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The Relationship of Forward Pass Catching Ability in Football and Selected Anatomical Measurements and Motor Responses

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THE RELATIONSHIP OF FORWARD PASS CATCHING ABILITY IN FOOTBALL AND SELECTED ANATOMICAL MEASUREMENTS AND MOTOR RESPONSES.

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THE RELATIONSHIP OF FORWARD PASS CATCHING ABILITY IN FOOTBALL AND SELECTED ANATOMICAL MEASUREMENTS AND MOTOR RESPONSES.

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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M.P.V.

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CHAPTER I

INTRODUCTION

Significance of the Study

American football has undergone many significant changes since its first recorded game between Rutgers and Princeton in 1869.[1] One change has been the growth in the importance of the forward pass to the offense. Rockne cites the year of 1912 as a turning point of the growth in popularity of football. It was during this year that the Rules Committee removed many of the restrictions against the forward pass and made more definite the penalties against interfering with the receiver. Rockne states that this increase in the popularity of football is due "entirely to the open game, to the increase of the versatility of the offense, and to the perfection of the technique of the forward pass."[2]

In order to have a functional pass attack, a good passer, pass protection, and receivers who can catch the football, are necessary.[3] Of the afore mentioned three, Fuoss feels that the receiving phase is the most important factor in a potent passing offense. Men who have been

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[1] Knute Rockne, Coaching (New York: Devin-Adair Company, 1931), pp. 59-62.

[2] Ibid., pp. 59-62.

[3] Donald E. Fuoss, "Why Passes Are Incomplete or Intercepted," Athletic Journal, 50:36, May, 1970.

associated with the coaching profession know that the passer can be great, the receiver fast, and pass protection perfect, but if the receiver cannot catch the football, the passing game fails.[4]

Much has been written about developing the quarterback. McKinley agrees that developing a quarterback is important, but states, "that a quarterback is only as good as the receivers to whom he is throwing."[5]

The ability of a receiver to catch a football depends on certain physical qualities. If a select number of such qualities could be identified, it would be of value to coaches for predicting the success of their receivers on the basis of these traits. Knowing what qualities a good pass receiver possesses would also be of value to college and professional coaches in their recruitment programs. The present study was directed toward investigating the relationship of selected anatomical measurements and motor responses to forward pass catching ability in football.

Statement of the Problem

The purpose of this investigation was to study the relationship between forward pass catching ability in football and the qualities of grip strength, hand size, kinesthetic perception, peripheral vision, depth perception, hand reaction time, hand-eye coordination, agility, and leg power.

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[4]Ibid., p. 36.

[5]Jim McKinley, "Developing the High School Receiver," Athletic Journal, 50:74-5, March, 1970.

Hypothesis

A multiple regression equation can be developed from the selected antomical measurements and motor responses that will predict success in football pass catching ability.

Limitations and Delimitations

The study was limited to the following:

1. Twenty three athletes from the South Dakota State University football team were used as subjects.

2. Only the area of catching forward passes in football was investigated.

3. The pass routes followed by the receivers were only the post in, post out, curl in, curl out, down in and down out.

4. The variables that were investigated were grip strength, hand size, kinesthetic perception, peripheral vision, depth perception, hand reaction time, hand-eye coordination, agility and leg power.

Definition of Terms

Strength. Strength was defined as the ability of a muscle or muscle group to exert maximum tension in a single contraction.[8]

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[6] Nelson L. Ross, "A Study to Determine the Effect of the Vertical Rope Climb on the Development of Grip Strength in Male High School Physical Education Students Engaged in a Six-Week Unit in Wrestling," (unpublished Master's thesis, East Tennessee State University, Johnson City, Tennessee, 1968), p. 8.

[7] Ibid., p. 2.

[8] Carl E. Willgoose, Evaluation in Health Education and Physical Education (New York-Toronto-London: The McGraw Hill Book Company, 1961), p. 118.

Kinesthetic Perception. The ability to perceive the position and movement of the body and its joints during muscular action; also referred to as muscle sense.[9]

Peripheral Vision. The ability of the individual which enables him to distinguish or discriminate objects or properties of those objects in his peripheral field of vision.

Depth Perception. The coordinated use of the two eyes results in a single mental impression. The perception of depth is the individual's ability to appreciate or discriminate a third dimension in his environment and to orient himself in relation to other people and objects within his visual field.[10]

Reaction Time. The time interval between the onset of the stimulus and the initiation of the response under the condition that the subject has been instructed to respond as rapidly as possible.

Agility. The physical ability which enables an individual to rapidly change body position and direction in a precise and rapid manner.[11]

Leg Power. Leg power is the ability of the legs to provide the inertia to propel the body through space.[12]

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[9] Barry L. Johnson and Jack K. Nelson, Practical Measurements for Evaluation in Physical Education (Minneapolis: The Burgess Publishing Company, 1970), p. 182.

[10] B. Clark and J. Warren, "Depth Perception and Interpupillary Distance as Factors in Proficiency in Ball Games," American Journal of Psychology, 47:485-7, 1935.

[11] Johnson and Nelson, op. cit., p. 100.

[12] Johnson and Nelson, op. cit., p. 80.

CHAPTER II

REVIEW OF THE LITERATURE

Considerable research has been completed in the area of testing general motor ability and ability in specific athletic activities. However, studies have been completed that touched briefly on all phases of football or upon specific areas of football potential. The review of literature chapter is concerned with those studies which deal with football ability and with those which deal specifically with the variables being investigated in this study.

Literature Related To Grip Strength And Hand Size

Hunsicker and Greey pointed out the necessity of isolating and understanding the physiology of specific muscle groups that are the object of research before the investigation is undertaken.[1] According to Thompson, the muscle groups responsible for the gripping action in the human hand are the Flexor Digitorum Sublimus and the Flexor Pollicis Longus. The Flexor Digitorum Sublimus muscle has its point of origin on the inner condyle of the humerous and coronoid process of the ulna. Split tendons attach to the sides of the middle phalanx of the four fingers as a point of insertion. This muscle is responsible for the flexion of the fingers and the wrist. The Pollicus Longus muscle has its origin on the upper two-thirds of the anterior surface of the radius, and the point of insertion is the base of the middle phalanx of

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[1]Paul Hunsicker and George Greey, "Studies in Human Strength," The Research Quarterly, 28:118, May, 1957.

the thumb. This muscle serves to flex the thumb and the wrist.[2] There are numerous muscles located in the hand which have little to do with grip strength. Stack reported their function to deal mainly with manual dexterity of the fingers and thumb.[3]

Anthropometric measurements made by Bowers have pointed to the significant relationships of hand and arm size to grip strength.[4] Everett and Sills reported that the width of the hand was more highly related to grip strength than was the length of the hand or the length of the fingers.[5] On the other hand, Scott expressed the general feeling that hand and arm size are misleading in the judgement of grip strength.[6]

According to Barrow and McGee the level of strength development possessed by individuals has long been of interest to physical educators and athletic coaches.[7] Various methods of measuring strength have been employed by researchers. Fleishman indicated

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[2]Clem W. Thompson, Kranz Manual of Kinesiology (Saint Louis: The C. V. Mosby Company, 1965), pp. 49-59.

