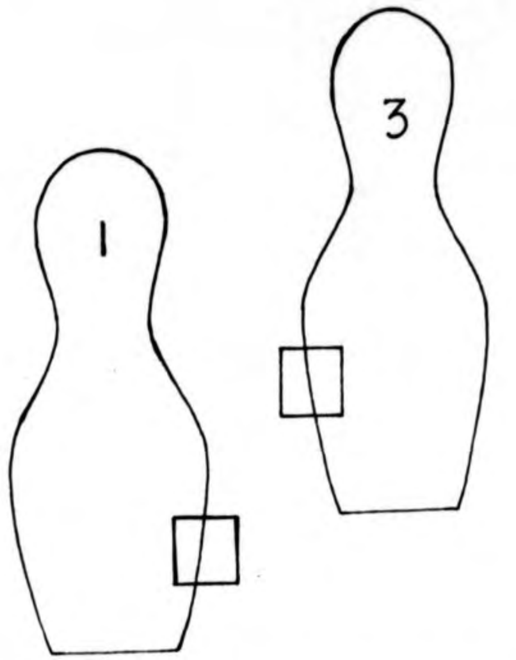
VISUAL AID 7: POSITION OF THE FEET ON THE FOURTH STEP TO ENHANCE STABILITY



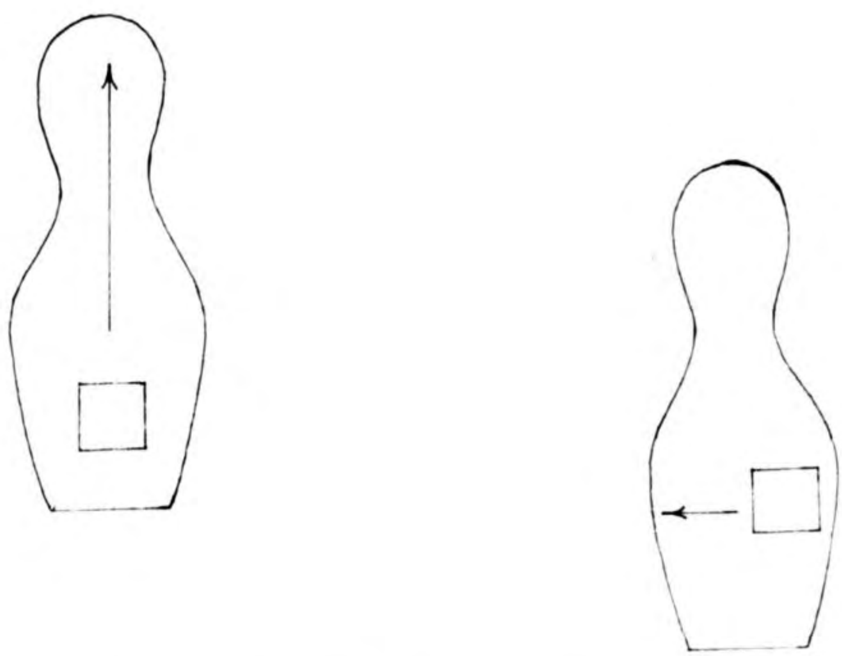
VISUAL AID 8: THE ROLL OF THE BALL ON THE ALLEY AND THE EFFECT OF THE DEFLECTING FORCE



VISUAL AID 9: THE IMPORTANCE OF THE ANGLE OF CONTACT FOR SPARE BOWLING



VISUAL AID 10: POINT OF AIM FOR STRIKE PIN ACTION



VISUAL AID 11: POINT OF AIM FOR DIRECTIONAL PIN FALL

Typed by

ELIZABETH BOOKER