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A STUDY TO DETERMINE THE APPLICABILITY OF AN ELECTRONIC APPARATUS TO TEACHING IN PHYSICAL EDUCATION

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A STUDY TO DETERMINE THE APPLICABILITY OF AN ELECTRONIC APPARATUS TO TEACHING IN PHYSICAL EDUCATION

Mordechai Silberstein

A dissertation presented to the
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A STUDY TO DETERMINE THE APPLICABILITY OF
AN ELECTRONIC APPARATUS TO TEACHING
IN PHYSICAL EDUCATION

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ABSTRACT

A STUDY TO DETERMINE THE APPLICABILITY OF
AN ELECTRONIC APPARATUS TO TEACHING
IN PHYSICAL EDUCATION

by Mordechai Silberstein

This study was designed to determine the applicability of the Eamcovop, an electronic apparatus designed and constructed by the author for the measurement and computation of the velocity of a projectile, to the teaching of certain aspects of physical education or athletics. A modified Dekan Performance Analyzer was used as a control device in the study.

The purposes of the investigation were: (1) to establish the reliability coefficients of the Eamcovop, (2) to determine the applicability of the Eamcovop to teaching, and (3) to employ the Eamcovop to determine if there is a significant difference in a baseball pitcher's velocity from the stretch and wind-up positions.

The subjects for the investigation were ten male baseball pitchers from the Middle Tennessee State University varsity baseball team in 1979-80. The subjects ranged in age from seventeen years to twenty-three years.

The reliability coefficients were established with the Eamcovop set in a permanent position with a baseball suspended from the ceiling at a height that would cause it to break the beams of lasers when released and allowed to swing naturally. The ball was released by four subjects at the same height and distance from the Eamcovop for each of the seventy trials. Similar trials were conducted using the Dekan Performance Analyzer. Means and standard deviations were computed for the two machines using the data collected, and Pearson product moment correlations were computed to establish the reliability of the Eamcovop at velocities under ten miles per hour and at velocities nearing one hundred miles per hour.

Each pitching subject had fifteen throws recorded for speed and gross accuracy from the wind-up and stretch positions on the Eamcovop and on the Dekan Performance Analyzer. The thirty pitches were thrown at maximal speeds on each machine for a total of sixty pitches per subject. Five of the subjects threw from the wind-up position first, and five threw from the stretch position first. Gross accuracy was determined by having each pitch called a ball or a strike by a staff member of the Athletic Department at Middle Tennessee State University.

The pitching data were first analyzed by computing the mean velocities for each subject from both pitching positions, and by totaling the number of strikes thrown from each position. The mean velocities and total strikes were then subjected to *t* tests for paired data to determine whether significant differences existed between the two pitching variables for velocity or gross accuracy. The data were further analyzed by Pearson product moment correlations to find if any relationships existed between the two pitching positions for velocity or gross accuracy. Finally, Spearman's coefficients of rank correlation were utilized to determine if there were relationships between velocity and gross accuracy from the wind-up and stretch pitching positions.

The *t* tests for paired data resulted in no significant differences in velocity between the two pitching positions on either machine, and in no significant differences in gross accuracy between the two pitching positions on either machine. The *t* tests for paired data did result in significant differences in measured velocity between the two machines for the wind-up position, and in significant differences in measured velocity between the two machines for the stretch position. No significant differences in gross accuracy between the two machines were found for either pitching position.

The Pearson product moment correlations resulted in no significant correlations for velocity between the two pitching positions on the two machines. The inference drawn was that velocities achieved from one pitching position were not necessarily related to velocities achieved from the other pitching position.

The Pearson product moment correlations resulted in no significant correlations for gross accuracy between the two pitching positions on the Eamcovop. A significant positive correlation coefficient was obtained for accuracy between the two pitching positions on the Dekan Performance Analyzer; however, this was probably due to variations in human performance factors beyond the control of the study. The inference drawn was that those pitchers who were accurate from the wind-up may or may not have been as accurate from the stretch.

The Spearman coefficients of rank correlation resulted in no significant correlations between speed and gross accuracy from the wind-up or stretch positions on either machine. The inference drawn was that, as a subject's speed increased, the accuracy of the pitches may not necessarily have gotten better or worse from either pitching position.

The following conclusions were drawn: (1) the Eamcovop is at least as reliable as the Dekan Performance Analyzer in measuring the velocities of pitched baseballs, and is technically superior to the Dekan Performance Analyzer in other areas; (2) the stretch pitching position is as fast as the wind-up pitching position with a runner on third base; and (3) there is a significant difference between the Eamcovop and the Dekan Performance Analyzer as a teaching tool; the technical superiority of the Eamcovop makes it more suitable for teaching purposes than the Dekan Performance Analyzer.

Characteristics of the Eamcovop which make it useful in the teaching of physical education and athletics were discussed. The advantages include greater timing accuracy due to the use of the laser beam instead of electro-mechanical devices, the use of relatively inexpensive materials in construction of the apparatus, unhindered mobility of the subject, and flexibility of application to a wide variety of both research and teaching situations by means of the ability of the Eamcovop to measure velocity throughout the whole or any portion of a distance and to measure velocity in any of four directions.

ACKNOWLEDGMENTS

Many people were generous in their contributions to this investigation, and the author is deeply indebted to all of them. Special thanks go to Dr. Ralph Ballou, dissertation advisor, for his patient guidance. Sincere appreciation is also extended to Dr. Robert Aden, Dr. Jon MacBeth, Dr. Wallace Maples, and Dr. Amiel Solomon for their advice and assistance.

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Chapter 1

INTRODUCTION

There has been almost unanimous agreement concerning the importance of velocity in physical education and athletics. Yet, little scientific evidence has been found to substantiate the relative value of this factor.[1] The primary reason for this lack of evidence seems to be the fact that a device capable of measuring velocity in a variety of situations was not available.

The limited employment of kicking, hitting, and throwing as the physical performance criterion in various research designs has been due to the inability to measure the velocity of the kicked, struck, or thrown object accurately, and without inhibiting the performance of the subject.[2] The development of an accurate, versatile, and easily employed device for the measurement of projectile

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[1]Don R. Sebolt, "A Stroboscopic Study of the Relationship of Ball Velocity and Tennis Performance," Research Quarterly, 41:183, May, 1970.

[2]Richard C. Nelson, Conrad Larson, Charles Crawford, and Donald Brose, "Development of a Ball Velocity Measuring Device," Research Quarterly, 37:150, March, 1966.

velocity, either directly or indirectly, would have important implications for physical education. The wide diversity of circumstances where such a device could be employed would add a completely new dimension to physical education research. The scientific testing of sports skill techniques, training programs, ergogenic aids, and equipment could be done more easily and accurately, and perhaps more frequently. For example, in 1958 efforts were made to determine the velocity of a fast ball of a minor league pitcher who had a reputation for being fast, but extremely wild. Due to the timing device employed, the test proved inconclusive as forty minutes were required before the subject was able to have a pitch timed.[3]

Contemporary literature suggests that baseball coaches are constantly searching for scientific methods to improve player performance,[4] yet it was interesting to note that a pamphlet entitled What Research Tells the Coach About Baseball contained thirty-eight pages.[5] In reality, the

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[3]Ron Fimrite, "The Bringer of the Big Heat," Sports Illustrated, 42:36, June 16, 1975; Mark L. Johnson, "Two Outs and a Man on Second," Athletic Journal, 53:46, January, 1973; Don Weiskopf, "Changes in Baseball," Athletic Journal, 51:8-20, March, 1971.

[4]Walter Alston and Don Weiskopf, The Complete Baseball Handbook (Boston: Allyn and Bacon, Inc., 1972), p. 332.

[5]Guy G. Reiff, What Research Tells the Coach About Baseball (Washington, D.C.: American Association of Health, Physical Education, and Recreation, 1971).

teaching of baseball skills has been based primarily either upon the opinion or the experience of professional coaches and players.[6]

Effective pitching has been regarded as being responsible for 55 to 90 percent of a team's chances of winning a single game.[7] Alston looked for these three characteristics of successful pitching: (1) use of a good, live ball, (2) throwing hard, and (3) control.[8] Dugan also listed the ability to throw hard as a basic requirement of a successful pitcher.[9] Consequently, coaches have always searched for new methods to improve the velocity of a pitched ball. However, the lack of a valid and reliable measuring device has hampered the gathering of research data on pitching.

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[6]Donald K. Edwards and Franklin A. Lindeburg, "A Comparison of the Jab-Step vs. the Cross-Over Step in Running a Short Distance, Research Quarterly, 40:284, May, 1969.

[7]Donald Landolphi, "Emphasizing the Basics," Athletic Journal, 53:50, March, 1973; Doug Holmquist, "Control and Strategy in Pitching," Athletic Journal, 48:11, February, 1968; Donald K. Edwards, "The Mechanics of Pitching," Athletic Journal, 42:40, February, 1963; Connie Mack, Connie Mack's Baseball Books (New York: Alfred A. Knopf, Inc., 1950), p. 82; Arthur Mann, How to Play Winning Baseball (New York: Grosset and Dunlap, 1953), p. 23.

[8]Alston and Weiskopf, p. 118.

[9]Ken Dugan, How to Organize and Coach Winning Baseball (West Nyack, N.Y.: Parker Publishing Co., 1971), p. 134.

Successful pitchers throw in a manner that is easiest and most effective for them.[10] Each pitcher has his own form and delivery.[11] Alston states that a "well coordinated and rhythmic delivery will provide extra speed and power, and help achieve better control."[12] Pitchers assume either the regular pitching position or the stretch position on the mound; over a period of time the basic movements of the regular position have been modified. The pumping action and backward swing have been eliminated altogether or reduced by many major league pitchers. Tom Seaver has called the full pumping action passé.[13] The purpose of these actions is to loosen and relax the arm and shoulder muscles and to develop better rhythm and deception.[14] However, Alston claims that a pitcher who does not get over the top and out in front to release the ball at the right moment may, by simplifying his motion, get more power behind the pitch.[15]

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[10]Alston and Weiskopf, p. 118.

[11]Alston and Weiskopf, pp. 118, 134.

[12]Alston and Weiskopf, p. 118.

[13]Alston and Weiskopf, p. 161.

[14]Edwards, p. 40; Dick Groch, "Analyzing the Pitcher," Athletic Journal, 50:113, March, 1970; Mack, p. 86; Mann, p. 33; Don Weiskopf, "Deceive 'Em," Athletic Journal, 48:55, January, 1968.

[15]Alston and Weiskopf, p. 122.

In this study, the velocity of a pitched ball was studied using an electronic apparatus developed by the author and designed for measuring and computing the velocity of projectiles.[16] The Eamcovop was predicted to be easier to construct and to operate, more precise, more accurate, more mobile, and less expensive than other machines of the same type. Velocity can be measured in four directions: in a positive or a negative direction, horizontally, or vertically. The resultant time is instantly shown on the counter.

Further, this investigator believed that this project not only would prove the value of this apparatus for research but would also demonstrate the applicability of this apparatus to teaching in physical education. Perhaps the study will stimulate interest in velocity measuring instruments so that an instrument more suitable to the peculiar conditions of the physical educator will be developed.

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[16]Mordechai Silberstein, "Electronic Apparatus for Measurement and Computation of the Velocity of a Projectile" (unpublished independent study, Appalachian State University, Boone, North Carolina, 1975).

STATEMENT OF THE PROBLEM

This study was designed to determine the applicability of an electronic apparatus for the measurement and computation of the velocity of a projectile in the teaching of certain aspects of either physical education or athletics.

PURPOSES OF THE STUDY

The purposes of the study were: (1) to determine the reliability coefficients of the Eamcovop, (2) to determine the applicability of the Eamcovop to teaching, and (3) to employ the Eamcovop to determine if there is a significant difference in a baseball pitcher's velocity from the wind-up and stretch positions.

The result of the research will enable educators to develop programs and exercises that can aid in teaching. This study will demonstrate the applicability of the Eamcovop to physical education and athletics. Further, it will be shown that the Eamcovop is preferable to the Dekan Performance Analyzer in this area.

The data from the investigation will be analyzed using _t_ tests for paired data, Pearson product moment correlation coefficients, and Spearman's coefficients of rank correlation.

Once the test results are compiled, the investigator may be able to improve the pitcher's performance and individual techniques by suggesting certain adjustments in pitching the ball. He will also be able to suggest specific training and strengthening programs for the different pitching motions.

LIMITATIONS OF THE STUDY

This study was limited as follows:

1. This study was limited to the ten pitchers on the MTSU baseball team.

2. This study was limited to the velocity of the pitched ball in a testing situation rather than an actual game situation.

3. This study was limited to a comparison between a modified Dekan Performance Analyzer and the Eamcovop in order to determine whether or not the Eamcovop is a more reliable apparatus for testing the velocity of projectiles.

4. This study was limited to the subjects' throwing velocities from both the full wind-up and stretch pitching positions.

5. This study was limited by the lack of familiarity with the Eamcovop, which may have caused the subjects to throw harder than normal, thus influencing the results.

6. This study was limited to measurement of the velocity of a fast ball only.

7. This study was not designed to measure accuracy other than in a gross sense.

DEFINITIONS OF TERMS

Full wind-up position--that pitching position in which the pitcher faces directly toward home plate with the shoulders parallel and the feet perpendicular to the pitching plate. From this position he may initiate his delivery of the ball to the batter by taking one step backward and one step forward with the non-pivot foot.[17]

Stretch position--that pitching position in which a left-handed pitcher faces first base and a right-handed pitcher faces third base, with the shoulders perpendicular and feet parallel to the pitching plate. From this position the pitcher may make any preliminary motion, but he must come to a one-second, complete stop before delivering the ball to the batter.[18]

Pitching plate. The pitcher's plate shall be a rectangular slab of whitened rubber, twenty-four inches by six inches. It shall be set in the ground so that the distance between the front edge of the pitcher's plate and

[17] National Baseball Congress of America, 1972 Official Baseball Rules (St. Louis: Sporting News, 1972), p. 27.

[18] National Baseball Congress of America.

rear point of home plate shall be sixty feet and six inches.[19]

Fast ball. This is a ball thrown in such a way as to incorporate speed and spin to make the ball travel in a straight line.[20]

Eamcovop. This is an electronic apparatus for measurement and computation of the velocity of a projectile. The basic equipment includes four right triangular shaped structures with a fitted mirror on the vertical side of each triangle, two lasers, two phototransistors, an amplifier, and a timing device.[21]

Velocity of the projectile. In this study the velocity was measured through a twelve inch zone in front of the plate.

Dekan Performance Analyzer. For the purposes of this study, the Dekan Performance Analyzer was modified so that a relay was constructed in order for the timing to begin when contacts were open and to stop when the contacts were closed.

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[19]National Baseball Congress of America.

[20]Dell Bethel, The Complete Book of Baseball Instruction (Chicago: Contemporary Books, Inc., 1978), p. 33.

[21]Silberstein, p. 5.