[3]Graham H. Stack, "Muscle Function in the Fingers," Journal of Bone and Joint Surgery, 44:905, 1963

[4]Louis E. Bowers, "Investigation of the Relationship of Hand Size and Lower Arm Girths to Hand Grip Strength as Measured by Selected Hand Dynamometers," The Research Quarterly, 32:308, October, 1961.

[5]Peter Everett and Frank Sills, "The Relationship of Grip Strength to Stature, Somatotype Components, and Anthropometric Measurements of the Hand," The Research Quarterly, 42, May, 1952.

[6]M. Gladys Scott, Analysis of Human Motion (New York: Appleton - Century - Crofts, 1963), p. 244.

[7]Harold M. Barrow, and Rosemary McGee, A Practical Approach to Measurement in Physical Education (Philadelphia: Lea and Febiger, 1964), p. 115.

that testing static strength of the hand can best be done by a dynamometer which records maximum force that is opposed to a fairly immovable object.[8]

When choosing the specific type of instrument to be used in the measurement of grip strength, the question of validity and reliability must be considered. Clarke stated that the validity of instruments scientifically designed and manufactured to measure strength is high.[9] Reliability coefficients of .94 for the cable tensiometer, .91 for the Smedley adjustable dynamometer, and .89 for the Naragansett hand spring dynamometer were reported by Bowers.[10]

Hunsicker and Greey stated that body position is an important factor in strength measurement. Standing with a good base with knees slightly bent, and a comfortable feeling are recommended for grip strength testing. They also reported that the greatest grip strength measured was found with a ninety degree elbow flexion.[11]

Rasch, in discussing the number of trials to be given in grip strength testing, allowed "three squeezes" and recorded the highest score.[12] Bowers considered the average of four trials as a measure of the subject's grip strength.[13] When discussing the feasibility of using

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[8]Edwin A. Fleishman, <u>The Structure and Measurement of Physical Fitness</u> (Englewood Cliffs: Prentice-Hall Inc., 1964), p. 46-52.

[9]H. Harrison Clarke, <u>Application of Measurement to Health and Physical Education</u> (Englewood Cliffs: Prentice-Hall, Inc., 1967), p. 147.

[10]Bowers, loc. cit.

[11]Hunsicker and Greey, op. cit., p. 112

[12]Rasch, op. cit., p. 507

[13]Bowers, op. cit., p. 311.

a single trial in grip strength tests, Montpetit, Montoye, and Laiding reported one trial as compared to two trials, decreased the mean grip strength about one kilogram, which could cause a significant difference in a research study.[14]

Right and left handedness are measurable factors in grip strength. Bookwalter said that "more variation in left hand grip exists than in right hand grip". He also related that right hand grip strength is consistently greater than left hand grip strength in relation to age and weight.[15] Montpetit, Montoye, and Laiding contended that left-handed people are more likely to have dominant grip strength in their right hands and that right-handed people are likely to have dominant grip strength in their left hands. This is thought to be due to the influence of a right-handed society.[16]

According to Montpetit, Montoye, and Laiding, grip strength is highly related to other motor traits.[17] Cratty expressed that grip strength, arm speed, and reaction time are independent, and exhibit little relationship. However, he reported a "high correlation between grip strength and persistence" in performing a task.[18]

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[14] Richard R. Monpetit, Henry J. Montoye, and Lawrence Laiding, "Grip Strength of School Children, Saginaw, Michigan: 1899 and 1964," Research Quarterly, 38:234, May, 1967.

[15] Karl W. Bookwalter, "Grip Strength Norms for Males," The Research Quarterly, 21:251, October, 1950.

[16] Montpetit, Montoye, and Laiding op. cit., p. 231

[17] Ibid.

[18] Bryant J. Cratty, Movement Behavior and Motor Learning (Philadelphia: Lea and Febiger, 1967), p. 225.

Considering the relationship of grip strength in certain athletics, Pierson and O'Connell found no significant difference in the grip strength of gymnasts, football players, and basketball players.[19] Rasch and Kroll reported, that wrestlers do not have stronger hand grips when compared with participants in other sports. The authors did state, however, that strength was significantly superior in successful wrestlers as compared with unsuccessful wrestlers.[20]

Bowers concluded of her study of the relationship of anthropometric measurements and grip strength measurement: "Through the correlational analysis it was evident that weight, anthropometric measurement of the hand, height, and mesomorphy, were the most influential variables in the prediction of hand grip strength".[21]

Literature Related to Kinesthetic Perception

Phillips states that "efficient kinesthesis is essential to defined motor performance".[22] Roloff also considers kinesthetic sense to be one of the factors contributing to the ability of an individual in learning an activity or a skill.[23]

Previous work done by Honzik with rats shows that the kinesthetic sense is important in at least some types of learning. He points

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[19]William R. Pierson and Eugene R. O'Connell, "Age, Height, Weight, and Grip Strength," The Research Quarterly, 33:442, May, 1962.

[20]Rasch and Kroll, loc. cit.

[21]Bowers, op. cit., p. 161.

[22]B. E. Phillips, "Kinesthesis and Its Relation to Learning Motor Skills," Research Quarterly, 12:571, October, 1941.

[23]Louise L. Roloff, "Kinesthesis in Relation to Motor Learning," Research Quarterly, 24:210, May, 1953.

out that where by itself kinesthesis may be relatively unimportant to maze learning, it seems essential to the smooth flow of movements and assumes this function only in conjunction with other cases of stimuli and only after learning has begun on the basis of other stimuli. However, Honzik concluded in his study, that not only is kinesthesis unnecessary both to learning and to the perfected habit, learning on the basis of kinesthesis alone is impossible.[24]

According to Roloff, kinesthesis is not a single sense but a composite, since a number of sense organs contribute to kinesthetic perception. Four main types of sensory endings or receptors contribute to the kinesthetic sense. They are the muscle spindles found in the muscles themselves, the Golgi corpuscles in the tendons, the Paciniun corpuscles in the tendons and joints, and the free nerve endings between muscle fibers in tendons, fasia, and joints. These sensory endings are stimulated by stretch or tension and by pressure. They are called proprioceptors. Kinesthetic impressions from these proprioceptors acquaint us with the position of our arms and legs with respect to the rest of the body. Roloff states that "without such information which is relayed to the central nervous system there could be no coordinated and adjusted movements".[25]

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[24]C. H. Honzik, "Role of Kinesthesis in Maze Learning" Science, 22:373, 1936.

[25]Louise L. Roloff, "Kinesthesis in Relation to the Learning of Selected Motor Skills," (Unpublished Doctor of Philosophy Dissertation, Iowa State University, Ames, 1952), p. 19.