HYPOTHESES

The hypotheses as related to this study are:

1. The Eamcovop is technically superior to the Dekan Performance Analyzer.

2. No significant difference exists in a baseball pitcher's velocity with a runner on the third base when throwing a fast ball from the full wind-up and stretch positions.

3. There will be no significant difference between the Eamcovop and the Dekan Performance Analyzer as a teaching tool; however, the Eamcovop will be better for teaching purposes than the Dekan Performance Analyzer.

Chapter 2

REVIEW OF LITERATURE

Little evidence has been found to substantiate the value of velocity in athletics and physical education. However, there are many devices that have been used to measure velocity. This chapter will present a review of those devices under five sub-headings, which are: (1) review of the literature related to projectile velocity measuring devices, (2) investigations concerning factors that affect the speed and accuracy of a thrown baseball, (3) studies related to the mechanics of throwing a baseball, (4) a study investigating the differences in the velocity of a pitched baseball from the wind-up and stretch pitching positions, and (5) a brief summary of the literature reviewed.

DEVICES FOR MEASURING VELOCITY OF A PROJECTILE

This portion of the chapter contains literature related to devices that measure projectile velocity, and is divided into five parts: (1) stopwatches and distance,

(2) light fields and photocells, (3) sound waves, (4) film, and (5) miscellaneous devices.

Devices for Measuring Velocity with Stopwatches and Distance

A popular, simple means to determine the velocity of a projectile or a runner has been to take a known distance and measure the length of time it takes the projectile or runner to traverse that distance as timed with a stopwatch. Hewitt, Dyer, and Dyer employed this method with a tennis ball volley test.[1] Hewitt, in another tennis study, measured the distance the balls rebounded to estimate their velocity.[2]

Johnson, in a study to determine velocity and accuracy of the tennis serve, marked the court so that the distance the ball traveled could be determined. The time taken from the moment of impact until the ball landed was measured in 1/16 of a second. A newly adjusted 1/100 of a second stopwatch was employed, with the same investigator timing each trial. The distance and time for each trial

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[1]Jack E. Hewitt, "Revision of the Dyer Back-Board Tennis Test," Research Quarterly, 36:156-157, May, 1965; JoAnna T. Dyer, "The Backboard Test of Tennis Ability," Research Quarterly Supplement, 6:63-74, 1935; JoAnna T. Dyer, "Revision of Backboard Test of Tennis Ability," Research Quarterly, 9:25-31, May, 1938.

[2]Jack E. Hewitt, "Hewitt's Tennis Achievement Test," Research Quarterly, 37:231-240, May, 1966.

were recorded, and the horizontal velocity was obtained in feet per second.[3]

Rowland and Urban employed similar methods to ascertain the velocity of a thrown ball. By taking a predetermined distance and then measuring the time from the moment the ball was released until it hit the ground, with a stopwatch, they were able to determine ball velocity.[4]

Schrader devised two methods to subjectively determine the velocity of the tennis serve. The first method involved subjective evaluations of the velocity using numerical rating scales. The second method involved the measurement of ball flight time and the distance covered.[5]

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[3]Joan Johnson, "Tennis Serve of Advanced Women Players," Research Quarterly, 28:123-126, May, 1957.

[4]David J. Rowlands, "The Effect of Weight Training Exercises Upon the Throwing Power and Strength of College Baseball Players," paper presented at the National AAHPER Convention, May 4, 1963, cited by Richard C. Nelson, Conrad Larson, Charles Crawford, and Donald Brose, "Development of a Ball Velocity Measuring Device," Research Quarterly, 37: 151, March, 1966; Sara B. Urban, "The Effect of Specific Feedback Emphasizing Velocity and Angle of Projection of the Softball Thrown for Distance of Third Grade Boys and Girls" (unpublished Master's thesis, University of California, Santa Barbara, 1971), cited in Completed Research in Health, Physical Education, and Recreation, 14:81, 1972.

[5]Suzanne K. Schrader, "Subjective Assessment of Velocity and Angle of Projection of the Tennis Serve" (unpublished Master's thesis, Southern Illinois University, Carbondale, 1972), cited in Completed Research in Health, Physical Education, and Recreation, 15:127, 1973.

Devices for Measuring Velocity with Light Fields and Photocells

This design employed the placement of two light-sensitive fields a specified distance apart. When a projectile passed through the first field it would block out a portion of the light, thus providing the triggering mechanism which started a timing device. As the projectile passed through the second field it would again block out portions of the light which would stop the timer. Horizontal velocity was then computed from the equation: $V = \frac{D}{T}$ or velocity equals distance divided by time.

Aten and Gabert employed a device known as a velocimeter to measure the speed of a projectile. The basic electronic equipment consisted of two photomultipliers, light traps to provide a dark field, a power supply, a digital counter, and an oscilloscope. The elapsed time of the flight of the ball through a distance of one meter was measured by a digital counter to the nearest 1/10,000 of a second. The oscilloscope amplified the signal originating from the photomultipliers. Two detector horns were designed to detect an object in flight and speed one meter apart as measured from the center of each horn. The photo-tube units were comprised of 931-A photomultipliers, and virtually no light struck the cathodes until a projectile passed by. The cathodes then sampled the presence of the projectile by the reflected light. A backdrop and dark field were necessary for the functioning of the velocimeter which operated in the dark field and sampled the incident light from the projectile. The backdrop served to absorb any stray light source which might raise the threshold of the sensitivity of the photomultipliers. The time of the flight of the ball through a distance of one meter after release was detected by the velocimeter and electronically indicated on the digital counter. The time was later converted to velocity in feet per second.[6]

Nelson, Larson, Crawford, and Brose improved on similar earlier devices by widening the field. This was done to permit the subject to be able to throw in a normal pattern rather than having to concentrate on accuracy as well as velocity. The apparatus was constructed as an experimental model, and after employing it under test conditions its shortcomings and limitations were identified.[7]

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[6]Rosemary Aten, "The Effects of Repeated Trials with Score Information Provided or Withheld, on Throwing Velocity of High and Low Performers" (unpublished Doctoral dissertation, University of Wisconsin, Madison, 1971), pp. 28-32; Trent E. Gabert, "An Investigation of Selected Factors Related to Consistently Reproducing a Specified Velocity and to Perception of Change in Velocity of a Self-Projected Object in Three-Dimensional Space" (unpublished Doctoral dissertation, University of Wisconsin, Madison, 1971).

[7]Richard C. Nelson, Conrad Larson, Charles Crawford, and Donald Brose, "Development of a Ball Velocity Measuring Device," Research Quarterly, 37:151-154, March, 1966.

The apparatus consisted of a timer, capable of measuring a time interval to the nearest 1/10,000 of a second, connected to two identical light fields and photocell circuits. Each light field consisted of three 150-Watt spotlights focused on three triangular lucite lenses that in turn concentrated the light on three photoelectric cells. A twenty-two volt battery provided the current to the photocell circuits. A main sensitivity control adjusted each set of three cells, and each photocell could be adjusted individually.

The wooden frames were constructed in such a manner as to allow the height of the lenses and lights to be adjusted in relationship to the floor while keeping the distance between them constant. The subjects tested reported no difficulty in throwing through the field that was twenty-one inches high.

When the ball passed between a bank of three photoelectric cells and their light source, it blocked out a portion of the light entering one of the cells. A minor change in voltage within the photocell circuit was caused by the light intensity change. This difference in voltage was magnified and transmitted to the timer. Thus, the change in voltage caused by the ball passing over the photocells triggered the timer. The second light field was placed exactly four feet from the first one. The timer was stopped by the change in voltage caused by the ball when it entered the second field. The velocity was calculated by dividing the distance (four feet) by the time recorded.

The apparatus was calibrated by adjusting the input voltage of the system. The trigger mechanism was either in the on or off position depending upon whether the input voltage was either above or below a certain level. The voltage was fixed at a point so that any decrease in the intensity of the light would cause the trigger to switch on or off. The calibration procedure was easily done so that it could be repeated often to ensure uniform results.

An error in the calculated velocity would occur if the ball did not follow a perpendicular path to both light fields. A distance of more than four feet would be covered if the ball did not follow a perpendicular path, thus causing an underestimation of the actual velocity.[8]

Brose and Hanson employed the device developed by Nelson et al. to conduct a study concerning overload training and its effects on throwing accuracy. To determine the reliability of the timing device, a pendulum swing was employed. A metal rod with a ball attached to it was swung through the two banks of photocells. The apparatus performed consistently with enough sensitivity to distinguish the differences in the release of the ball.

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[8]Nelson, Larson, Crawford, and Brose, pp. 151-154.

The sensitivity of the photocells and the true distance traveled by the ball were two possible sources of error. The moment the device triggered may have differed due to the sensitivity of the photocells to the alternating current of the spotlight. Second, a projectile not passing perpendicular to the two photocell banks traveled a greater distance than the minimum possible distance employed to determine the velocity. The height of the device was adjusted for each subject in an attempt to minimize this possible source of error.[9]

Toyoshima and Miyashita employed a cadmium sulfide photocell to determine ball velocity. Five photocells wired with diodes were placed in individual bamboo tubes in order to concentrate the light in a metal frame. Five tubes, with their electric circuits, were set vertically every fifty millimeters. The distance from the first frame to the second was one-half meter for the young boys and one meter for the adults. The frames of the photocells were placed on a desk with the height of the frame adjusted according to the height of each subject.

The thrown ball passed in front of the first frame blocking out a portion of the light entering one of the cells. This difference in light intensity caused a change

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[9]Donald E. Brose and Dale Hanson, "Effects of Overload Training on Velocity and Accuracy of Throwing," Research Quarterly, 38:529-530, December, 1967.

in the voltage within the photocell circuit. The voltage was then amplified and transmitted to the recorder. The same process occurred in the second frame. The fact that Toyoshima and Myashita's device had no spotlight made it easier to transport, thus making it more practical than Nelson's.[10]

Kerr developed an experimental device to measure limb velocity that consisted of six photoconductive cells mounted in an arc at fifteen degree intervals. The light source, consisting of six light bulbs, was mounted on the base. Holes were drilled directly above the lights in the base and a small block of wood with a 12 mm plano-convex lens was attached to each hole. This produced a light beam approximately one-quarter inch in diameter onto each photoconductive cell. The photoconductive cells were connected to a subminiature galvanometer mounted in a visocorder oscillograph. A baseline was formed on the light-sensitive visocorder recording paper by the light current from the active photoconductive cells. An immediate break in the tracing was caused by an interruption of the light source on any of the photoconductive cells. When the light beam recontacted the photocell, the tracing returned to the baseline. A fluorescent light was employed to expose the

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[10]Shintaro Toyoshima and Mitsumasa Miyashita, "Force-Velocity Relation in Throwing," Research Quarterly, 44:87-90, March, 1973.

tracing to allow immediate and rapid velocity calculations by measuring the distance between the first and last breaks in the tracing.[11]

Devices for Measuring Velocity with Soundwaves

Malina and Rarick and Straub employed a combination of soundwaves and photoelectric cells to start and stop their respective timing devices. Both devices consisted of the same basic components, which included an adjustable set of photoelectric cells with a light source, a canvas target with two lanes, a vibration detection system, a .01 second electric timer, and a control system.[12]

In Malina and Rarick's study, volleyball standards were employed to suspend the photocells and light source thirty feet from the target. A single 150-Watt spotlight enclosed in a cylindrical structure to reduce extraneous light and provide a narrow beam to the cells was employed

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[11]Barry A. Kerr, "Weight and Velocity Factors in Kinesthetic Learning and Transfer of Training" (unpublished Doctoral dissertation, University of Wisconsin, Madison, 1969), pp. 42-44.

[12]Robert M. Malina and G. Lawrence Rarick, "A Device for Assessing the Role of Information Feedback in Speed and Accuracy of Throwing Performance," Research Quarterly, 39: 221-222, March, 1968; William F. Straub, "The Effect of Overload Training Procedures Upon the Velocity and Accuracy of the Overarm Throw" (unpublished Doctoral dissertation, University of Wisconsin, Madison, 1966), pp. 63-65.

as the light source. The six cells were placed one inch apart in a vertical column twelve inches in length. The sensitivity of the cells was such that the electromagnetic relays were activated when a projectile passed over one of the cells or parts of adjacent cells. The height adjustment was made by simply loosening an attached wing nut. In order to prevent the subject's arm from interrupting the light beam to the photocells prior to release, a restraining line was placed thirty feet, ten inches from the target.

The target was made of a nine foot by nine foot piece of canvas with a network of one-half inch #18/20 pressed metal screening and supporting heavy duty metal wiring firmly secured to and covering the entire rack. Completing the vibration detection system was a head phone attached to the metal screening.

Since the distance the projectile traveled was a constant thirty feet, the speed of the throw was a reflection of the elapsed time from the break in the light beam to contact with the target. The timer was started when the relay was activated by the interruption of the light source by the shadow of the ball. When the ball contacted the target, the metal screening started vibrating, activating the panel. The relay was de-energized, thus stopping the timer, which gave the ball flight time in hundredths of a second.[13]

Slater-Hammel and Andres conducted a study which involved the measurement of the velocity of a pitched ball in order to better understand the demands of the batting situation. To measure the velocity a special electronic device was developed. A standard electric clock was started by the opening of a switch and stopped by a soundwave. A regulation baseball was partially coated with DuPont's conducting silver #4817, and fitted on the last phalanx of the index and adjacent fingers were small copper electrodes. This design enabled the grip and release of the ball to act as the switch. The electrical circuit was closed when a subject held a ball with the electrodes across the coated area of the ball, with the release of the pitched ball serving to open the switch and start the timing device. A speaker unit was placed within two feet of home plate so that the soundwaves created in catching the ball over the plate caused the timer to stop. Since normal outdoor sounds interfered with the operation of the timer, it was necessary to conduct the study in a gymnasium.[14]

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[13]Malina and Rarick, pp. 221-222.

[14]A. T. Slater-Hammel and E. H. Andres, "Velocity Measurement of Fast Balls and Curve Balls," Research Quarterly, 23:95, March, 1952.

Pruden employed two sets of microphones to measure the speed of an arrow. The microphones were positioned such that one would receive the snap of the bow string, starting the clock, and the other the impact of the arrow to stop the clock. The average velocity could be calculated with an uncertainty of one or two percent, with a small correction for the speed of sound.[15]

Devices for Measuring Velocity with Film

Selin employed two high speed cameras to photograph baseball pitchers; one operated at sixty-four frames per second and the other at 128 frames per second. The trajectory of each pitch was recorded in the vertical plane by the ground level camera and in the horizontal plane by the camera directly above the line of flight of the ball.