Phillips attempted to investigate the relationship between kinesthesis and early performance in two perceptuo-motor skills. He gave ten kinesthetic tests to a group of college men. The two perceptuo-motor skills were playing a ten-foot putt and playing a golf ball for accuracy at a target point eighteen feet from the tee. Phillips found a low, positive relationship between certain phases of kinesthesis and success in performance during the early stages of acquiring the skills. However, with some phases of kinesthesis he found zero and negative relationships.[26]

Young gave nineteen kinesthetic tests to a group of college women. She suggested that three of these tests might be used as a battery of tests for additional research in the study of kinesthesis. These three items gave a multiple correlation of .984 when correlated with the score on all nineteen tests. The tests recommended were Arm Raising, Leg Raising, and Balance Stick.[27]

In addition to other tests Fisher used the Young Battery of Kinesthesis Tests in a study made with high school girls. She found a low, but positive, correlation between the kinesthesis tests and both general motor ability and general motor capacity. The correlations were too low to be used for prediction purposes. She recommended using two of the Young tests, Arm Raising and Balance Stick, and a target pointing tests.[28]

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[26]Phillips, op. cit., p. 571.

[27]Olive G. Young, "A Study of Kinesthesis in Relation to Selected Movements," Research Quarterly, 16:227-87, 1945.

[28]Rosemary Fisher, "A Study of Kinesthesis in Selected Motor Movements," (Unpublished Master's thesis, State University of Iowa, Ames, 1945), p. 31.

The "Victory Through Fitness" Workshop suggested four tests which might be used to measure kinesthetic perception. Those tests were called Reproducing Foot Position, Walking on a Path, Pointing to a Target, and Throwing at a Target.[29] The Workshop reported, along with most writers, that kinesthetic perception was important in the ability to perform motor skills but that very little was known about measuring it.

Scott tested 104 college women on twelve different kinesthetic tests.[30] Included in these tests were those recommended by Young, Fisher, the "Victory Through Fitness" Workshop, and LaFuze.[31] The reliabilities and validities of eight of these tests were high enough so that the eight tests could be recommended for further study.

Many writers refer to the "feel" of movement. Billig says:

> We are agreed that good body mechanics does not depend merely on good alignment but on the balance of the various segments. This in turn depends upon the degree of mobility of these segments. But there is still another important element: the feeling that we are achieving, balance. Through this 'feeling' we sense whether we are in balance or not. This aptitude is scientifically referred to as the kinesthetic or proprioceptive sense.[32]

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[29] Victory Through Fitness, National Association of Physical Education for College Women, Workshop, University of Wisconsin, Madison, Wisconsin, (June, 1943), p. 46.

[30] Gladys M. Scott, Analysis of Human Motion (New York: F. S. Crofts and Co., 1942), p. 101.

[31] Ibid.

[32] Harvey E. Billig, Jr., and Evelyn Loewendahl, Mobilization of the Human Body (Stanford California: The Stanford University Press, 1949), pp. 47-49.

Literature Related to Peripheral Vision

In a study of visual perception, Vernon stated: "Form perception is so dim and blurred in the periphery that moving objects appear with relatively greater clarity than do stationary ones." She noted that the impression of movement as such, without perception of the moving object, is a characteristic experience in peripheral vision. "Such a movement," stated Vernon, "catches our attention with extreme rapidity and we immediately respond by turning the eyes and the head in order to focus the eyes on it and see it clearly."[33]

It has been established that the visual field extends almost 180 degrees horizontally and 130 degrees vertically.[34] When viewed with binocular vision, the clarity with which parts of the visual field are seen depends upon the direction of sight. If an object is focused directly upon the fovea, clearest vision will occur. An object is seen with less acuity the more it is viewed in the periphery.[35]

Sherman's study eliminated verbal directions and greatly limited the visual perception of students in a beginning drawing class. His students sat in total darkness and then saw a lantern slide model flashed on a large screen. The model was visible for but one-tenth of a second. Then within one and one-half minutes the students were

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[33]Magadalen D. Vernon, A Further Study of Visual Perception (London: Cambridge University Press, 1952), p. 163.

[34]William Howell, A Testbook of Physiology John Fulton, Editor (Philadelphia and London: W.B. Saunders Company, 1949), pp. 382-298.

[35]James Gallagher, "A Study of Changes in Eye Movement and Visual Focus During the Learning of Juggling" (Unpublished Master's thesis, Pennsylvania State University, State College, 1961), p. 21.

required to reproduce the model. Sherman stated that students exposed to this technique, which prevented visual attention to movements, learned to reproduce drawings equally as well and in a much shorter time than students instructed by conventional methods.[36]

Sherman also added an implication of his study for training athletes. He stated:

> Most sports--notably football, basketball, baseball, hockey, soccer, tennis and handball--require a high degree of visual skill if competency is to be achieved in the sport. The good player must be able to see the whole visual field in which the play is emerging and he must see most of it as peripheral vision, out of the corner of his eye. The training in drawing increased the field of peripheral vision of students in the demonstration by 86 percent and increased the accuracy of depth judgments in the periphery by 400 percent.[37]

Sherman also claimed that peripheral vision was more important than central vision because peripheral vision was sensitive to the more gross aspects of visual cues, namely position and mass, whereas central vision concerns itself more with identification, analysis and detail, thus is more critical and tends to lead to reflection and association, not to immediate action.[38]

Concerning vision in certain sports and motor skills, Gallagher states that it is becoming more and more apparent that a keen, nearly-perfect, natural vision is not as important a factor in motor learning

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[36]Hoyt Sherman, Drawing by Seeing (New York: Hinds, Hayden and Eldridg, 1947), pp. 1-77.

[37]Ibid., pp. 56-57.

[38]Hoyt Sherman, "Aspects of Visual Perception and Their Relationships to Motor Activity," 53rd Annual Proceedings, College Physical Education Association (Washington, D. C.: College Physical Education Association, 1950), pp. 8-17.

as was once believed. Gallagher points to the fact that there are a good number of successful athletes in both the collegiate and professional ranks who wear corrective lenses.[39] Winograd also found that visual acuity and various measures of eye-functioning had no significant relationship to the success factor in baseball.[40]

Barclay, in a study to ascertain the relation that exists between vision and certain athletic skills, found no significant relationships between various eye-efficiency scores and scoring success in basketball competition. Barclay indicated that the common expression, "He has a good eye," cannot be statistically supported.[41]

On the other hand, Hobson and Henderson studied the relationship between success in playing basketball and the size of the visual field. They found that the best pass-concealer according to coaches' ratings had a visual field on the horizontal plane fifteen degrees larger than the other players.[42] Stroup reported that he found a substantial difference among the range of the field of motion perception of basketball players and non-basketball players, and proposed that the

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[39] James D. Gallagher, op. cit., p. 16.

[40] Samuel Winograd, "The Relationship of Timing and Vision to Baseball Performance," Research Quarterly of the American Association for Health, Physical Education and Recreation, 13:481-494, December, 1942.

[41] George D. Barclay, "The Relationship Between Efficient Vision and Certain Sensory Motor Skills," (Unpublished Doctoral dissertation, New York University, New York City, 1938), pp. 1-87.