Velocity and rate of rotation of the ball were taken from the films that recorded the complete trajectory of the pitch. Two synchronized chronoscopes, one placed adjacent to the pitcher and the other adjacent to the plate, were employed to determine the time required for the pitch to complete its trajectory. The length of the trajectory was determined by measuring from the point of release to a point on the trajectory that was directly above a line drawn

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[15] Donald J. Pruden, "Velocity Measurements Outdoors with a Tape Recorder," Physics Teacher, 10:49, January, 1972.

through the center of the plate and parallel to the pitcher's rubber. By dividing the length of the trajectory by the observed time, the mean velocity was determined.[16]

Milson explained an easy means to measure velocity by employing a controlled-shutter, rapid-developing camera, and a strobe light. The shutter of the camera was opened and an object was moved across the visual field of the camera while the strobe light flashed. One exposure appeared for each flash of the light, and the shutter was closed when the object had passed the visual field. Measurement of the displacement between the resulting series of images along with the speed of the flashing strobe lights would provide the data needed to calculate velocity.[17]

Sebolt employed strobe lights and multiple-image photography to determine the velocity of tennis balls. The equipment consisted of two strobotacts synchronized to flash 20,000 times per minute for the maximum ball velocity tests and 15,000 times per minute for the controlled velocity tests. The shutter speed was set at a 1-second exposure,

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[16] Carl Selin, "An Analysis of the Aerodynamics of Pitched Baseballs," Research Quarterly, 30:233, October, 1959.

[17] James L. Milson, "The Destellador Flasher for Motion Studies," Science Teacher, 49:47, November, 1972.

and a shutter release cable triggered it manually. The lens aperture was set at f/1.8.

The technique employed to record the multiple-image photographs was kept constant for all tests. The camera's shutter was triggered as the ball was about to make contact with the racket exposing an image of the ball every time the strobotact flashed. Each exposure was recorded as the ball passed through the camera's line of sight. Thus, a photograph of multiple high-speed exposures of a moving tennis ball was provided for the researcher. Velocity was calculated by employing the following formula:

$$v = \frac{(k)(s)(f)}{d}$$

in which:

v = velocity

k = proportional constant (physical diameter of the tennis ball)

s = displacement of the tennis ball in the photograph

f = frequency of strobe flash

d = photographic diameter of tennis ball.[18]

Nelson, in order to determine the velocity of a spiked volleyball, employed standard cinematographic procedures. Mounted on the referee's stand, approximately

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[18]Don R. Sebolt, "A Stroboscopic Study of the Relationship of Ball Velocity and Tennis Performance," Research Quarterly, 41:183-184, May, 1970.

thirty feet from the spiker's position, was a Bolex 16mm camera set to operate at sixty-four frames per second. By filming a ball dropped from a known height, the assumed time per frame, .0156 seconds per frame at sixty-four frames per second, was found to be correct. During each of the trials a yardstick was photographed in the plane of the path of the spiked ball. The descent of the set-up, the spike, and the path of the ball for approximately five feet were filmed. The distance the ball went in a given number of frames was determined from the film and then adjusted to the actual distance. The number of frames provided the elapsed time, and the velocity of the ball was calculated by dividing the distance traveled by the time.[19]

Browne employed motion picture filming, tracing, and measurement techniques to determine ball velocity. Simultaneous front-and-side view motion pictures were taken of each subject. Two cameras placed eighty feet from the subject were employed with a camera speed of sixty-four frames per second. A timing device was placed at a forty-five degree angle to the cameras and ran constantly throughout the filming. The time was determined by measuring the angles of movement of the clock hands and converting the angles to seconds. The angles of movement of

[19]Richard C. Nelson, "Follow-up Investigation of the Velocity of the Volleyball Strike," Research Quarterly, 35:83, March, 1964.

the clock hands and velocity scores for all of the throwing trials were obtained by measurement from the tracings of microfilm projections of the motion picture film.[20]

Miscellaneous Devices for Measuring Velocity

Miller and Shay measured the speed of a thrown softball with the Hale Timer (developed by Creighton J. Hale). A regulation softball was coated with aluminum foil. Two electrodes were attached to the second joint of the index and middle fingers of the right hand of the subjects by adhesive tape. A wire was taped to the lateral side of the forearm, the lateral side of the upper arm, and down to the pitcher's back to connect the electrodes to the timer. According to each subject, this arrangement did not hamper his throwing motion. The catcher stood directly on home plate forty-six feet away from a regulation pitcher's plate. Inside the catcher's mitt between the hand and the padding where the ball would hit was a double-screen pad, two inches by two inches.

The circuit was opened as the softball was held in the pitcher's hand with the two electrodes touching the aluminum-coated ball. When the ball was released, the circuit closed and the clock started. The clock stopped

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[20]Mary E. Browne, "Relationship of Selected Measures of Acting Body Levers to Ball-Throwing Velocities," Research Quarterly, 31:394-395, October, 1960.

when the two parts of the double-screen pad contacted each other after the ball hit the mitt.[21]

Van Huss, Nelson, and Hagerman conducted a study to determine if employing an overweight ball to warmup with had an effect on throwing velocity and accuracy. The throws were measured during the study employing a chronoscope calibrated to 1/1000 of a second. The device was activated by a finger release and stopped by a microswitch when the ball contacted the target. The pitching distance was reduced to thirty feet, three inches for the test so that fewer throws would be lost due to an inability to hit the target.[22]

Litwhiler and Hamm employed a Dekan Performance Analyzer, calibrated to 1/100 of a second, to determine the velocity of a pitched ball thrown from a distance of sixty feet, six inches. The throwing hand had two finger contacts taped to it, one on the index finger and the other on the middle finger. These contacts were coupled together above the finger and connected to the timer. At the moment of release the timer was activated due to the break in the electrical circuit. Ultrasensitive microswitches mounted on

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[21] Robert G. Miller and Clayton T. Shay, "Relationship of Reaction Time to the Speed of a Softball," Research Quarterly, 35:433-435, October, 1964.

[22] W. D. Van Huss, L. Albrecht, and R. Nelson, "Effect of Overload Warmup on the Velocity and Accuracy of Throwing," Research Quarterly, 33:472-474, October, 1962.

the backs of the target stopped the timer when the baseball contacted the target.[23]

Hubbard employed two plugs to trigger a timing device. The plugs were attached by a string to a baseball so that a specified distance was traveled by the ball during the time interval between the removal of the first and second plugs. The effectiveness of this method was reduced by the string on the ball and the restriction of the throwing movement of the subjects.[24]

The author (Silberstein) originally developed an electronic apparatus for measurement and computation of the velocity of projectiles. The fundamental design is similar to that employed by other researchers in that the projectile is timed for a specified distance and then the velocity is computed from that information. The main differences are the use of laser beams instead of lights and the use of mirrors to reflect beams in the creation of a sensitive field.[25]

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[23]Danny Litwhiler and Larry Hamm, "Overload: Effect on Throwing Velocity and Accuracy," Athletic Journal, 53:64-65, January, 1973.

[24]Alfred W. Hubbard, unpublished paper presented at the Research Council Equipment Section Meeting, National AAHPER Convention, April, 1960, cited by Richard C. Nelson, Conrad Larson, Charles Crawford, and Donald Brose, "Development of a Ball Velocity Measuring Device," Research Quarterly, 37:150, March, 1966.

[25]Mordechai Silberstein, personal statements, September, 1979.

The basic equipment includes four right triangular shaped structures with a fitted mirror on the vertical side of each triangle, two lasers, two phototransistors, an amplifier, and a timing device. (See Appendix C.)

At the bottom of two of the mirrors are small holes through which the two laser beams are emitted. The mirrors and lasers are positioned in a manner that allows the beams to be reflected back and forth up the mirrors until they contact the phototransistors. As the projectile breaks the beam in the first field, the timer is started. When the projectile breaks the beam of the second field, the timer is stopped and the velocity can then be computed.[26]

Keller, to determine the difference in velocity potential from the wind-up and stretch positions, employed an electrical circuit composed partly of two metal foil strips, a resistor, a capacitor, and a volt meter. The two metal strips were placed in parallel six inches apart to complete the circuit. It was necessary for the subjects to throw the baseball in such a manner that the ball broke both metal strips. When the ball severed the first strip, the circuit was broken which caused energy to decay from the capacitor. As the ball broke the second strip, the resistance was stopped and the leakage came to a halt.

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[26]Mordechai Silberstein, "Electronic Apparatus for Measurement and Computation of the Velocity of a Projectile" (unpublished independent study, Appalachian State University, Boone, North Carolina, 1975), pp. 1-5.

Pre- and post-voltage readings were made, and the velocity of the ball was computed from this information.[27]

FACTORS AFFECTING VELOCITY AND ACCURACY

A study by Grotty, Insalaco, and Root was conducted to determine the effect of leg strength on the throwing velocity of a baseball. Nineteen subjects were divided into three groups with one group given a weight training program, one a sprint training program, and the third, a control group, no special training program other than a daily throwing regimen. The results indicated that the sprint group had the greatest improvement in leg strength while the control group improved the most with regard to throwing velocity.[28]

There have been several inquiries into the effect of the pitcher's position on the pitching plate, point of aim, and stride on both accuracy and velocity of a pitched ball. McKee conducted an investigation to determine if

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[27] George P. Keller, "A Comparison of the Velocity of Fastballs Thrown from the Windup and Stretch Positions" (unpublished Master's thesis, Southeast Missouri State College, 1972), pp. 18-19.

[28] Gerald A. Grotty, Angelo C. Insalaco, and Weston B. Root, "A Study to Determine the Effect of Leg Strength on the Speed of Throwing in Baseball" (unpublished Master's thesis, Springfield College, 1955), cited by George P. Keller, "A Comparison of the Velocity of Fastballs Thrown from the Windup and Stretch Positions" (unpublished Master's thesis, Southeast Missouri State College, 1972), p. 8.

speed and accuracy of a thrown baseball were influenced by variations in the direction of a pitcher's stride. Four different stride variations were tested employing eight members of the Springfield College Baseball Team as subjects. The results indicated that none of the four stride variations yielded better results for pitching accuracy and velocity.[29]

Edwards' study was concerned with the effects of position on the pitching plate and stride. This investigation differed from McKee's in that overstriding and understriding, as opposed to striding direction, along with non-pivot foot placement on the pitching plate, were investigated. Forty-seven varsity and freshman pitchers from five Midwestern universities were utilized as subjects. The investigator concluded that changing the stride length or foot position on the pitching plate would not necessarily correct any pitching control problems.[30]

The influence of pivot foot placement on the pitching plate and its relationship to the velocity of a

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[29]Albert E. McKee, "Variations in the Direction of the Pitching Stride and Their Effect on Speed and Control of the Pitched Ball" (unpublished Master's thesis, Springfield College, 1963), cited by Keller, p. 8.

[30]Donald K. Edwards, "The Effects of Stride and Position on the Pitching Rubber on Control in Baseball Pitching," Research Quarterly, 34:9-12, March, 1963.

thrown baseball was studied by Robbins. Seven members of the Springfield College pitching staff were employed as subjects. The pivot placements, tested from both the stretch and wind-up positions, were with the foot on the front edge of the pitching plate and the foot in front of and parallel to the pitching plate. None of the pivot foot placements were significantly different in terms of ball velocity, and the difference in velocity between the wind-up and stretch positions was also negligible.[31]

Brose and Hanson conducted a study to investigate the effects of overload training on velocity and accuracy of throwing. Subjects were twenty-one University of Maryland baseball players who were randomly placed into three equal groups. Two of the groups employed specific overload training, one threw weighted baseballs, and the other employed a pulley device that resisted the mechanics of throwing. The third was a control group. No significant difference was found between the training groups and the control group in throwing velocity or accuracy.[32]

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[31] Bruce B. Robbins, "A Comparison of Methods of Pivot Foot Position and the Relationship to the Speed of a Pitched Ball" (unpublished Master's thesis, Springfield College, 1966), cited by Keller, p. 9.

[32] Donald E. Brose and Dale Hanson, "Effects of Overload Training on Velocity and Accuracy of Throwing," Research Quarterly, 38:529-530, December, 1967.

Van Huss, Albrecht, and Nelson investigated the relationship of overload warm-up to the speed and accuracy of throwing. Fifty members of the Michigan State University freshman baseball team served as subjects. Each subject threw ten maximal throws with a regulation baseball. Following a ten minute rest period, each subject took the overload warm-up which consisted of fifteen throws with gradually increased velocity, followed by ten maximal throws with an eleven-ounce baseball. The speed and accuracy of ten additional throws with a regulation baseball were measured immediately following the overload warm-up. The authors concluded that the overload warm-up significantly improved the velocity of throwing, but that the accuracy response was negatively altered.[33]

Litwhiler and Hamm also studied the effects of overload training on throwing accuracy and velocity. Five pitchers on the Michigan State University Baseball Team participated in a twelve week training program, utilizing weighted baseballs. The results indicated a significant increase in throwing velocity, from a mean velocity of 112.3 feet per second to 128.7 feet per second, and an increase in throwing accuracy, but not a significant one.[34]

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[33]Van Huss, Asbrecht, and Nelson, pp. 472-474.

[34]Litwhiler and Hamm, pp. 64-65.

MECHANICS OF THROWING

Lyon conducted an investigation employing cinematographic analysis to determine if the velocity attained by a pitcher is related to a definite pattern of joint movement. Seven University of Wisconsin pitchers, eight baseball players, and a major league pitcher were utilized as subjects for the study. The results indicated that those subjects having the greatest forward flexion at the hip joint at the time of release had the highest recorded velocity; increasing the degree of shoulder flexion at the time of release helps to increase throwing velocity; an angle of spinal rotation of between 105 degrees and 115 degrees from the line drawn directly from the subject to the target is the most advantageous; and there is little relationship to the degree of movement in the joints and ball velocity as long as the joint actions are not working against the forward motion of the body.[35]

Mapes employed electromyography to determine the functions that selected muscles of the arm and shoulder girdle perform during the baseball throw. The muscles were investigated in terms of the following functions: (1) ballistic movement, (2) follow-through, and (3) check

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[35]William R. Lyon, "A Cinematographical Analysis of the Overhand Baseball Throw" (unpublished Master's thesis, University of Wisconsin, 1961), cited in Completed Research in Health, Physical Education, and Recreation, 3:45.

action. Three former college baseball players were employed as subjects. The conclusions drawn by the author based on the results were: (1) ballistic movement was not observed during any part of the throwing movement due to the agonistic function of at least one, but not always the same one, of the ten muscles studied; (2) in terms of the follow-through, an antagonistic function was performed by the long head of the biceps brachii, and the middle and posterior heads of the deltoid, and an agonistic function was performed by the upper part of the trapezius, the lower part of the serratus anterior, the teres major, the middle head of the triceps brachii, the anterior head of the deltoid, and the latissimus dorsi; and (3) check action antagonistic function is performed by the middle and posterior heads of the deltoid, the teres major, latissimus dorsi, and the long head of the biceps brachii.[36]

Sandstead utilized cinematographic analysis to study eighteen players on the Eastern Illinois University baseball team to determine if a relationship existed between outward rotation of the humerus and baseball throwing velocity. The

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[36]Donald F. Mapes, "Electromyographic Study of Functions of Selected Muscles in: Check Action, Ballistic Movement and Follow-Through During the Baseball Throw," Dissertation Abstracts, 25:990, August, 1964.

author, on the basis of the results, concluded that there was a positive relationship between the two.[37]

SPEED FROM THE STRETCH AND WIND-UP POSITIONS

Keller conducted a study utilizing ten varsity pitchers at Southeast Missouri State College. Each subject performed a total of ten trials, five from the wind-up and five from the stretch. The pitchers threw inside from a portable mound alternating pitching positions. It was necessary for them to throw the ball in such a manner that it broke two metal strips of foil nine and one-half feet from the pitching plate. The author found no significant difference in the velocity of the thrown baseball from the two pitching positions. The author believed that the two pitchers who threw much faster from the stretch position pushed off the pitching plate much harder from the stretch than they did from the wind-up, while the two pitchers who threw much faster from the wind-up were classified as arm throwers by the author. He also noted that the latter two had very smooth wind-ups which he felt enabled them to take

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[37]Hollister L. Sandstead, "The Relationship of Outward Rotation of the Humerus to Baseball Throwing" (unpublished Master's thesis, Eastern Illinois University, 1968), cited in Completed Research in Health, Physical Education, and Recreation, 10:124.

advantage of the summation of force achieved from the greater range of motion.[38]

SUMMARY

The literature revealed a wide diversity of different ideas, including motion picture filming, stop-watches, and electrical devices, for the measurement of projectile velocity. Most approaches involved some method of starting and stopping a clock, and most determined velocity by the time taken to cover a certain distance. None of the devices measured the velocity either directly or quickly. There was little disagreement on the proper technique for throwing a baseball, but the literature revealed little agreement on exactly what enabled one pitcher to throw faster than another.