[42] Robert Hobson and M. T. Henderson, "A Preliminary Study of the Visual Field in Athletics," Iowa Academy of Sciences, 48:331, 1941.

range of the field is a great factor contributing to basketball ability.[43]

Concerning testing of perception in the peripheral field of vision, Cobb states that, "testing this ability is a highly subjective process". He draws this conclusion from the fact that the tester must depend upon the accurate description of the subject's sensations as reported by the subject himself. The literature has pointed out that there is a definite lack of testing equipment in this area. Attempts have been made to devise new equipment and methods, but essentially they are all similar in nature. A description of Low's apparatus would provide knowledge of the basic pattern of testing that has been employed through the years. It consisted of a flat half-circle with a radius of about eighteen inches which was placed on the horizontal eye-level of the subject being tested. The subject's head was immobilized and the eye being tested was fixed on an object directly ahead of the edge of the platform. An apparatus much like a flashlight was used to illuminate a Landolt Ring which is a circle with a minute break in its continuity. The position of the break was moved to one of four places--right, left, top or bottom--and the size of the break was altered. The object was illuminated for .5 second and exposed at various angles in the peripheral field which was denoted on the platform.[44] The subject's

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[43] Francis Stroup, "Relationship Between Measurements of Field of Motor Perception and Basketball Ability in College Men," Research Quarterly 28:75, March, 1957.

[44] Robert A. Cobb, "A Comparative Study of Color Recognition in the Peripheral Field of Vision of Participants in Selected Sports," (Unpublished Master's thesis, Springfield College, Springfield, 1967) p. 52-3.

ability to accurately perceive the position of the break at the various angles was considered to be indicative of his peripheral visual acuity.[45]

Literature Related to Depth Perception

The first trace of interest in this aspect of visual perception goes back to the Greeks at the time of Ptolemy (150 A.D.), who was the first to record the frequent debates regarding the apparent size of the moon.[46] The controversy centering around the size and position of the moon in relation to man, the observer, was continued over many centuries and the literature on the topic includes contributions by such people as Kepler (1640), De Cartes (1644), Berkely (1709), Lambert (1765), and Helmholtz (1866). Even in this present age there is considerable room left for exploration and argument as to the nature and influence of man's visual perceptions, including depth.[48]

It was Leonardo da Vinci who described the mechanism of perceived depth to everyone's satisfaction. Da Vinci's account of the mechanism of depth perception almost exactly parallels the modern explanations of binocular parallel (depth perception), which in essence describes how the two eyes together gain an impression of depth.[49]

Although Dove laid the foundations for the development of

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[45] Frank N. Low, "Some Characteristics of Peripheral Visual Performance," American Journal of Physiology, 146:573-584, July, 1946.

[46] Duke-Elder and Sir W. Stewart, A Textbook of Ophthalmology I (St. Louis: The C. V. Mosby Company, 1940, pp. 1136.

[47] Ibid., p. 1070.

[48] Harry Asher, Experiments in Seeing (New York: Basic Books, Inc. 1961), p. 271.

[49] Stewart, op. cit., p. 1077.

instruments designed to simulate depth, it was Helmholtz who is given the credit for being the first man to actually measure stereoscopic acuity in 1866.[49] His device consisted of three vertical needles suspended against a plain background, viewed under constant illumination. The subject was seated at a distance of thirty-four millimeters from the test device. Hemholtz estimated that the subject could differentiate between the needle positions when they were separated by .25 millimeters using both eyes but not with a single eye. He established this distance as the minimum threshold for binocular depth perception. This distance has been estimated recently as being much too great.[50]

Sir Brooksbank James of England modified Helmholtz's three needle apparatus by introducing a device which contained only two rods.[51] The apparatus was painted black and had two white poles in the center which could be moved by the examiner.[52] A further modification and redesign of this test apparatus was undertaken by Howard 1919. It is the Howard instrument which is still in use today.[53]

Basically Howard's apparatus consisted of two rods separated by six centimeters. The test area of the device was viewed through an opening in the front of a box by a subject seated at a distance of six

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[49]Stewart, op. cit., p. 1077.

[50]Ibid., p. 1077.

[51]G. I. Brooksbank James, "On the Measurement of the Stereoscopic Visual Acuity," Lancet, 1:1763-1766, June, 1908.

[52]H. W. Seiger, "Variation is Illumination of the Depth Perception Apparatus," Journal of Aviation Medicine, 15:401-403, December, 1944.

[53]Harvey J. Howard, "A Test for the Judgement of Distance," American Journal of Ophthalmology, 2:656-675, September, 1919.

meters. The inside of the box was painted white instead of the black employed by James. The anterior wall was left black to facilitate viewing the rods. The test area, instead of using natural illumination, was provided with light from a seventy-five watt bulb placed over the center of the test area.[54]

In administering the test, Howard suggests that the rods be briefly exposed by a shutter device. The subject judged the designated rod as being closer to him or farther away from him than the stationary left rod.[55] A description of the final modification of the Howard apparatus, which is in current use today, can be found in any psychological handbook which discusses perception and test of depth. It was with the development of the Howard apparatus that testing the range of an individual's stereoscopic perception came into practical use. Since 1919, both military and automotive personnel have used vision testing extensively to ascertain the depth thresholds of pilots and drivers.[56]

Visual discrimination of depth is a highly complex process because there are so many factors which can influence the individual's final judgement. Sloan and Altman proposed that all tests of depth might be valid measures of different aspects of the visual situation. If this were so, then each test of depth may be measuring a different component of depth perception and researchers may find that depth perception is not a simple visual ability but a highly complex and composite

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[54]Siger, op. cit., pp. 401-403.

[55]Ibid., p. 403.

[56]Patricia D. Mail, "The Influence of Binocular Depth Perception in the Learning of a Motor Skill" (Unpublished Master's thesis, Smith College, June, 1965), p. 10.

integration of many factors.[57]

According to Mail the analysis of and reaction to visual cues is important in a wide variety of gross motor skills.[58] The ability to perceive depth has been claimed to be important to the individual who wishes to succeed in his chosen activity. McCloy listed depth perception as one of the probable requisites in motor educability. As McCloy stated:

> It is highly probable that in many athletic sports depth perception is a factor of importance. The ability to field a fly ball, to intercept a hard driven ground ball in baseball, to intercept and catch a long pass in basketball, to shoot goals, and to execute many other performances would seem to be related to depth perception.[59]

In surveying the literature, this investigator found few studies which substantiate the importance of depth perception as a factor in successful performance. Mail states in her study that, "In spite of this paucity, the concept of the 'good eye' is still accepted as a requisite for success in such games as tennis, polo, cricket, basketball, baseball, football, golf, bowling, and related sports". She goes on to say that, "In most games where the participant is required to meet or hit a fast-moving ball with precision and accuracy, the 'eye' factor is almost always assumed to be necessary and immediate".[60]

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[57]Louise L. Sloan and Adelaide Altman, "Factors Involved in Several Tests of Binocular Depth Perception," American Medical Association Archives of Ophthalmology, 52:524-543, October, 1954.

[58]Mail, op. cit., p. 14.

[59]Charles H. McCloy and Norma D. Young, Tests and Measurements in Health and Physical Education (New York: Appleton-Century-Crofts, Inc., 1954), pp. 497.

[60]Mail, op. cit., p. 15.

Banister and Blackburen in 1931 suggested, but did not experimentally establish, depth perception as a factor for success in batting a ball. They added the proposal that the concept of the "good eye" may not really be an eye factor at all, but rather some innate visuo-motor coordination coupled with learning training and/or experience.[61]

Winograd in 1942 showed that superior athletes demonstrated vision superior to that of non-athletes. He also found reliable differences in visual scores between varsity baseball players, non-athletes, and rejected team candidates in the area of depth perception and binocular visual efficiency, as well as among other factors.[62]

Montebello in 1953 showed that baseball players demonstrated a greater advantage in stereoscopic sensitivity than did non-athletes. He believes that the ability to recognize changes in speed of pitched balls seemed to be a skill demanding great need for stereoscopic vision.[63]

Miller in 1960 noted that in many instances tests demonstrate that visual excellence has not been shown to be related to actual performance in sports. She also demonstrated in her study that skillful players exhibit superior visual capacities over unskilled

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[61] H. Banister and J. H. Blackburn, "An Eye Factor Affecting Proficiency at Ball Games," British Journal of Psychology, 21:382-384, April, 1931.

[62] Samuel Winograd, "Relationship of Timing and Vision to Baseball Performance," Research Quarterly of the American Association for Health, Physical Education, and Recreation, 13:481-493, December, 1942.

[63] Robert A. Montebello, "The Role of Stereoscopic Vision in Some Aspects of Baseball Playing Ability," (Unpublished Master's thesis, Ohio State University, Columbus, 1953), p. 53-54.

players in the same sport.[64]

In 1943 Dickson studied depth perception in relation to basketball shooting ability. He felt that "the perception of distance is probably the most important factor in the success of basketball goal shooting". Although he devised several new and unique tests of depth perception for his study, he was not able to establish any significant results which would indicate that depth perception could be used as a predictive factor in basketball shooting ability. He concluded that "the tests of depth perception do not measure the factors of depth perception requisite to basket-shooting ability". Dickson also expressed the belief that many studies of depth perception had failed to take into account kinesthetic sense of the part of the participant.[65]

In 1935 Clark and Warren found no significant relationship between interpupillary distance and depth perception, and that the depth perception of athletes did not differ from that of the controls. They concluded that "either depth perception as measured by the Howard-Dolman test is unimportant in ball games . . ., or the test does not give an accurate measure of depth perception."[66]

In 1952 at the Olympic Games in Helsinki, Finland, Graybiel and

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[64]Donna Mae Miller, "The Relationship between Some Visual Perceptual Factors and the Degree of Success Realized by Sports Performers" (Unpublished Doctoral dissertation, University of Southern California, Los Angeles, 1960).

[65]Joseph F. Dickson, "The Relationship of Depth Perception to Goal Shooting in Basketball," (Unpublished Doctoral dissertation, State University of Iowa, Iowa City, 1934), pp. 11-12.

[66]B. Clark and N. Warren, "Depth Perception and Interpupillary Distance as Factors in Proficiency in Ball Games," American Journal of Psychology, 47:485-487, July, 1935.

others met with Russian physicians and athletes. One of the topics was the relationship of vision to exercise and training. Using a device similar to the Howard-Dolman apparatus, the Russians found that tennis players exhibited a better depth perception than did football players. The study concluded that "as a group, more skillful players perceived depth more accurately".[67]

Finally, in 1956 Olsen, using a Howard-Dolman apparatus, reported significant differences in depth perception among athletes, intermediate athletes, and non-athletes. Both the athletes and the intermediate athletes possessed much better depth perception than did non-athletes. Olsen felt that "It would seem from the few studies investigating depth perception in athletics, that little if any relationship exists between the ability to discriminate distance of objects and motor performance."[68] In light of the evidence from the literature, this statement is open to debate. Rather, it would appear that there is simply a great deal more to learn about the role of depth perception in motor performance.

Literature Related to Hand Reaction Time

The first attempt at reaction-time experimenting took place more than one-hundred years ago by a famous physiologist named Helmholtz.[69]

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[67] A. Graybiel, Ernest Jokl, and Claude Trapp, "Russian Studies of Vision in Relation to Physical Activity and Sports," Research Quarterly of the American Association for Health, Physical Education and Recreation, 26:603-605, December, 1955.

[68] Einar A. Olsen, Relationship Between Psychological Capacities and Success in College Athletics," Research Quarterly of the American Asssociation for Health, Physical Education and Recreation, 27:79-89, March, 1956.

[69] Robert S. Woodworth and Harold Scholosberg, Experimental Psychology (New York: Henry Holt and Company, Inc. 1954), p. 948.

In 1850 he succeeded in measuring the speed of conduction in a frog's motor nerve and found as a result that the farther the nerve impulse had to traverse the longer the latency period would be.

Keller in an investigation dealing with total body reaction times of 359 athletes and 275 non-athletes from two high schools and a university, found a positive relationship between the ability to move the body quickly and successfully in athletic activities. He also found that those athletes participating in baseball, basketball, football, and track had significantly better reaction time than those participating in gymnastics, wrestling and swimming.[70]

Beise and Peasley conducted a study of arm and foot reaction time involving 47 skilled women performers in golf, tennis, and archery and 14 unskilled performers far below the average in physical performance. They found a significant difference in large muscle reaction time and speed of movement in favor of the skilled group.[71]

Westerland and Tuttle in their study of reaction time in track, using a finger response testing device came to the following conclusion: "There is a high degree of relationship between speed in running seventy-five yards and reaction, the coefficient being .863".[72]

Lautenbach and Tuttle in their study proved that there is a

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[70]L. B. Keller, "The Reaction of Quickness of Bodily Movement to Success in Athletics," Research Quarterly, 13:146-155, May, 1942.

[71]Dorothy Beise and Virginia Peasley, "The Relation of Reaction Time, Speed and Agility of Big Muscle Groups to Certain Sports Skills," Research Quarterly, 8:133-142, March, 1937.

[72]J. H. Westerland and W. W. Tuttle, "Relationship Between Running Events and Reaction Time," Research Quarterly, 2:95-100, October, 1931.

significant relationship between voluntary response as measured by reaction time and involuntary response as measured by reflex time in the same events.[73] Measuring the reflex time of the knee jerk they came to the following conclusion: "There is a high degree of relationship between reflex time and speed in sprinting, the coefficient of correlation is .815".[74] Burley reports a significantly faster reaction time among baseball and basketball players than among football lineman and backs.[75]

Burpee and Stroll state:

> In sports we need to know not only how quickly an athlete can react by pressing a key but also with what speed and accuracy he can move six to ten feet in catching a ball, tagging out a player, hitting a puck, tennis ball, hand ball, or volley ball.[76]

They continue:

> Although several splendid attempts have been made to isolate the factors involved in attaining success in physical education activities, few if any have attempted to measure the importance of reaction time. This is largely because suitable apparatus has not usually been available.[77]

Patrick states that a player needs quick reaction time to meet opportune situations. He further states, "Quick reaction time is

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[73] J. H. Westerlund and W. W. Tuttle, "Relationship Between Reflex Time and Running Events in Track," <u>Research Quarterly</u>, 3:138-143, October, 1932.

[74] Ibid., p. 139.

[75] L. R. Burley, "A Study of the Reaction Time of Physically Trained Men," <u>Research Quarterly</u>, 8:133-142, March, 1937.

[76] R. H. Burpee and W. Stroll, "Measuring Reaction Time of Athletes," <u>Research Quarterly</u>, 7:110-118, March, 1936.