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[38]Keller, pp. 18-19.

Chapter 3

METHODS AND PROCEDURES

An experimental study was designed to measure the velocity of a pitched ball. Related to this is the necessity of changing styles if it can be determined that a particular style is more suited to the subject and will enable the student to develop greater velocity.

THE SUBJECTS

The subjects for the study were ten male baseball pitchers from the Middle Tennessee State University varsity baseball team in 1979-80. The subjects ranged in age from seventeen years to twenty-three years.

TESTING APPARATUS

The device used for measuring the velocity of a pitched ball was an electronic apparatus developed by the author due to a need in physical education and athletics to time the speed or velocity of different objects. The apparatus is capable of measuring the velocity of projectiles.

The measuring device used consists of four triangular shapes. These are made with fitted mirrors on each structure. The structures are right triangles with mirrors mounted on the vertical outside. The vertical wooden board is 10 cm x 200 cm, and the mounted mirror is 10 cm x 215 cm. Placed on the horizontal board of the structure is a platform which is 10 cm x 35 cm. For the support of the lasers, the height of the platform can be adjusted with regulators so that this measurement is flexible according to different needs. The structures are stabilized by the use of a base which crosses the horizontal board and measures 10 cm x 100 cm. Further stabilization is gained by securing cables at the top of the structures and extending them to the ends of the base board. The cables have a place for adjustment to insure stabilization. The inclined board which is attached to the top of the vertical board and the opposite end of the horizontal board gives stabilization to the right angle itself. The horizontal board of the structure is 10 cm x 120 cm and has two regulators at its ends to adjust in case the angle needs to be changed because of environmental irregularities. At the ends of the base board are regulators which are used to stabilize the device and to work along with the other regulators in adjusting the angle of the structure. All of this equipment is duplicated four times to produce four structures. The laser platform and a phototransistor regulator are duplicated only twice, and are used on only half of the structures. On two of the structures there is a small hole 10 cm from the floor in the vertical board and mirror. Also, placed on the vertical boards of two devices is a phototransistor regulator which faces into the inside of the triangle. This phototransistor regulator houses a phototransistor. The regulator can be moved to any position on the vertical board, and the phototransistor on the regulator can be moved from left to right. This insures that the laser beam will be able to strike the phototransistor. The Eamcovop utilizes two lasers (Model 360). The lasers emit a red light which is needed for this system. The three-terminal phototransistor has exceptionally stable characteristics and high illumination sensitivity. The electrically connected base lead increases its applicability when the red light is used. One amplifier is needed for the system, which must be made especially for the purpose of the device. The amplifier reduces 120 volts to 15 volts. It detects the pulse caused in the phototransistor by the bombardment of the laser beam and sends this information to a counter. The amplifier must have maximum sensitivity to accomplish this (the parts of the amplifier are not available and must be made by the experimentor or the investigator). The amplifier is used to amplify the electric voltage that is used in the counter. This counter, or electronic timer, will be used to read the velocity of the projectile being measured down to the nearest millisecond. In order to transmit the impulse from the phototransistor to the amplifier, four cables are needed for electronic conduction. Two are ten meters long, and two are five meters long. The shorter cables are attached to the closest phototransistor, and the longer cables are used for the other phototransistor.

The phototransistor is composed of an open transistor suspended by a cylindrical lens. As light falls upon the lens, it is focused on the active element and a small voltage pulse is produced. Within this phototransistor the light is amplified a hundred times and enters the amplifier with a one millivolt pulse. The amplifier is composed of an operational integrated circuit chip which has an amplification of 10,000 times. This further amplifies the pulse to a level of ten to fifteen volts. Since light is constantly on the phototransistor, as a projectile cuts the beam of light a negative pulse is produced. As the light returns to the phototransistor, a second pulse is produced. This pulse is positive. The counter, which utilizes the first pulse to start the timing, must be set for negative pulse. The amplified negative pulse then starts the timing, and the elapsed time accumulates until the projectile intercepts the second beam. A second negative pulse then turns off the timer. Located on the amplifier is a sensitivity control which is used to adjust the height of the pulse. When the path length is composed of many reflections, the sensitivity must be increased in order to make the timing measurement. Conversely, when fewer reflections are used, the sensitivity may be turned down. The amplifier also contains a filter which reduces the amount of extraneous light pick-up.

The phototransistor circuit is composed of a GE-17 transistor, the phototransistor, a 120 Ω , a 1 MΩ and 3.9 MΩ resistor, and 1 uF capacitor. Basically, all these components are used to amplify the very weak incoming light signal. When light enters, the phototransistor current flows through the 120 Ω resistor, and a voltage develops. It is this voltage which is to be amplified further in the integrated circuit amplifier. The integrated circuit amplifier is composed of a 741 integrated circuit chip, two 1 KΩ and one 10 KΩ potentiometer, two 10 MΩ resistors, and two 1 uF capacitors. These components produce an amplification that is 10,000 times greater than the original impulse. The 10 K Ω potentiometer is the sensitivity control. The capacitor of .005 uF and 10 MΩ resistor reject most voltages below three hertz. This filter eliminates spurious pulses caused by persons running on the floor. Both of the phototransistors for timing the projectile motion are connected in parallel and use the same amplifier circuit. In order to utilize this system, one must use a pulse activated timer which receives a minimum of one volt negative pulses. Also, it must be able to read time to the nearest millisecond. The phototransistor and the amplification system are accurate to 1 millisecond. The amplifier constructed is the only one which will make the system work and at this time can not be purchased. (See Appendix D.)

VALIDATING THE APPARATUS

In order to determine which verification setting was to be employed and where the operator would be standing during the testing, the following procedures were utilized. The Eamcovop was tested at the Murphy Center Gymnasium at Middle Tennessee State University. One subject threw a baseball from a portable pitcher's mound to a catcher sixty feet, six inches away. Thirty pitches were thrown at maximal speeds for each setting with the investigator standing behind the counter and the thrower, and thirty for each setting with the investigator standing behind the counter and the catcher. The highest percentage of recorded strikes determined which setting and, along with the physical requirements of the apparatus, determined which standing positions were to be employed during the testing for this investigation. The Eamcovop was situated between the pitcher and the catcher.

When all the proper equipment was assembled for testing the Eamcovop and all the necessary precautions were taken, the measurement could begin. Although the apparatus was capable of measuring either vertical or horizontal speeds, only horizontal speeds were measured in the study. The projectile broke the first laser beam between the first two triangles to start the measurement and then broke the second beam between the last two triangles to stop the measurement. The measurements were timed and displayed on the counter or timer and were recorded from there. All data were collected during the period of January 15, 1980, to February 15, 1980.

RELIABILITY TESTS

The Eamcovop has a verification setting that can be adjusted to .1 of a second, .01 of a second, .001 of a second, or .0001 of a second. Reliability trials for the Eamcovop were conducted at the .01 and .0001 settings based on the validation findings. Trials for the Dekan Performance Analyzer were conducted at the .01 setting, the only setting available on that device.

Reliability data for the Eamcovop were collected using a baseball suspended from the ceiling at a height that caused it to break the top beam of each laser when released and allowed to swing naturally. The ball was released thirty-five times by each subject at the same height and distance from the Eamcovop for each of two tests. This was accomplished by having the subject sit backwards in a folding metal chair facing the Eamcovop. The chair was placed at a distance that caused the string attaching the ball to the ceiling to be pulled tight when the ball was placed on the top of the back of the chair, and the only movement made by this hand was an opening of the fingers to let the ball go. When the ball swung back, it was caught in the opposite hand and placed back into the other hand.

For the Eamcovop at a setting of .0001 of a second, four subjects released the ball thirty-five times during each of two tests giving a total of 280 trials. Similar procedures were used to obtain 280 trials for the Dekan Performance Analyzer at a setting of .01 of a second. For the Eamcovop at a setting of .01 of a second, one subject released the ball thirty-five times during each of two tests giving a total of seventy trials.

THE EXPERIMENTAL STUDY

This study was conducted during the period of January 15, 1980, to February 15, 1980, in auxiliary gymnasium number one of the Charles M. Murphy Athletic Center. The purposes of the investigation were to determine: (1) the technical merits of the Eamcovop, (2) that no significant difference exists between a ball's velocity when pitched from stretch or wind-up positions, and (3) the applicability of the Eamcovop to teaching.

TESTING PROCEDURE

The subject's pitches were timed by the Eamcovop. The investigator stood behind the counter located behind the catcher. The type of baseball used was a white, Worth 912(T), alum tanned, lively center, wool wound, official league teamline ball. After each pitch the ball's time and whether it was a ball or strike were recorded.

The subjects wore baseball uniforms. A new baseball was employed at the start of each testing session for each subject. The subjects were not able to see how fast the ball was being thrown until the first fifteen pitches were completed. This was done in an attempt to make the testing situation as much as possible like an actual game.

Each subject was told that he would throw fifteen pitches from the wind-up and fifteen pitches from the stretch positions. He was informed that accuracy was important and that he should attempt to pitch as hard as he normally would in a game situation. It was further explained that he would check the runner on third base before each pitch in his usual manner. Each pitch would be called by the umpire, but the subject would throw as though the count were no balls and no strikes for all thirty pitches. The umpire was either Coach Stanford or Assistant Coach Carmen Fusco, neither of whom is a certified baseball umpire. Each subject was informed that he would be given the opportunity to look at his results after the testing was completed, if he so desired.

The investigator was standing behind the counter, or timer, with an assistant next to him to record each pitch. After each pitch the Eamcovop counter, or timer, showed the time measured. The assistant then recorded the time along with the accuracy rating.

Each pitcher was given as much time as he needed to warm up. As he was warming up he was informed whether he would throw from the wind-up or stretch position. It was felt by the investigator that this could be done arbitrarily since there would be no chance that environmental factors would influence the results. Five of the subjects threw from the wind-up first and five from the stretch. When the subject indicated that he was ready, the test began. After fifteen pitches were recorded, the subject was allowed to have a five minute period to look at the data sheet. When the subject indicated he was ready for the second half, that part of the testing was conducted. Each subject had the same conditions for both parts of the test since he completed one immediately following the other.

STATISTICAL ANALYSIS

Reliability of the apparatus was analyzed using standard deviations and Pearson product moment correlations. Eight standard deviations were computed for the Eamcovop at a setting of .0001 of a second and two standard deviations were computed for the Eamcovop at a setting of .01 of a second. Similarly, eight standard deviations were computed for the Dekan Performance Analyzer at a setting of .01 of a second. A Pearson product moment correlation was then computed using the raw data gathered for the Eamcovop at the setting of .0001 of a second and for the Dekan Performance Analyzer at the setting of .01 of a second. The purpose of this correlation was to establish the reliability coefficient of the Eamcovop at velocities under ten miles per hour.

To establish the reliability of the Eamcovop at velocities normally attained in pitching, two more Pearson product moment correlations were computed using data collected during the actual testing. One correlation was computed using mean velocities attained from the wind-up position on the Eamcovop and on the Dekan Performance Analyzer, and one correlation was computed using mean velocities attained from the stretch position on the Eamcovop and on the Dekan Performance Analyzer.

The pitching data were analyzed by computing the mean velocities for each subject from both pitching positions and totaling the number of strikes thrown from the two positions tested. This was done for each of the two machines, the Eamcovop and the Dekan Performance Analyzer. The data were then subjected to *t* tests for paired data to determine whether significant differences existed between the two pitching variables for velocity or accuracy, and whether significant differences existed between the two machines for velocity or accuracy.

The data were further analyzed by Pearson product moment correlations to find out if any relationships existed between the velocities of the balls pitched from the stretch and wind-up positions on the two machines. Pearson product moment correlation coefficients were also computed to find out if any relationships existed between the accuracies of balls pitched from the stretch and wind-up positions on the two machines. Finally, Spearman's coefficient of rank correlation was utilized to determine if there were any relationships between speed and accuracy from the wind-up and stretch pitching positions on either machine.

Chapter 4

ANALYSIS AND TREATMENT OF DATA

A presentation and discussion of the results are included in this chapter. The first part of the chapter contains an analysis of the data, while the last portion presents a discussion of the results of the study. The discussion is divided into two sections, one on the Eamcovop and the Dekan Performance Analyzer and the other on the results of the speed and gross accuracy testing. It should be noted that the data on gross accuracy are presented solely as an adjunct to the data on velocity and were not a major part of the study.

RESULTS

Analysis of the Reliability Tests

Means and standard deviations were computed for the Eamcovop set at .0001 of a second and .01 of a second, and for the Dekan Performance Analyzer set at .01 of a second. The data are summarized in Table 1. (See Appendix G for detailed information.)

Table 1

Reliability Tests
Standard Deviation Summary

Machine	No. of Trials	Setting (seconds)	Mean Velocity (mph)	Standard Deviation
Eamcovop	70	.01	6.04	.07
Dekan	280	.01	4.46	.12*
Eamcovop	280	.0001	5.94	.16*

*Condensed from 8 standard deviations computed for 4 subjects on 2 tests, 35 trials per test.

At the .0001 of a second setting, the mean velocity of the pendulum ball on the Eamcovop was 5.94 mph with a standard deviation of .16 in 280 trials. At the .01 of a second setting, the mean velocity of the pendulum ball on the Eamcovop was 6.04 mph with a standard deviation of .07 in 70 trials. The mean velocity on the Dekan Performance Analyzer was 4.46 mph with a standard deviation of .12 in 280 trials. The standard deviations indicate that the Eamcovop is at least as consistent and reliable in timing as the Dekan Performance Analyzer at velocities under 10 mph.

The raw data from the reliability trials were used to compute a Pearson product moment correlation. The purpose of the correlation was to find out if there was a relationship between the velocities attained with the pendulum ball on the two machines. Table 2 presents a summary of the data.