[77] Ibid., pp. 116-118.

considered to be an important earmark of a good athlete".[78] Erickson relates, "The relationship between reaction time and success in athletes is a point of controversy and is not definite, although some studies indicate a positive relationship between the two."[79]

Literature Related to Hand-Eye Coordination

McCloy, as early as 1939, stressed the importance of hand-eye coordination by suggesting that it should be an important factor in the testing program,[80] and, with the other fifteen components of motor educability, should be tested in as pure a form as possible and explored at each important age level.[81] He added, however, that the tests for hand-eye coordination which had been devised had not been validated in the field of physical education.[82]

Ross in 1961 found in the physical education literature no standardized tests specifically for measuring hand-eye coordination, so she devised four tests which involve the manipulation of an object. Her four tasks, a ring toss, a ball bounce (below the waist), a wall rebound-catch, (above the waist) and a target throw (using bean bags), all received high reliability scores in a pilot study using the odd-even method

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[78] J. Patrick, "Quick Reaction Time Means Athletic Ability," Athletic Journal, 10:30-68, September, 1949.

[79] C. E. Erickson, "A Study to Determine the Relationships Between Certain Psychological Capacities and Success in Coaching Football" (Unpublished Doctoral dissertation, Boston University, Boston, 1953), pp. 44-45.

[80] C. H. McCloy, Tests and Measurements in Health and Physical Education (New York: Harper & Row, 1963), pp. 466.

[81] C. H. McCloy, "A Preliminary Study of Factors in Motor Educability," Research Quarterly, 11:28-39, May, 1940.

[82] McCloy, op. cit., pp. 466.

with twenty-four subjects, grouped into eight categories each from the second, fourth, and sixth grades.[83]

Wilberg in 1960 divided hand-eye coordination into two distinct events: 1) the initial visual location of the stimulus, and 2) the motor reaction in response to the situation. In attempting to find the relation of initial visual location of the original stimulus and the motor response when the number of alternatives in the visual field increased, he found that subjects made generally two types of errors: 1) in locating the stimulus object correctly, and 2) incorrect motor response, which was generally due either to loss of perceptual information or incorrect use of the information. The motor response was more often incorrect than the initial visual location of the object.[84]

Davis and Lawther noted that highly skilled motor performances seem to involve a great deal of automatic habit performance. In their <u>Successful Teaching of Physical Education</u>, they stated:

> The sports and games themselves demand almost constant variation in skill sequences and combination. The performer keeps his attention focused on the perception of cues for the next appropriate behavior while he is responding automatically to cues already received.[85]

His batting pattern adjusts while he focuses intently on the rapidly

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[83] Mattie E. Ross, "The Relationship of Eye-Hand Coordination Skills and Visual Perception Skills in Children," (Unpublished Doctoral dissertation, Ohio State University, Columbus, 1961), pp. 45-6.

[84] Robert B. Wilberg, "Hand-Eye Coordination Determined by the Variability in Visual and Motor Errors," (Unpublished Master's thesis, University of Oregon, Eugene, 1960), p. 33.

[85] Elwood C. Davis and John D. Lawther, <u>Successful Teaching in Physical Education</u> (New York: Prentice Hall Incorporated, 1948), p. 338.

approaching ball. He dribbles the basketball and changes rate or direction while he is centering his attention on teammates down the floor ahead of him, estimating their speeds and their distances from opponents. His hands move into position while he focuses intently on the rapidly approaching football.[86]

On the subject, Parker stated:

> Ordinarily the learner's attention should be centered on the objective result of the movement, not on the movement itself. An elaborate analysis of the movement in terms of anatomy and operation of the parts of the body concerned is generally a waste of time and often prevents the attaining of the best results.[87]

Swift studied the acquisition of skill in ball tossing. He used six subjects in the experiment. Swift discovered that while in the act of tossing the balls, the eyes and attention of the subjects appeared to be on the balls in the air. He concluded that both the catching and the tossing were executed by the hand alone, for the most part practically outside of the field of vision and of attention. Swift further suggested that the method of execution was discovered and improved without conscious effort in the beginning.[88] Lawther pointed out that

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[86] Ibid., p. 338.

[87] Samuel C. Parker, Methods of Teaching in High School (Boston: Ginn Company, 1920), p. 119.

[88] Edgar James Swift, "Studies in the Psychology and Physiology of Learning," American Journal of Psychology, 14:201-251, April, 1903.

"automatic action demands learning not to focus on parts; it demands continuity of action."[89]

McDonald wrote that the beginner must learn which clues to respond to, and which to ignore. He noted as a skilled performer learns the cues to respond to, he also learns to respond to fewer cues. A skilled typist, for example, can place his fingers in the correct positions and move them without looking at his hands or at the letters that he is typing.[90]

The few measures of hand-eye coordination that have been devised have been done in the field of psychology. One of the very first to experiment with test instruments was W. R. Miles with his Pursuit Pendulum in 1920[91] and the Pursuitmeter in 1921.[92] (The pendulum released water at the height of every arc. The subject attempted to catch the water released in a small cup marked to measure the amount caught.) The Pursuitmeter was an electrical instrument with a moving target which changed direction, and thus required great accuracy on the part of the subject. This instrument has since been modified and improved.

The Pursuit Pendulum was the inspiration for the machine designed and built by Wilhelmine Koerth in cooperation with Seashore. Now designated the "Koerth Pursuitmeter", it was built "to measure

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[89]John D. Lawther, "The Development of Motor Skills and Knowledge" Education Psychology Charles Skinner editor (New York: Prentice Hall Incorporated, 1945), p. 148.

[90]Frederick J. McDonald, Educational Psychology (San Francisco: Wadsworth Publishing Company, Incorporated, 1959), p. 312.

[91]Walter R. Miles, "A Pursuit Pendulum," Psychological Review 27:361-376, September, 1920.

[92]Walter R. Miles, "Pursuitmeter," Journal of Experimental Psychology, 4:77-105, April, 1921.

capacity for the acquisition of skill in coordination of eye and hand". It followed Miles' principle of using a moving stimulus following a fixed path at constant speed. This Koerth Pursuitmeter is the basis for many of the pursuit rotors in use today.[93]

Literature Related to Agility

A review of the literature indicates that the two factors most often stated in relation to agility are: 1) control of the body or parts of the body, and 2) efficient and rapid movements or changes of position. Lee and Wagner report that agility may be developed through participation in activities which demand a quick type of motor response, such as squat thrusts, rope jumping, and squat jumps. They also say that vaulting over low obstacles, stunts and tumbling, and games like basketball, are other excellent activities for the development of agility.[94]

In a study by Beise and Peaseley on the relationship of reaction time, speed, and agility of big muscle groups to certain sports skills (tennis, golf, archery), it was concluded that the above-named components seem to be fundamental to skill in certain sports activities. They further concluded that training for seven weeks in the sports mentioned above did not significantly affect the original scores on the reaction time, speed, and agility tests.[95]

In a more recent study by Bennett in which the Burpee Test was

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[93]Wilhelmine Koerth, "A Pursuit Apparatus. Eye-Hand Coordination," Psychological Monographs, 31:288-292, 1922.