Table 2

Reliability Tests
Pearson Product Moment Correlation
(Pendulum Ball)

Machine	Trials	Mean Velocity (mph)	Correlation
Dekan	280	4.46	r = .49*
Eamcovop	280	5.94	

*Significant at .001.

A significant correlation coefficient of .49 was obtained, indicating the two machines were consistently measuring the same factor.

To establish the reliability coefficient of the Eamcovop at velocities attained in actual pitches, two additional Pearson product moment correlations were computed using the data collected for the pitched balls. The data are presented in Table 3.

Table 3

Reliability Tests
Pearson Product Moment Correlations
(Mean Velocities)

Wind-up

Subject	Dekan	Eamcovop	Correlation
1	66.89	67.62	
2	72.90	73.82	
3	74.45	75.47	
4	86.27	87.31	
5	70.95	71.80	r = .9999
6	80.07	81.08	
7	73.06	74.12	
8	73.35	74.36	
9	74.07	75.04	
10	69.59	70.63	

Stretch

Subject	Dekan	Eamcovop	Correlation
1	76.33	77.41	
2	75.09	76.07	
3	75.48	76.66	
4	79.07	80.82	
5	72.73	73.88	r = .9989
6	78.73	79.69	
7	71.01	72.01	
8	69.37	70.43	
9	70.49	71.46	
10	64.66	65.71	

A significant correlation of .9999 was computed for the mean velocities obtained from the wind-up position on the two machines, and a significant correlation of .9989 was computed for the mean velocities obtained from the stretch position on the two machines. These correlations indicate that the two machines were measuring the same factor at velocities between fifty-seven and ninety-three mph for both pitching positions.

Analysis of Speed and Gross Accuracy Data for Dekan

A *t* test for paired data was performed on the data for the velocity of a thrown baseball from the wind-up and stretch positions. A *t* value of .58 was computed, and for nine degrees of freedom a *t* value of ±2.262 was needed to have a difference between the means at the .05 level of significance. The inference drawn was that there was no significant difference in the velocity of a baseball thrown from the wind-up and stretch positions.

A similar *t* test was employed on the data collected concerning the gross accuracy of the two pitching positions investigated. A *t* value of -.80 was computed, and for nine degrees of freedom a *t* value of ±2.262 was needed to have a difference between the means at the .05 level of significance. The inference drawn was that there was no significant difference in the gross accuracy of a baseball thrown from the wind-up and stretch positions. Table 4 presents a summary of the two t tests. The raw data are presented in Appendix E.

Table 4

t Test for Paired Data Summary

Dekan Velocity				
Variable	N	Mean (mph)	df	t Value
Wind-up	10	74.16	9	.58*
Stretch	10	73.29	9	

*Level required for significance at .05 with 9 df was ±2.262.

Dekan Accuracy				
Variable	N	Mean**	df	t Value
Wind-up	10	8.0	9	-.80*
Stretch	10	8.6	9	

*Level required for significance at .05 with 9 df was ±2.262.

**Mean is for strikes.

Analysis of Speed and Gross Accuracy Data for Eamcovop

A t test for paired data was performed on the data for the velocity of a thrown baseball from the wind-up and stretch positions. A t value of .47 was computed, and for nine degrees of freedom a t value of ±2.262 was needed to have a difference between the means at the .05 level of significance. The inference drawn was that there was no significant difference in the velocity of a baseball thrown from the wind-up and stretch positions.

A similar t test was employed on the data collected concerning the gross accuracy of the two pitching positions investigated. A t value of .92 was computed, and for nine degrees of freedom a t value of ±2.262 was needed to have a difference between the means at the .05 level of significance. The inference drawn was that there was no significant difference in the accuracy of a baseball thrown from the wind-up and stretch positions. Table 5 presents a summary of the two t tests. The raw data are presented in Appendix E.

Analysis of Speed and Gross Accuracy Data for the Wind-up

A t test for paired data was performed on the data for the velocity of a baseball thrown from the wind-up position on the two machines. A t value of -29.27 was computed, and for nine degrees of freedom a t value of ±2.262 was needed to have a difference between the means at the .05 level of significance. The inference drawn was that there was a significant difference in the velocity of a baseball thrown from the wind-up position on the two machines.

Table 5

t Test for Paired Data Summary

Eamcovop Velocity				
Variable	N	Mean (mph)	df	t Value
Wind-up	10	75.14	9	.47*
Stretch	10	74.41	9	

*Level required for significance at .05 with 9 df was ±2.262.

Eamcovop Accuracy				
Variable	N	Mean**	df	t Value
Wind-up	10	7.9	9	.92*
Stretch	10	6.7	9	

*Level required for significance at .05 with 9 df was ±2.262.

**Mean is for strikes.

A similar t test was employed on the data collected concerning the gross accuracy achieved from the wind-up position on the two machines. A t value of .10 was computed, and for nine degrees of freedom a t value of ±2.262 was needed to have a difference between the means at the .05 level of significance. The inference drawn was that there was no significant difference in the accuracy of a baseball thrown from the wind-up position on the two machines. Table 6 presents a summary of the two t tests. The raw data are presented in Appendix E.

Table 6

t Test for Paired Data Summary

Wind-up Velocity				
Variable	N	Mean (mph)	df	t Value
Dekan	10	74.16	9	-29.27*
Eamcovop	10	75.14	9	

*Level required for significance at .05 with 9 df was ±2.262.

Wind-up Accuracy				
Variable	N	Mean**	df	t Value
Dekan	10	8.0	9	.10*
Eamcovop	10	7.9	9	

*Level required for significance at .05 with 9 df was ±2.262.

**Mean is for strikes.

Analysis of Speed and Gross Accuracy Data for the Stretch

A t test for paired data was performed on the data for the velocity of a baseball thrown from the stretch position on the two machines. A t value of -15.10 was computed, and for nine degrees of freedom a t value of ±2.262 was needed to have a difference between the means at the .05 level of significance. The inference drawn was that there was a significant difference in the velocity of a baseball thrown from the stretch position on the two machines.

A similar t test was employed on the data collected concerning the gross accuracy achieved from the stretch position on the two machines. A t value of 1.25 was computed, and for nine degrees of freedom a t value of ±2.262 was needed to have a difference between the means at the .05 level of significance. The inference drawn was that there was no significant difference in the accuracy of a baseball thrown from the stretch position on the two machines. Table 7 presents a summary of the two t tests. The raw data are presented in Appendix E.

Analysis of the Pearson Product Moment Correlations

The data were further analyzed utilizing a Pearson product moment correlation to determine if there was a relationship between the velocities achieved from the wind-up and stretch positions. A non-significant correlation coefficient of .56 was obtained for the Dekan Performance Analyzer, and a non-significant correlation coefficient of .58 was obtained for the Eamcovop, indicating that velocities achieved from one pitching position were not necessarily related to velocities achieved from the other pitching position. A qualification for this inference for the fastest pitchers is given in Chapter 5.

Table 7

t Test for Paired Data Summary

Stretch Velocity				
Variable	N	Mean (mph)	df	t Value
Dekan	10	73.29	9	-15.10*
Eamcovop	10	74.41	9	

*Level required for significance at .05 with 9 df was ±2.262.

Stretch Accuracy				
Variable	N	Mean**	df	t Value
Dekan	10	8.6	9	1.25*
Eamcovop	10	6.7	9	

*Level required for significance at .05 with 9 df was ±2.262.

**Mean is for strikes.

A Pearson product moment correlation was performed on the data collected on gross accuracy from the two pitching positions. A significant correlation coefficient of .82 was computed for the Dekan Performance Analyzer, and a non-significant correlation coefficient of -.03 was computed for the Eamcovop. The discrepancy between the two values is probably due to uncontrollable human factors involved in throwing the balls. It seems reasonable to assume that no real relationship existed between the accuracy of the two pitching positions investigated. Thus, those subjects who were accurate from the wind-up position may or may not have been as accurate from the stretch position. Tables 8 and 9 are summary tables for the Pearson product moment correlations.

Table 8

Pearson Product Moment Correlations
Summary

Wind-up and Stretch--Dekan				
Variable	N	df	r	*t* Value
Velocity	10	8	.56	1.934*
Accuracy	10	8	.82	4.078*

*Level required for significance at .01 with 8 df (one-tailed test) was ±2.896.

Table 9

Pearson Product Moment Correlations
Summary

Wind-up and Stretch--Eamcovop				
Variable	N	df	r	*t* Value
Velocity	10	8	.58	1.994*
Accuracy	10	8	-.03	-.087*

*Level required for significance at .01 with 8 df (one-tailed test) was ±2.896.

Analysis of the Spearman Coefficients of Rank Correlation

Finally, the data were analyzed utilizing Spearman's coefficient of rank correlation to determine if a relationship existed between speed and gross accuracy. From the wind-up a correlation coefficient of .25 was computed for the Dekan, and from the wind-up a correlation coefficient of .12 was computed for the Eamcovop. From the stretch a correlation coefficient of .32 was computed for the Dekan, and from the stretch a correlation coefficient of .24 was computed for the Eamcovop. None of the four correlation coefficients met the test for significance at the .01 level; thus, no relationship was demonstrated between the speed and gross accuracy of the wind-up or between the speed and gross accuracy of the stretch. This indicated that, as a subject's speed increased, the gross accuracy of the pitches may not have become necessarily better or worse from either pitching position. Tables 10 and 11 are summary tables for the Spearman coefficients of rank correlation.

DISCUSSION

The Eamcovop and Dekan Performance Analyzer

The Dekan Performance Analyzer was utilized in this study as a control against which the Eamcovop could be evaluated. Differences in the design of the two machines,

Table 10

Spearman Coefficients of Rank Correlation Summary

Speed and Accuracy--Dekan				
Variable	N	df	r	*t* Value
Wind-up	10	8	.25	.738*
Stretch	10	8	.32	.966*

*Level required for significance at .01 with 8 df (one-tailed test) was ±2.896.

Table 11

Spearman Coefficients of Rank Correlation Summary

Speed and Accuracy--Eamcovop				
Variable	N	df	r	*t* Value
Wind-up	10	8	.12	.351*
Stretch	10	8	.24	.701*

*Level required for significance at .01 with 8 df (one-tailed test) was ±2.896.

as well as other factors, must be taken into consideration when discussing the results of the tests and the usefulness of the Eamcovop in teaching situations. (Photographs and a diagram of the Eamcovop are presented in the appendixes.)

The basic difference between the two machines is that the Dekan Performance Analyzer uses electro-mechanical switches to clock the start and stop of the ball, while the

Eamcovop uses pulses in the laser beam fields to clock the start and stop. The necessarily slower reaction times of the electro-mechanical switches compared to laser beam pulses result in overall lower recorded velocities of one to two miles per hour in the Dekan. In other words, the extra time needed for the electro-mechanical switches of the Dekan Performance Analyzer to operate results in consistently lower velocities than the Eamcovop. Theoretically, the Eamcovop should provide greater timing precision than the Dekan Pefformance Analyzer because the time lag inherent in the triggering of electro-mechanical devices is eliminated.

Another major difference which should be considered is that the Dekan Performance Analyzer requires that the subject be wired to the machine, whereas the Eamcovop requires no wiring. The wiring not only requires extra time on the part of the tester and subject but also may hinder or otherwise alter the mobility of the subject in such a way as to affect performance.

A very important difference between the two machines is that the Dekan Performance Analyzer measures only average velocity through the entire distance the ball travels. The Eamcovop, on the other hand, can be adjusted to measure velocity through any portion of the distance. In the present study, for example, the Eamcovop measured the velocity of the ball as it travelled the last one foot of the total distance, i.e., velocity near the point at which the ball would reach the batter. Since the velocity of a thrown ball decreases with distance from the pitcher, the velocity in the last one foot of the distance should be somewhat less than the average velocity over the entire distance. It should be noted that this difference in the measurement of velocities is in the opposite direction to the difference in velocities resulting from electro-mechanical time lag. Theoretically, velocity during the last one foot of the distance should be of more value in determining the effectiveness of the pitch than average velocity through the entire distance.

Other differences between the two machines include calibration requirements and the measurement of projectiles other than the baseball. Although the Eamcovop requires more time for initial set-up than the Dekan Performance Analyzer due to calibration requirements, once calibrated the Eamcovop can measure an unlimited number of throws without the requirement of the Dekan Performance Analyzer for wiring of each subject to the machine. Thus, for other than low volume testing situations, the Eamcovop may require less operating time than the Dekan Performance Analyzer. Furthermore, the Eamcovop is suitable for measuring projectiles other than the baseball--e.g., shuttlecocks, golf balls, arrows, softballs, tennis balls, basketballs, soccer balls, volley balls--without modification of the machine. The Dekan Performance Analyzer would require individual modifications for each such measurement.

In the actual testing situation employed in this study, the physical requirements of the two machines dictated some differences in the positioning of the investigator during observation of the throws. For example, the Dekan tests required the investigator to be stationed in line with the subject because of the wires attached to the subject. For the Eamcovop tests, the investigator was positioned near the last one foot of the distance because of the wires attached to the apparatus. Whether or not the position of the investigator influenced the subjects' throws can not be determined.

A minor incident during the tests using the Eamcovop should be mentioned. Although the mirrors on the apparatus were protected by fencing, one thrown ball grazed a mirror and shattered it. A ten minute pause was required while the mirror was replaced.

The testing situation was designed to simulate real play to the fullest extent possible. The subjects wore baseball uniforms, a pitcher's mound was provided, and the subjects were instructed to pitch as if they were in an actual game. It must be noted, however, that testing in a gymnasium can only approximate a real life situation, and this limitation must be taken into consideration during any review of the results.

Finally, the contributions of Coach Stanford and the Middle Tennessee State University baseball players should be taken into account. Their cooperation and willingness to conform to the requirements of the study provided the backbone for the data collected.

The Dekan Performance Analyzer has been an effective teaching tool for many years. As demonstrated in the present study, the Eamcovop performs the same functions as the Dekan Performance Analyzer with at least as much reliability. The Eamcovop, therefore, can be regarded as an effective teaching tool. In addition, the Eamcovop may provide substantial advantages over the Dekan Performance Analyzer in certain applications within the field of education. The characteristics of more accurate timing, the ability to measure velocities throughout portions of the distance, unhindered mobility of the subject, and applicability to a variety of projectiles used in games without modification of the apparatus all imply greater usefulness of the Eamcovop than the Dekan Performance Analyzer in teaching situations aimed at performance testing and improvement of performance.

Speed and Accuracy Results

There is little argument about the mechanics of throwing a baseball. However, pitching is much more specialized because maximum velocity is not always required nor, obviously, is minimum distance. Since the increased popularity of the no-pump wind-up, few people have argued that the preliminary movements of the full wind-up add to the velocity of the ball.[1] The literature reveals many reasons for employing the full wind-up. They range from loosening the muscles and clothing to deception.[2] However, these same advantages are also achieved by the stretch position.[3] Bass stated that the full wind-up, no-pump wind-up, and stretch all require the same considerations.[4] From the point the pitcher has pivoted during the wind-up until he has completed his follow-through, the movements are exactly the same as pitching from the stretch. The results of the investigation indicate that it is from this point that the velocity of the pitch is determined and that nothing is gained in terms of velocity from the preliminary movements of the full wind-up.