[94]Mable Lee and Miriam W. Wasner, Fundamental of Body Mechanics and Conditioning (philadelphia: W. B. Saunders Company, 1949), p. 61.

[95]Dorothy Beise and Virginia Peaseley, op. cit., pp. 133-142.

used, she found swimming, basketball, and modern dance were superior to folk dance in developing agility, but that there was no significant difference in effectiveness among the three sport activities in this respect.[96]

In discussing football as a game of speed, agility, reaction and strength, Tips stated that, ". . . in our own situation, we think that if we have to give up something we will give up strength for speed and agility."[97]

The search of the related literature indicated that tests of agility are categorized as either tests which include running or those which do not involve running. The tests which involve running were observed to be either the shuttle or obstacle type run.[98]

Ilsley tested agility incorporating pull-ups, vaulting, broad jumping, and a one-hundred yard sprint.[99] Gates and Sheffield administered three batteries of tests which primarily involved the change of direction factor to determine the ability of seventh, eighth, and ninth grade boys. Obstacle runs, shuttle runs, and side stepping drills were

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[96]C. Bennett, "Relative Contribution of Modern Dance, Folk Dance, Basketball, and Swimming to Motor Abilities of College Women," Research Quarterly, 27:253-262, October, 1956.

[97]Tom Tips, "Defensive Line Drills," Proceedings of the Thirty-Eighth Annual Meeting, American Football Coaches Association, (January 9-11, 1961), p. 94.

[98]Donald D. Gates and R. P. Sheffield, "Tests of Change of Direction as Measurements of Different Kinds of Motor Ability in Boys of the Seventh, Eighth, and Ninth Grades," Research Quarterly, 11:140-147. October, 1940.

[99]Morrill L. Ilsley, "Study of Correlation in Measurement of Men Students at Pomona College," Research Quarterly, 11:116, March, 1940.

incorporated into their test batteries.[100]

The apparent complex nature of agility makes it difficult to measure because most measurements are concerned with one basic type of change of direction.[101] Cumbee, in a factorial analysis of agility tests, discriminates between change of direction factors as she states:

> Two of the variables appearing on this factor, the Burpee and the short potato race, are what physical educators have called "agility" measures. They involve a total body "Quick change of direction". The present writer is hesitant to call this a quick change of direction factor because of the low correlation of the Burpee with this factor . . . . The use of more tests as the side-step, zig-zag and dodging run might give more evidence that the type of ability involved in this factor is a quick change of direction.[102]

Hilsendager, Strow and Ackerman also found that the tests created to test agility do not all test the same factor. They recommend the development of additional agility tests.[103]

Selected agility tests have been found to correlate highly with sports ability. The Brace Test and the Iowa Revision of the Brace Test were reported by McCloy and Young to be highly correlated with sports ability.[104] The Cozens Dodge Run, because of its emphasis on a change

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[100] Gates and Sheffield, loc. cit.

[101] Richard C. Smith, Jr., "The Effects of Selected Drills Upon The Improvement of Agility," (Unpublished Master of Science Thesis, South Dakota State University, Brookings, South Dakota, 1969), p. 12.

[102] Frances Z. Cumbee, "Factorial Analysis of Motor Coordination," Research Quarterly, 25:418, December, 1954.

[103] Donald R. Hilsendager, Malcolm H. Strow, and Kenneth J. Ackerman, "Comparison of Speed, Strength, and Agility Exercises in the Development of Agility", Research Quarterly, 40:75, March, 1969.

[104] McCloy and Young, op. cit., pp. 85-90.

of direction factor, contributed to sports ability.[105] The Illinois Agility Run was found by Hilsendager, Strow, and Ackerman to be related to sports ability.[106]

Literature Related to the Vertical Jump

Almost all tests of motor ability include the vertical jump in one variation or another. It is the single test more often used by coaches in determining general athletic ability.[107]

Bovards and Cozens, in studying the relationship between the Sargent Jump and various athletic tests, found that a group of college students exhibiting a high degree of athletic heterogeneity showed a correlation of .55 between the jump and four athletic events. The events were the running high jump, the standing broad jump, the rope-climb for speed, and the 980 yard run. A very small correlation between the Sargent Jump and height and weight was ascertained.[108]

McCloy in 1932 found experimental evidence for the validity of the Sargent Jump and stated that it was the best single test available for predicting power.[109]

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[105] Theresa Anderson and C. H. McCloy, "The Measurement of Sports Ability in High School Girls," Research Quarterly, 18:1-11, March, 1947.

[106] Hilsendager, Strow and Ackerman, op. cit., p. 74.

[107] Charles Harold McCloy, Tests and Measurements in Health and Physical Education (New York: Appleton Century Crafts, Inc., 1954), p. 142.

[108] J. F. Bovards and F. W. Cozens, "The Leap-Meter", University of Oregon Publication, Eugene, Oregon, Physical Education Series, No. 2, 1928.

[109] Franklin Henry, "The Practice and Fatigue Effects in the Sargent Jump," Research Quarterly, 13:16, March, 1942.

Van Dalen stated that track and field events are known as power events and include running, throwing, and jumping, all of which require maximum contraction in the minimum amount of time. He, therefore, assumes that there may be a high relationship between the Sargent Jump and basketball ability because basketball consists chiefly of running, jumping, and throwing.[110]

[110] Deobald Van Dalen, "New Studies in the Sargent Jump," Research Quarterly, 2:113, May, 1940.

CHAPTER III

METHODS AND PROCEDURES

The selection of the college subjects, methods of securing data and measuring the variables of grip strength, hand size, kinesthetic perception, peripheral vision, depth perception, hand reaction time, hand-eye coordination, agility, and leg power are presented in this chapter.

Source of the Data

Twenty-three subjects were selected by the head football coach at South Dakota State University. He was asked to select the subjects so as to give a general cross section of positions played and ability in football pass catching. A cross section of positions was essential in order to have subjects with varying degrees of pass catching ability. All subjects were members of the varsity football squad at South Dakota State University. Table I indicates selected characteristics of the subjects. Two of South Dakota State's quarterbacks and one graduate assistant with previous quarterbacking experience, were used as passers in this study.

Collection of the Data for the Independent Variables

The data collected were the players scores in the testing areas of grip strength, hand size, kinesthetic perception, peripheral vision, depth perception, hand reaction time, hand-eye coordination, agility and leg power. The variables were selected on the basis of their possible

TABLE I

CHARACTERISTICS OF THE TWENTY-THREE SUBJECTS

Subject		Age	Ht.	Wt.	Playing Position
1.	PA	18	6'2-1/2"	225	Offensive Guard
2.	DB	19	5'9"	179	Defensive Corner Back
3.	WB	19	6'1-3/4"	208	Tight End
4.	CC	18	6'3"	190	Free Safety
5.	JD	19	5'11"	188	Offensive Half Back
6.	MD	18	5'11"	190	Offensive Half Back
7.	RH	18	5'10-1/2"	175	Line Backer
8.	BH	20	6'3"	230	Defensive Tackle
9.	PH	19	6'1-1/2"	180	Split End
10.	DJ	18	5'11-1/2"	195	Strong Safety
11.	MK	20	6'0"	195	Defensive Corner Back
12.	MN	18	5'7"	193	Line Backer
13.	PN	19	6'1/2"	200	Offensive Guard
14.	BP	22	6'3"	210	Split End
15.	RR	18	5'10"	195	Line Backer
16.	RR	20	6'3-1/2"	200	Split End
17.	MS	19	5'11-1/2"	200	Offensive Half Back
18.	BJ	19	5'9 "	182	Defensive Corner Back
19.	PT	19	6'1"	190	Line Backer
20.	LT	18	5'11-3/4"	195	Offensive Fullback
21.	RV	21	5'10"	190	Free Safety
22.	DW	20	5'9-1/2"	198	Defensive End
23.	DW	19	6'2-1/4"	225	Offensive Tackle

importance to pass catching ability. Only one test of each independent variable was administered and testing began March 22 and ended on March 26, 1971.