Jenkins stated that the only difference between his full wind-up and stretch throwing motions was that he did

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[1]Guy G. Reiff, What Research Tells the Coach About Baseball (Washington, D.C.: American Association of Health, Physical Education, and Recreation, 1971), p. 11.

[2]Dick Groch, "Analyzing the Pitcher," Athletic Journal, 50:113, March, 1970; Connie Mack, Connie Mack's Baseball Books (New York: Alfred A. Knopf, Inc., 1950), p. 86; Donald K. Edwards, "The Mechanics of Pitching," Athletic Journal, 42:40, 76, February, 1963.

[3]Groch, p. 113; Edwards, p. 76.

[4]B. H. Bass, "Getting to the Basics of Pitching," Athletic Journal, 49:70, February, 1969.

not bring his hands over his head in order to save time with the stretch.[5] Throughout the literature there has been a calling for uniformity in each pitch. This is a must for control and deception. Alston explained that the same pitching procedures should be employed from the stretch as from the wind-up.[6] Thus, if each pitch is thrown with exactly the same motion, from the same height, and released at the same angle, there is no reason to assume that they would be thrown at different speeds or with varying accuracy. Consequently, the fact that the results of this study agree in large part with the studies by Keller and Robbins[7] should not be surprising.

Further testing may provide insight into the relative advantages and disadvantages of pitching from the wind-up and stretch positions. Limitations on the present

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[5]Ferguson Jenkins, Inside Pitching (Chicago: Henry Regnery Co., 1972), p. 12.

[6]Walter Alston and Don Weiskopf, The Complete Baseball Handbook (Boston: Allyn and Bacon, Inc., 1972), p. 135.

[7]George P. Keller, "A Comparison of the Velocity of Fastballs Thrown from the Windup and Stretch Positions" (unpublished Master's thesis, Southeast Missouri State College, 1972); Bruce B. Robbins, "A Comparison of Methods of Pivot Foot Position and the Relationship to the Speed of a Pitched Ball" (unpublished Master's thesis, Springfield College, 1966), cited by George P. Keller, "A Comparison of the Velocity of Fastballs Thrown from the Windup and Stretch Positions," unpublished Master's thesis, Southeast Missouri State College, 1972, p. 9.

study may account for the lack of significance at the .01 level of confidence for most of the correlation coefficients. The one significant correlation, i.e., that between gross accuracy of the two positions on the Dekan Performance Analyzer, is probably due to human factors beyond the control of this study. These results are interesting in light of what Alston wrote, that accuracy while throwing from the stretch may be due to a lack of practice, while simplifying the movements of the total motion helps to improve control.[8] The stretch position has the least amount of movement of all the pitching motions, thus it has the potential for being the most accurate. Consequently, those subjects who were more accurate from the wind-up position may have been so due to a lack of practice with the stretch position, while those subjects who were more accurate from the stretch position may have benefited from the decrease in body movement.

No relationship existed between speed and gross accuracy from either position. Since some of the subjects may have been throwing closer to their maximal speed than others, this may have influenced the accuracy results. Though it seemed to the author and Coach Stanford that the subjects were attempting to duplicate a game situation as closely as possible and an offer had been made to the

[8]Alston and Weiskopf, p. 135.

subjects to stay after the testing was completed to obtain their maximal velocity, one can not be positive that the testing situation did not affect the results.

A similar study utilizing subjects who have participated in an intense practice period with the stretch position may yield different results. Though all of the subjects were experienced pitchers, in organized baseball relatively little practice time is actually spent throwing from the stretch position. If Alston is correct and a lack of time spent on the stretch position does influence control, then the results may be significantly in favor of the stretch position.

Many pitchers employ the full wind-up when it may be advantageous to utilize the stretch, but not absolutely essential. Jenkins will employ the full wind-up with a runner on third unless that runner happens to be a highly proficient base stealer.[9] Most pitchers use the wind-up with the bases loaded unless the count is three balls and two strikes with two outs. However, employing the wind-up in these situations gives the runners the opportunity to take unusually large leads, making double plays extremely hard to execute and allowing runners to advance farther than they would have had the pitcher been employing a stretch motion. Pitchers employ the wind-up in these situations

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[9]Jenkins, p. 12.

because they feel more comfortable with it, giving them the notion that they are more accurate and faster. However, if more practice time were spent throwing from the stretch, then it would probably begin to feel just as comfortable as the wind-up. Alston stated that the chief advantage of the no-pump wind-up is that it takes unnecessary movement out of the early stages of the delivery and allows for greater control.[10] If this is true, then throwing from the stretch should be even more accurate, or at least as accurate as the no-pump wind-up.

The indications are that it may be best to do away with the wind-up altogether, at least for those pitchers who are now employing the no-pump wind-up delivery, and have pitchers throw only from the stretch. Since speed is not affected by the preliminary actions of the wind-up, and many authorities agree that better control and ball movement is possible with less movement from the start of the delivery to the time the ball is released, the stretch-only theme makes sense. With the increased practice time, it is possible to conclude that the pitcher's performance at worst would be the same as when he threw from the wind-up, and quite possibly even better, since the pitcher would not have to bother with mastering and practicing two types of deliveries. This, however, would be such a radical change

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[10] Alston and Weiskopf, p. 122.

it probably would be extremely difficult to convince the conservative baseball people to give it a try.

Chapter 5

SUMMARY, CONCLUSIONS, EDUCATIONAL APPLICATIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Included in this chapter is a summary of the investigation. The conclusions are presented along with a brief discussion of the use of the Eamcovop in research and educational situations. Finally, recommendations for further study are made.

SUMMARY

The purposes of the investigation were to establish the reliability coefficients of the Eamcovop, an electronic apparatus for measurement and computation of the velocity of a projectile, to determine the applicability of the Eamcovop to teaching, and to employ the Eamcovop to determine if there is a significant difference in a baseball pitcher's velocity from two pitching positions. The Eamcovop was then employed to help determine if there was a significant difference in velocity and gross accuracy of a baseball thrown from the wind-up and stretch positions with a runner on third base. It should be noted that the data on gross accuracy were presented solely as an adjunct to the data on velocity and were not a major part of the study.

The subjects for the investigation were ten male baseball pitchers from the Middle Tennessee State University varsity baseball team in 1979-80. The subjects ranged in age from seventeen years to twenty-three years.

The reliability coefficients were established with the Eamcovop stationed in a permanent position with a baseball suspended from the ceiling at a height that would cause it to break the top beam of each laser when released and allowed to swing naturally. The ball was released at the same height and distance from the Eamcovop by four subjects during two tests of thirty-five trials each. This was accomplished by having the subject sit backwards in a folding metal chair facing the Eamcovop. The chair was placed at a distance that would cause the string attaching the ball to the ceiling to be pulled tight when the ball was placed on the top of the back of the chair. The only movement made by the hand was an opening of the fingers to let the ball go. When the ball swung back, it was caught in the opposite hand and placed back into the other hand. After the reliability data were collected, tests of actual pitches were conducted.

Each pitching subject had fifteen throws recorded for speed and gross accuracy from the wind-up and stretch pitching positions. The thirty pitches were thrown at maximal speeds for each setting with the investigator standing behind the counter and the thrower for the Dekan

Performance Analyzer, and standing behind the counter and the catcher for the Eamcovop. Five of the subjects threw from the wind-up position first, and five threw from the stretch position first. The runner on third base stood in a stationary position six feet from third base. Gross accuracy was determined by having each pitch called a ball or strike by staff members at Middle Tennessee State University who had a baseball background.

Each pitcher was allowed to warm up until he stated he was ready to begin the testing. As the subject was warming up, he was informed whether he would throw from the wind-up or stretch position first. After the subject threw the first fifteen pitches that were recorded, he was allowed to rest. When the subject stated he was ready, the next fifteen pitches were thrown from the remaining position.

After each pitch, the recorder placed the speed of the pitch, along with whether it was a ball or strike, in the appropriate columns on the data sheet. The subjects were told to disregard the total number of balls and strikes and throw each pitch as though there were no balls or strikes on the batter. After the first fifteen pitches were thrown, the subject was allowed to look at the data sheet.

The data for reliability were analyzed by standard deviations and a Pearson product moment correlation. The latter was used to establish the reilability of the Eamcovop at velocities under ten miles per hour using a pendulum ball. Pearson product moment correlations were computed using pitching data to establish the reliability of the Eamcovop at actual pitching velocities.

The pitching data were first analyzed by computing the mean velocities for each subject from both pitching positions and then by totaling the number of strikes thrown by each subject for each of the four tests. After this was completed, the means and totals were subjected to t tests for paired data to determine whether significant differences existed between the two pitching variables for velocity or gross accuracy, and whether significant differences existed between the two machines for the wind-up or stretch positions. The data were further analyzed by a Pearson product moment correlation to find if any relationship existed between the velocities recorded by the subjects from the two pitching positions investigated. Another correlation coefficient was computed employing the same method utilizing the gross accuracy data collected. Finally, Spearman's coefficient of rank correlation was utilized to determine if there was a relationship between speed and gross accuracy from the wind-up and stretch pitching positions.

A non-significant t of .47 was computed for the velocity of a thrown baseball from the wind-up and stretch positions for the Eamcovop, and a non-significant t of .58

was computed for the velocity of a thrown baseball from the wind-up and stretch positions for the Dekan Performance Analyzer. A non-significant *t* of .92 was computed for the accuracy of the two pitching positions investigated for the Eamcovop, and a non-significant *t* of -.80 was computed for the accuracy of the two pitching positions investigated for the Dekan Performance Analyzer.

A significant *t* of -29.27 was computed for the velocity of a baseball thrown from the wind-up position on the two machines, and a significant *t* of -15.10 was computed for the velocity of a baseball thrown from the stretch position on the two machines. A non-significant *t* of .10 was computed for gross accuracy achieved from the wind-up position on the two machines, and a non-significant *t* of 1.25 was computed for gross accuracy achieved from the stretch position on the two machines.

A non-significant Pearson product moment correlation coefficient of .58 was obtained by the Eamcovop for the relationship between the velocity achieved from the wind-up and stretch positions. The inference was that velocities achieved from one pitching position were not necessarily related to velocities achieved from the other pitching position. A qualification of this inference for the fastest pitchers is given later in this chapter. A non-significant Pearson product moment correlation coefficient of .56 was obtained by the Dekan Performance Analyzer for the relationship between the velocities achieved from the wind-up and stretch positions. The inference was that velocities achieved from one pitching position were not necessarily related to velocities achieved from the other pitching position. A qualification of this inference for the fastest pitchers is given later in this chapter.

A non-significant Pearson product moment correlation coefficient of -.03 was computed for the relationship between the gross accuracy data from the two pitching positions on the Eamcovop, while a significant Pearson product moment correlation coefficient of .82 was computed for the relationship between the gross accuracy data from the two pitching positions on the Dekan Performance Analyzer. Because of the likelihood of natural human variation as an uncontrolled variable in the study, the inference drawn was that in reality those subjects who were accurate from the wind-up may or may not have been as accurate from the stretch.

From the wind-up, a non-significant Spearman's rank correlation coefficient of .12 was computed, and, from the stretch, a non-significant rank correlation coefficient of .24 was computed for the relationship between speed and gross accuracy for the Eamcovop. From the wind-up, a non-significant rank correlation coefficient of .25 was computed, and, from the stretch, a non-significant rank correlation coefficient of .32 was obtained for the relationship between speed and gross accuracy for the Dekan Performance Analyzer. The inferences drawn were that no relationship existed between the speed and gross accuracy of the wind-up, and that no relationship existed between the speed and gross accuracy of the stretch. Thus, as a subject's speed increased, his gross accuracy may not have become necessarily better or worse from either pitching position.

CONCLUSIONS

Within the scope of the study, the following conclusions are warranted:

1. The Eamcovop is at least as reliable as the Dekan Performance Analyzer in measuring the velocities of pitched baseballs, and theoretically superior to the Dekan Performance Analyzer in other areas.

2. The stretch pitching position is as fast as the wind-up pitching position with a runner on third base.

3. There is a significant difference between the Eamcovop and the Dekan Performance Analyzer as a teaching tool; the technical superiority of the Eamcovop makes it more suitable for teaching purposes than the Dekan Performance Analyzer.

EDUCATIONAL AND RESEARCH APPLICATIONS

A number of machines have been developed to measure velocity in different ways, but the Eamcovop is unique for several reasons. First of all, it makes use of recent technological advancements--specifically, the laser beam--to provide a measure of timing accuracy previously unattainable by electro-mechanical devices. Such accuracy enhances its use as a research instrument. Second, the Eamcovop uses materials which are relatively inexpensive, bringing it within the budget range of many educational institutions and physical education departments. Third, the Eamcovop provides for unhindered mobility of the subject, a feature hitherto available only at appreciable expense in time and materials--e.g., as in the case of filming techniques. Fourth, the Eamcovop offers flexibility in its application to a wide variety of both research and teaching situations by means of its ability to measure velocity throughout the whole or any portion of a distance, and its ability to measure velocity in any of four directions.

In the present study, a modified Dekan Performance Analyzer was used as a control device against which the Eamcovop could be compared. The Dekan Performance Analyzer was chosen because of its wide acceptance and long history of use in physical education. The technical superiority of the Eamcovop compared to the Dekan Performance Analyzer is apparent both on theoretical grounds and on the basis of actual application in a testing situation such as that used in the present study. There are a number of ways in which the Eamcovop can be applied to research and teaching situations in the area of athletics and physical education.

One use is in the classroom where the Eamcovop can be utilized to demonstrate various theories of velocity and their application to sports. For example, a pendulum ball can be released by both instructor and students to gain practical experience of the effects of angle and spin on velocity. Since the Eamcovop, once calibrated, can accommodate an unlimited number of trials without individual subject hook-ups, a large number of students can gain practical experience in a short period of time.

Coaches can use the Eamcovop in a wide variety of applications. For example, Coach Stanford in the present study ranked his players before testing, then compared his ranking to the results of the tests to determine areas of agreement and disagreement. Such a technique may be useful not only for evaluating the strengths and weaknesses of individual team members but also for sharpening the perceptions of the coach and providing objective feedback concerning subjective judgments. (See Appendix F for rankings.)

One pitcher, ranked tenth by the coach prior to testing, actually achieved the greatest velocities in performance from both positions on both machines. Another pitcher, ranked seventh by the coach, consistently ranked second in the testing situation.

Differences in velocity between the two positions for individual pitchers also became apparent. For example, the pitcher ranked fastest by the coach actually ranked ninth in the stretch position and fifth in the wind-up position. The player ranked sixth by the coach actually ranked third in the stretch position and tenth in the wind-up position. Differences such as these can be the basis for individualized training and practice programs.

Although, overall, there was no correlation between velocities from the two pitching positions, it should be noted that the two fastest pitchers from the wind-up position were also the fastest from the stretch position, and that the third fastest pitcher from the wind-up was fourth fastest from the stretch. This may indicate that those pitchers who throw fastest from the wind-up also throw fastest from the stretch.

Another application is in the area of training in athletics and sports. Players can be tested prior to a training program, then tested again to determine whether or not the training produced the desired effect. In this way, objective evidence can be obtained on which comprehensive training programs may be based.

In a sport such as karate, the Eamcovop can be used to measure the velocity of individual limb movements. Profiles can be drawn of velocities attained in different movements in order to gauge the proficiency of players and to identify areas needing improvement. In the area of physical fitness, the Eamcovop lends itself to research involving studies of kinesiology and ergogenic aids as well as sports techniques.

Another use of the Eamcovop is in the testing of equipment. Not only can different racquets, balls, and other gear be compared for relative advantages and disadvantages to individual players but also the same equipment can be tested under different conditions. For example, the effects of different temperatures, humidities, and storage conditions on the velocities of projectiles can be measured.

The specific areas of research and education in which the Eamcovop can be of use are too numerous to list comprehensively. It is apparent, however, that the Eamcovop has practical implications for the education of both students and teachers in those areas in which an understanding of velocities is important.

RECOMMENDATIONS FOR FURTHER STUDY

As a result of the study comparing the stretch to the wind-up pitching positions and the author's experiences with the Eamcovop and the Dekan Performance Analyzer, the following suggestions for further study are indicated:

1. A study duplicating this investigation, but with the subjects training extensively with the stretch position prior to the testing in order that they may become more familiar with it.

2. A study comparing the speed and accuracy of different pitches from the two delivery positions.

3. A similar study employing a large number of subjects divided into groups according to the number of years they have been pitching in order to determine if experience influences the results.

APPENDIXES

APPENDIX A

CONSENT FOR EXPERIMENTAL STUDY

CONSENT FOR EXPERIMENTAL STUDY

Title of Project:

Project Director:

This is to certify that I, ______________________________, hereby agree to participate in an experimental study under the supervision of ____________________________. I am _____ years of age.

The study will include:

1. Measurement of the velocity of a pitching ball from the wind-up position (30 trials).

2. Measurement of the velocity of a pitching ball from the stretch position (30 trials).

A detailed explanation of this study has been given to me and I understand the procedures to be followed. I have been informed of all inconveniences and risks reasonably to be expected from the procedures, and possible beneficial effects thereof. All of my inquiries have been answered, and I choose freely and voluntarily to participate.

________________________ ______________

Volunteer's Signature Date

I have defined and fully explained the studies involved to the above volunteer.

________________________ ______________

Investigator's Signature Date

APPENDIX B

DATA SHEET

DATA SHEET

NAME: ____

AGE: Years________ Months________

SUBJECT NUMBER: ____________________________________

FIRST PITCHING POSITION: ____________________________

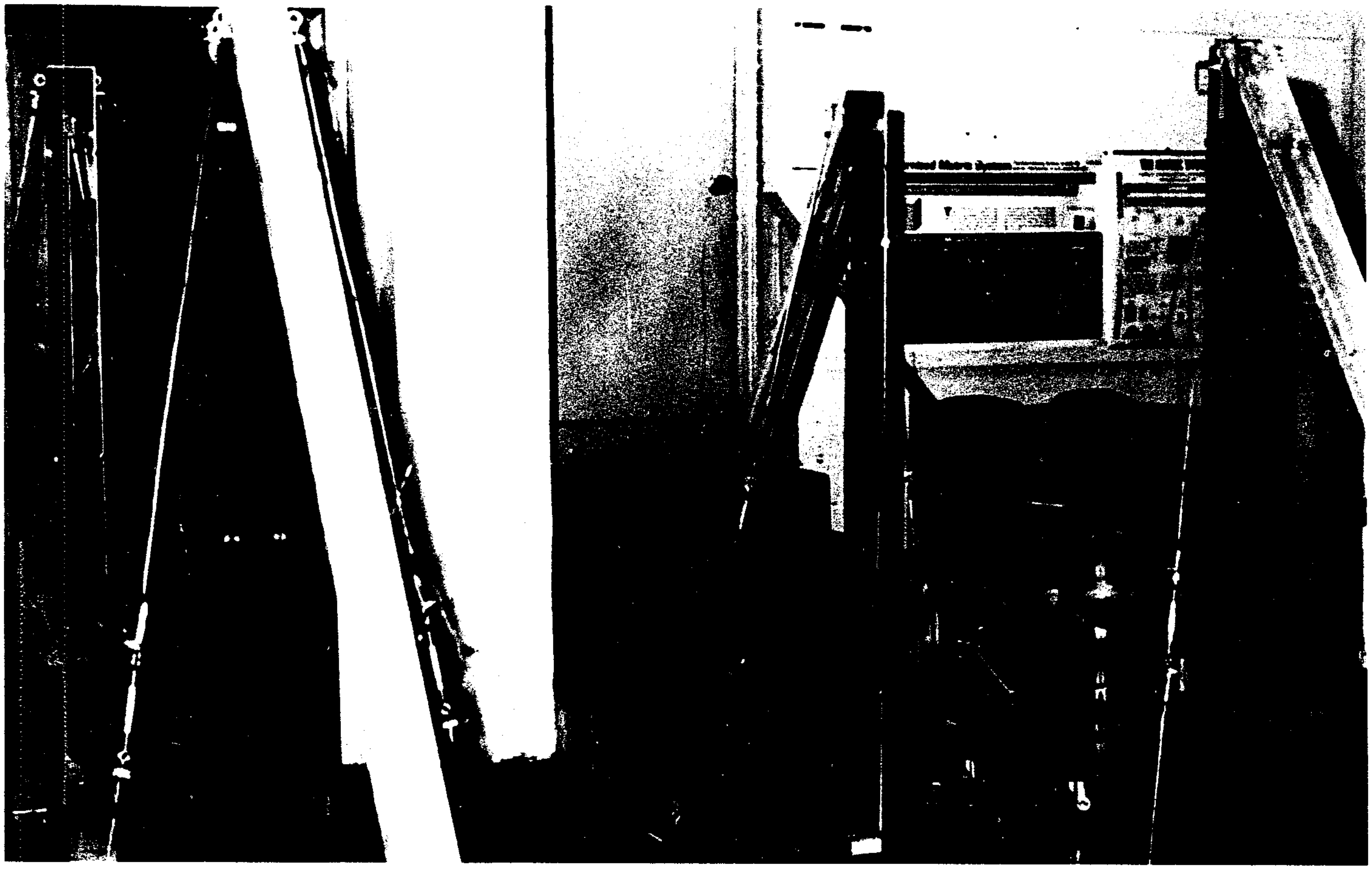
SECOND PITCHING POSITION: ___________________________

PITCH #	DISTANCE	TIME	SPEED	ACCURACY
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				

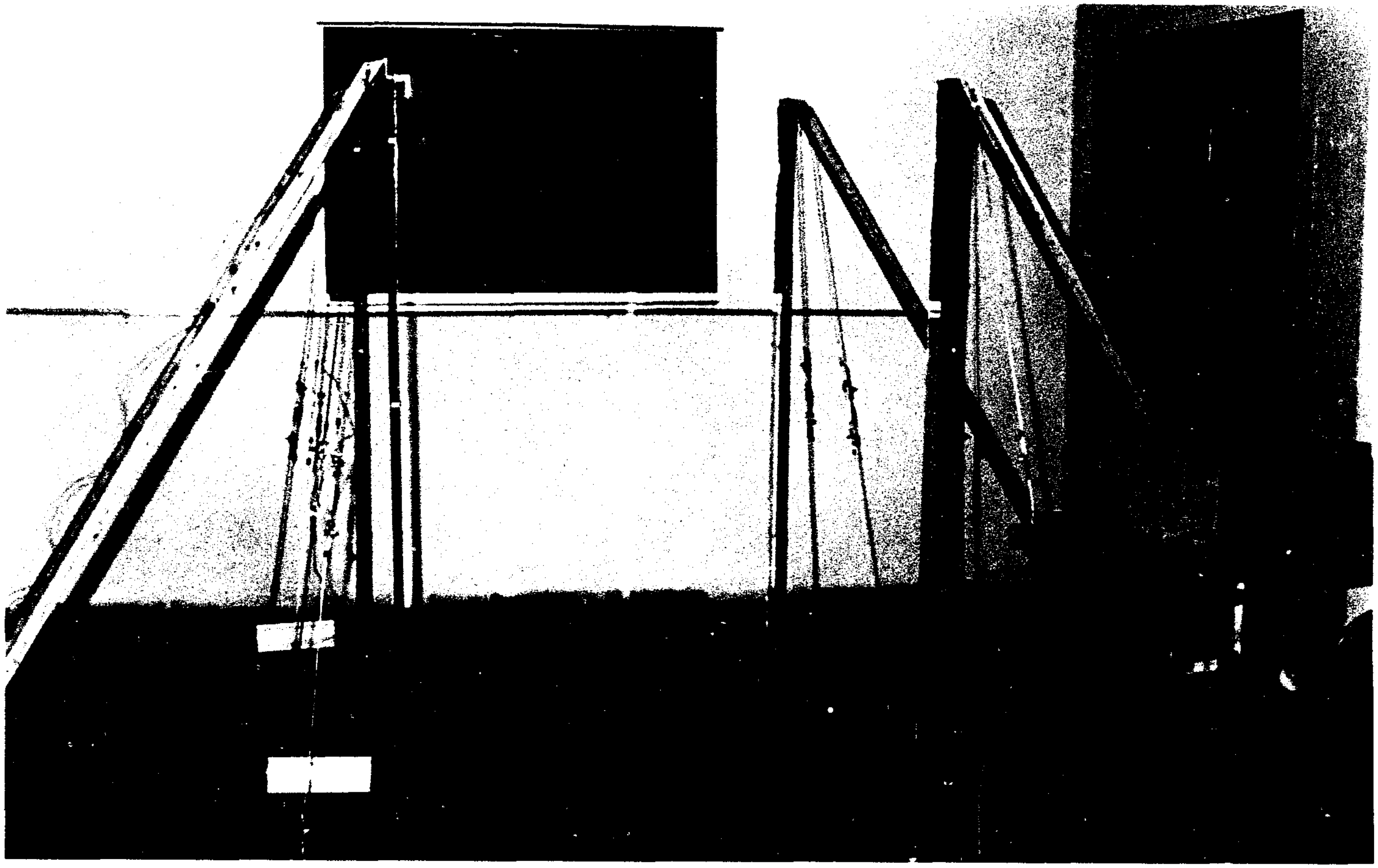
TIME 1/10 sec. 1/100 sec. 1/1,000 sec. 1/10,000 sec.

APPENDIX C

PHOTOGRAPHS OF THE EAMCOVOP



Eamcovop--Side View



Eamcovop--Front View

APPENDIX D

DIAGRAM OF THE EAMCOVOP AMPLIFIER

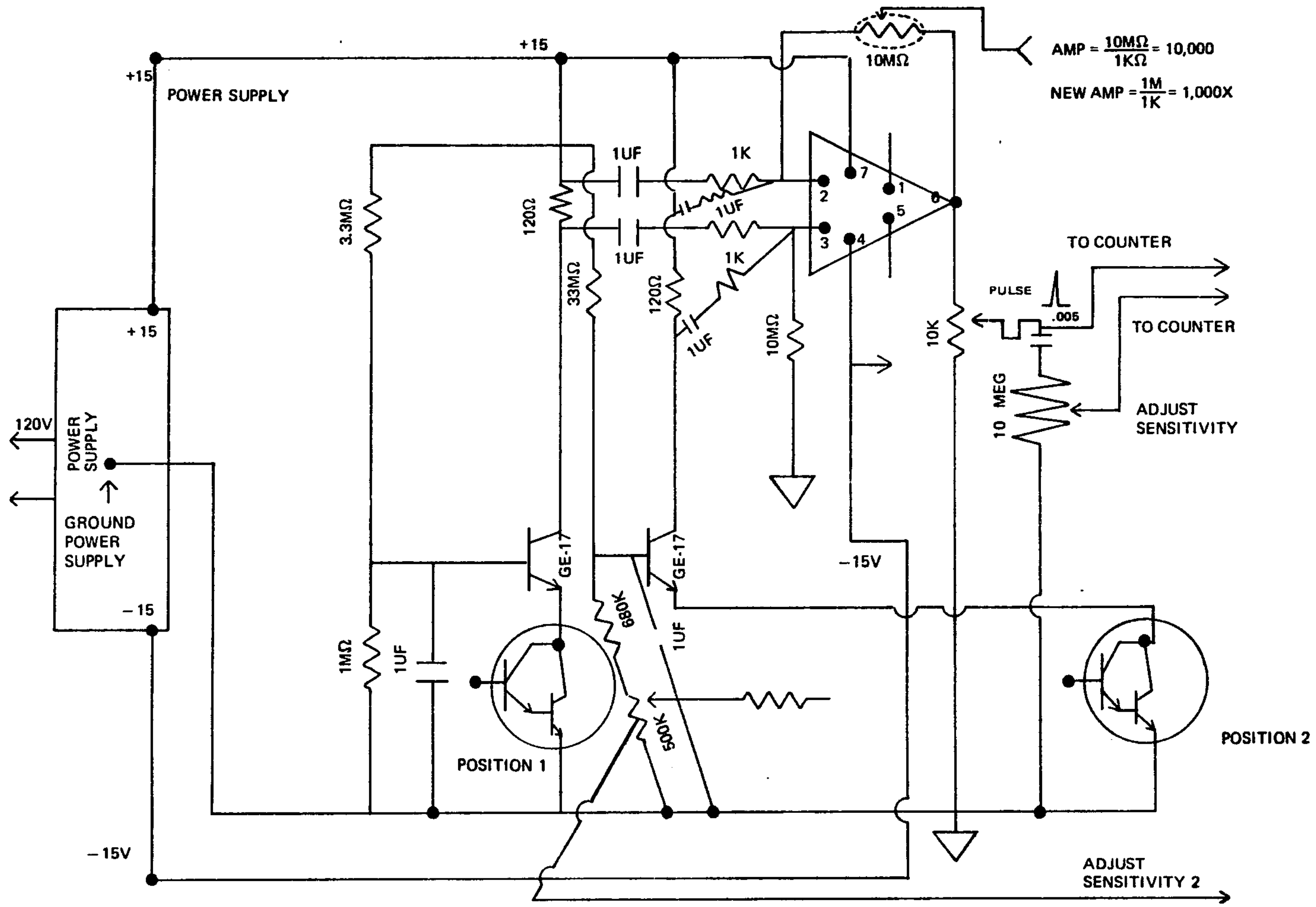


Diagram of
EAMCOVOP AMPLIFIER

APPENDIX E

RAW DATA OF SUBJECTS

RAW DATA OF SUBJECTS

Dekan Subject-Trial #1	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	73.66	S	79.33	S
2	63.46	S	75.00	S
3	71.2	B	73.66	S
4	69.96	B	76.39	S
5	62.50	S	76.39	S
6	69.96	S	71.2	B
7	63.46	B	79.33	S
8	57.29	S	76.39	S
9	65.48	B	73.66	S
10	58.09	S	75.00	S
11	75.00	B	79.33	S
12	72.37	S	77.83	S
13	71.12	B	82.50	S
14	65.48	S	71.12	B
15	64.45	B	77.83	S
Mean	66.89	8 = S 7 = B	76.33	13 = S 2 = B

Eamcovop Subject-Trial #1	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	65.18	B	78.91	B
2	64.20	B	72.38	B
3	72.77	S	83.56	B
4	73.55	B	78.73	S
5	76.27	S	80.40	S
6	60.55	B	76.10	S
7	65.25	B	74.60	B
8	58.23	S	77.48	S
9	64.26	B	80.21	S
10	70.00	B	72.23	B
11	63.37	S	77.48	S
12	70.73	B	77.83	S
13	72.61	S	74.35	S
14	64.08	B	76.44	S
15	73.31	S	80.40	B
Mean	67.62	6 = S 9 = B	77.41	9 = S 6 = B

RAW DATA OF SUBJECTS

Dekan Subject-Trial #2	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	69.96	B	71.12	S
2	71.12	S	77.83	S
3	61.57	B	68.75	B
4	73.66	S	71.12	S
5	69.96	B	79.33	B
6	77.83	S	76.39	S
7	69.96	B	79.33	S
8	77.83	S	76.39	S
9	77.83	S	76.39	S
10	75.00	S	72.37	S
11	62.50	B	77.83	S
12	77.83	S	69.96	B
13	71.12	S	80.88	S
14	76.39	S	75.00	S
15	80.88	S	73.66	S
Mean	72.90	10 = S 5 = B	75.09	12 = S 3 = B

Eamcovop Subject-Trial #2	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	81.75	S	74.27	B
2	77.48	S	76.61	B
3	72.23	B	81.85	B
4	78.82	S	70.86	B
5	62.55	S	78.82	S
6	63.66	S	73.39	S
7	75.59	B	77.30	S
8	78.82	B	77.58	S
9	78.91	S	80.31	B
10	70.95	S	77.22	B
11	78.82	S	80.59	B
12	70.88	S	71.25	S
13	74.68	S	69.72	S
14	71.17	B	78.91	S
15	70.95	S	72.30	S
Mean	73.82	11 = S 4 = B	76.07	8 = S 7 = B

RAW DATA OF SUBJECTS

Dekan Subject-Trial #3	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	68.75	B	73.66	S
2	75.00	S	71.12	B
3	71.12	S	73.66	S
4	79.33	S	75.00	S
5	77.83	S	71.12	S
6	77.83	S	66.53	B
7	76.39	S	76.39	S
8	79.33	S	75.00	S
9	65.48	B	73.66	S
10	66.53	B	77.83	S
11	79.33	S	79.33	S
12	69.96	S	80.88	S
13	77.83	S	79.33	S
14	71.12	S	79.33	S
15	80.88	S	79.33	S
Mean	74.45	12 = S 3 = B	75.48	13 = S 2 = B

Eamcovop Subject-Trial #3	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	81.85	S	80.21	B
2	72.15	B	80.31	B
3	78.82	B	81.75	S
4	70.95	S	80.50	B
5	80.40	S	78.82	S
6	67.57	S	80.88	B
7	66.52	S	74.68	B
8	80.40	S	76.61	B
9	77.39	S	77.39	B
10	78.82	S	67.57	B
11	78.73	B	72.15	B
12	80.40	B	77.48	B
13	72.15	S	74.68	B
14	76.10	S	72.15	B
15	69.79	S	74.76	B
Mean	75.47	11 = S 4 = B	76.66	2 = S 13 = S

RAW DATA OF SUBJECTS

Dekan Subject-Trial #4	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	84.12	S	75.00	S
2	87.77	S	69.96	B
3	87.77	S	72.37	B
4	89.67	S	82.50	S
5	89.67	S	82.50	B
6	80.88	B	79.33	B
7	82.50	B	79.33	B
8	82.50	B	79.33	B
9	84.18	B	85.94	S
10	84.18	S	77.83	S
11	89.67	S	76.39	S
12	87.77	B	85.94	S
13	87.77	S	80.88	S
14	85.94	S	85.94	S
15	89.67	S	84.19	S
Mean	86.27	10 = S 5 = B	79.07	9 = S 6 = B

Eamcovop Subject-Trial #4	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	90.67	S	85.22	B
2	86.97	B	86.97	B
3	88.78	B	81.85	B
4	88.89	B	86.86	S
5	90.55	S	77.39	B
6	85.23	B	78.82	B
7	85.33	B	86.75	B
8	83.56	S	80.31	B
9	83.66	B	80.40	B
10	81.85	B	80.21	B
11	90.79	B	83.56	S
12	90.55	S	83.66	B
13	88.78	B	73.31	B
14	88.89	B	70.95	B
15	85.12	S	76.01	B
Mean	87.31	5 = S 10 = B	80.82	2 = S 13 = B

RAW DATA OF SUBJECTS

Dekan Subject-Trial #5	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	68.75	S	75.00	S
2	71.12	S	72.37	B
3	66.53	B	69.96	S
4	65.48	S	77.83	B
5	71.12	B	76.39	S
6	76.39	S	77.83	B
7	69.96	B	73.66	B
8	72.37	S	79.33	B
9	77.83	S	68.75	S
10	72.37	B	73.66	S
11	73.66	B	71.12	B
12	71.12	B	68.75	S
13	69.96	S	67.62	S
14	71.12	S	67.62	S
15	66.53	S	71.12	S
Mean	70.95	9 = S 6 = B	72.73	9 = S 6 = B

Eamcovop Subject-Trial #5	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	67.64	S	72.30	S
2	72.15	S	68.86	B
3	70.88	S	69.57	B
4	72.23	B	69.79	B
5	74.68	S	72.23	S
6	73.39	S	74.68	S
7	78.82	S	69.72	S
8	73.55	B	80.40	B
9	70.95	B	74.84	B
10	77.30	S	78.82	S
11	72.23	S	76.44	S
12	66.52	B	79.56	B
13	67.57	S	70.88	S
14	72.07	S	73.63	B
15	69.72	S	76.52	S
Mean	71.80	11 = S 4 = B	73.88	8 = S 7 = B

RAW DATA OF SUBJECTS

Dekan Subject-Trial #6	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	80.88	S	79.33	S
2	77.83	B	77.83	S
3	73.66	B	76.39	S
4	76.39	B	84.18	S
5	80.88	B	77.83	S
6	82.50	B	73.66	B
7	85.94	B	75.00	B
8	89.67	B	71.12	B
9	87.77	S	80.88	B
10	89.67	S	84.18	B
11	91.67	S	84.18	S
12	77.83	S	80.88	B
13	67.62	S	73.66	B
14	68.75	B	79.33	B
15	69.96	B	82.50	B
Mean	80.07	6 = S 9 = B	78.73	6 = S 9 = B

Eamcovop Subject-Trial #6	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	70.95	S	83.56	S
2	69.86	S	79.37	S
3	68.59	S	74.68	B
4	78.91	S	81.95	S
5	92.64	S	85.01	S
6	90.67	B	85.12	S
7	88.78	B	81.85	S
8	90.55	B	72.38	B
9	86.97	S	76.18	B
10	83.56	S	74.68	B
11	81.85	S	78.82	S
12	77.57	B	85.01	S
13	74.68	B	77.48	S
14	78.73	S	78.91	B
15	81.85	S	80.31	B
Mean	81.08	10 = S 5 = B	79.69	9 = S 6 = B

RAW DATA OF SUBJECTS

Dekan Subject-Trial #7	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	79.33	B	71.12	B
2	77.83	B	68.75	B
3	75.00	S	67.62	B
4	73.66	S	68.75	B
5	72.37	B	71.12	B
6	73.66	S	69.91	S
7	72.37	B	71.12	S
8	68.75	B	73.66	B
9	71.12	S	71.12	B
10	72.37	S	69.91	B
11	71.12	S	71.12	B
12	73.66	S	71.12	S
13	71.12	B	72.37	S
14	71.12	S	73.66	B
15	72.37	B	73.66	S
Mean	73.06	8 = S 7 = B	71.01	5 = S 10 = B

Eamcovop Subject-Trial #7	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	73.47	B	74.68	B
2	72.38	B	74.60	B
3	72.46	B	73.55	B
4	74.27	B	72.38	S
5	72.53	S	72.46	S
6	73.16	B	70.95	S
7	72.84	B	72.61	B
8	69.08	B	74.35	B
9	73.55	S	73.00	S
10	74.52	S	70.00	S
11	73.39	B	72.15	S
12	74.76	B	69.72	B
13	76.18	S	68.66	B
14	78.82	B	69.79	B
15	80.31	S	71.17	S
Mean	74.12	5 = S 10 = B	72.01	7 = S 8 = B

RAW DATA OF SUBJECTS

Dekan Subject-Trial #8	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	75.00	S	68.75	S
2	76.39	S	67.62	S
3	73.66	S	66.53	B
4	72.37	B	65.48	B
5	73.66	B	68.75	S
6	76.39	S	71.12	S
7	71.12	B	71.12	B
8	73.66	S	72.37	S
9	73.66	S	67.62	S
10	72.37	S	65.48	B
11	73.66	S	71.12	S
12	71.12	B	72.37	S
13	73.66	S	71.12	S
14	72.37	B	69.96	S
15	71.12	S	71.12	S
Mean	73.35	10 = S 5 = B	69.37	11 = S 4 = B

Eamcovop Subject-Trial #8	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	72.15	S	72.23	B
2	73.39	B	70.88	B
3	74.68	B	72.30	B
4	72.23	B	73.31	S
5	74.60	S	72.15	B
6	73.24	S	66.58	S
7	74.52	S	68.66	S
8	74.76	B	73.31	B
9	72.07	B	72.07	S
10	77.39	S	72.30	S
11	74.35	S	69.86	B
12	73.63	B	66.58	B
13	74.84	S	67.57	S
14	77.57	S	68.66	S
15	76.01	S	69.93	S
Mean	74.36	9 = S 6 = B	70.43	8 = S 7 = B

RAW DATA OF SUBJECTS

Dekan Subject-Trial #9	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	77.83	S	72.37	B
2	76.39	B	71.12	B
3	73.66	B	69.96	B
4	72.37	B	71.12	B
5	72.37	B	68.75	B
6	73.66	B	69.96	B
7	73.66	B	71.12	B
8	72.37	B	67.62	B
9	77.83	S	68.75	B
10	76.39	B	71.12	B
11	73.66	B	71.12	B
12	75.00	B	69.96	B
13	71.12	B	69.96	B
14	73.66	B	72.37	B
15	71.12	B	71.12	B
Mean	74.07	2 = S 13 = B	70.49	0 = S 15 = B

Eamcovop Subject-Trial #9	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	72.46	B	72.23	B
2	74.11	B	73.39	B
3	72.61	B	70.95	B
4	75.93	B	70.88	B
5	74.93	S	72.23	S
6	77.66	B	72.38	B
7	78.91	B	69.93	B
8	72.38	S	68.59	S
9	74.52	S	72.07	B
10	74.76	S	70.73	B
11	73.16	B	69.86	B
12	73.47	S	72.30	S
13	74.43	S	70.58	B
14	77.48	B	72.38	B
15	78.82	S	73.31	S
Mean	75.04	7 = S 8 = B	71.46	4 = S 11 = B

RAW DATA OF SUBJECTS

Dekan Subject-Trial #10	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	65.48	B	66.53	S
2	66.53	B	61.57	B
3	71.12	B	65.48	S
4	67.62	S	63.46	S
5	71.12	B	61.57	B
6	69.96	B	61.57	B
7	68.75	B	64.45	S
8	71.12	S	65.48	B
9	69.96	B	71.12	S
10	71.12	B	63.46	S
11	67.62	B	64.45	S
12	73.66	S	62.50	B
13	67.62	S	60.66	B
14	71.12	B	67.62	B
15	71.12	S	69.96	S
Mean	69.59	5 = S 10 = B	64.66	8 = S 7 = B

Eamcovop Subject-Trial #10	Wind-up Speed (MPH)	Wind-up Accuracy	Stretch Speed (MPH)	Stretch Accuracy
1	72.46	B	71.92	S
2	72.07	B	68.73	S
3	68.66	B	61.70	S
4	74.68	B	63.54	B
5	68.73	S	65.06	B
6	72.00	B	64.44	S
7	70.88	B	72.15	S
8	72.15	B	66.58	B
9	69.93	S	65.50	B
10	70.65	B	62.61	B
11	72.23	S	62.55	S
12	68.59	B	64.51	S
13	72.53	B	66.52	S
14	67.44	B	62.78	S
15	66.45	S	67.11	S
Mean	70.63	4 = S 11 = B	65.71	10 = S 5 = B

APPENDIX F

COACH'S RANKING AND ACTUAL MEAN VELOCITIES
AND
MEAN VELOCITY RANKINGS

COACH'S RANKING AND ACTUAL MEAN VELOCITIES

Coach's Ranking of Subjects Prior to Testing*	Actual Performance Velocities			
	Dekan		Eamcovop	
	Wind-up	Stretch	Wind-up	Stretch
1	73.35	69.37	73.76	70.43
2	74.07	70.49	75.04	71.46
3	73.06	71.01	74.12	72.01
4	70.95	72.73	71.80	73.88
5	72.90	75.09	73.82	76.07
6	66.89	76.32	67.62	77.41
7	80.07	78.73	81.08	79.69
8	69.59	64.66	70.63	65.71
9	74.44	75.48	75.47	76.66
10	86.27	79.07	87.31	80.82

MEAN VELOCITY RANKINGS

Coach's Ranking of Subjects Prior to Testing*	Actual Performance Rank			
	Dekan		Eamcovop	
	Wind-up	Stretch	Wind-up	Stretch
1	5	9	5	9
2	4	8	4	8
3	6	7	6	7
4	8	6	8	6
5	7	5	7	5
6	10	3	10	3
7	2	2	2	2
8	9	10	9	10
9	3	4	3	4
10	1	1	1	1

*The fastest is ranked 1; the slowest is ranked 10.

APPENDIX G

RELIABILITY TESTS-STANDARD DEVIATIONS

RELIABILITY TESTS-STANDARD DEVIATIONS
(35 Trials Per Test)

Machine	Setting	Subject	Mean Velocity (mph)	Standard Deviation
Eamcovop	.01	1	6.0632	.0739
			6.0109	.0497
Dekan P.A.	.01	1	4.3549	.0520
			4.3434	.0467
		2	4.3697	.0411
			4.4020	.0475
		3	4.5637	.0915
			4.4709	.0856
		4	4.6440	.0659
			4.5400	.0812
Eamcovop	.0001	1	5.7730	.1415
			5.7501	.1582
		2	5.8540	.1089
			5.9910	.1233
		3	5.9890	.0911
			6.0447	.0775
		4	6.0680	.0676
			6.0154	.0731

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