Measurement of Grip Strength. A cable tensiometer was used to measure grip strength. This instrument measures the tension applied to it by the gripping action of the subject. One of the two hands on the face of the dial remained at the maximum score that was attained during the trial, while the other hand returned to the zero mark on the dial. The hand that remained at the maximum score on the dial of the tensiometer was recorded to the nearest whole number and then converted to pounds by a conversion table. The subject stood with good balance, knees flexed, arm at a 90° angle, and gripped the dynamometer in a sweeping motion that resembled that of an extended uppercut.[1] The dynamometer was held so that the dial faced the body. No score was recorded if the dynamometer or the subject's arm came in contact with the body or any other object during the trial. The best of three trials was recorded. Both hands were tested with the right hand being tested first. The subjects were introduced to the tensiometer prior to the testing session in order to familiarize them with the instrument. An effort was made to maintain a consistent testing environment throughout the testing of grip strength. The mean of the subjects left and right hand score was used as his grip strength.

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[1]Paul Hunsicker and George Greey, "Studies in Human Strength," The Research Quarterly, 28:118, May, 1957.

Measurement of Hand Size. Hand size was measured for both length and width on the metric scale to the nearest centimeter. For the measurement of the length, the subject was instructed to wet his hand on the wet towel provided, and to put his hand print on a blackboard. (See Picture 1) The subject was instructed to keep his arm as close to a 90° angle as possible. The tester then carefully put a chalk mark on the upper and lower extremes of the hand print. The distance between the two chalk marks was recorded to the nearest centimeter. The right hand was measured first, then the left.

For the measurement of the width, the subject laid his hand flat on a table and the measurement was taken across the back of the hand from the knuckle of the index finger to the knuckle of the little finger. The right hand was measured first and then the left. A caliber was used for this measurement and was recorded to the nearest centimeter. The final hand size recording consisted of the sum of the width and the length. The mean of the right and left hands was recorded.

Measurement of Kinesthetic Perception. Two tests were used to test kinesthetic perception:

(1) Balance Stick.[2] A stick which was one inch square and twelve inches long was securely taped to the floor with adhesive tape. The subject was given the following verbal direction:

> Stand with one foot lengthwise on the stick. When your foot is secure, close your eyes and lift the other foot off the floor and hold your balance as long as possible. You may do anything you like as long as you do not

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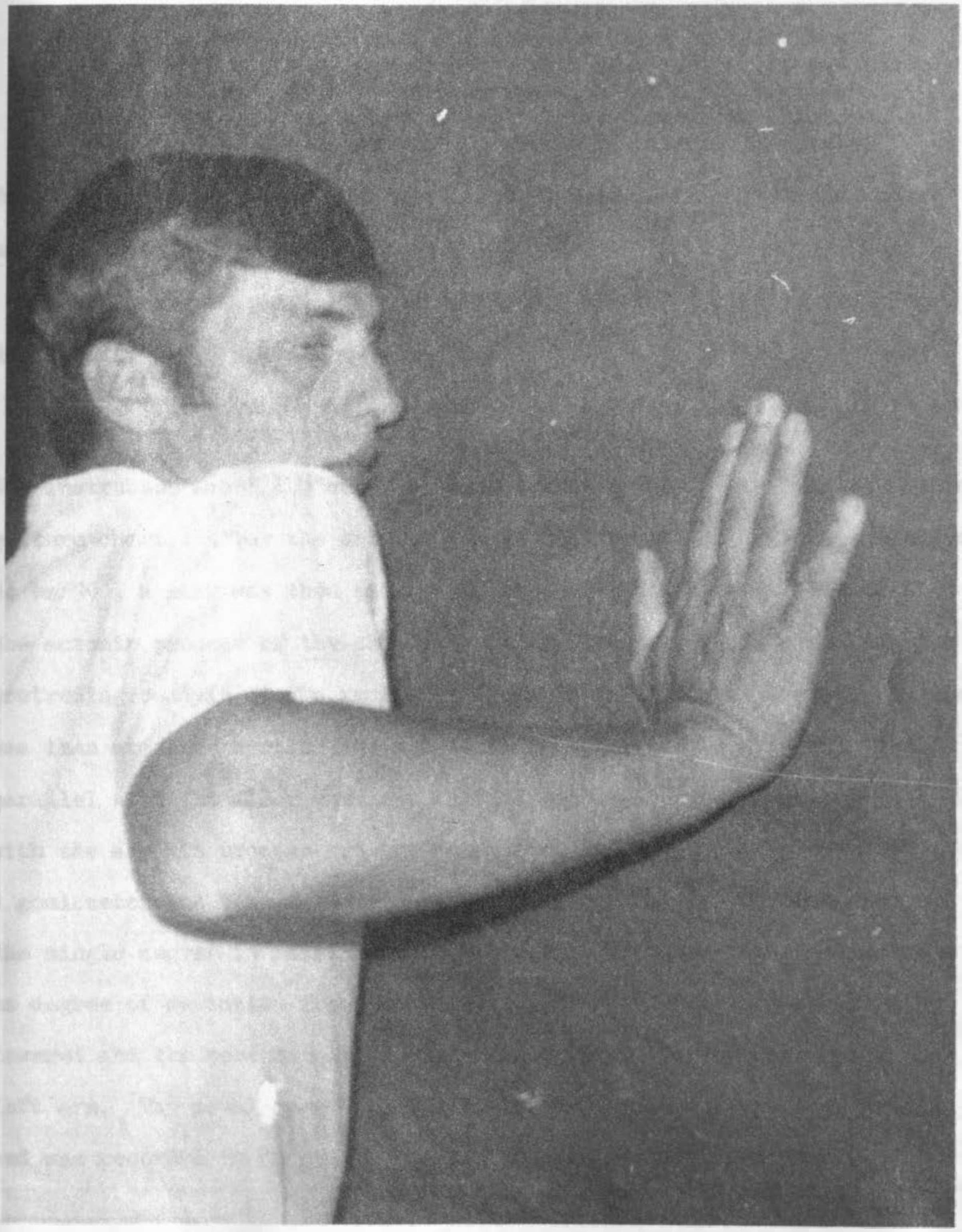
[2]Olive G. Young, "A Study of Kinesthesis in Relation to Selected Movement," Research Quarterly 16:277-87, 1945.



PICTURE I. MEASUREMENT OF HAND LENGTH

> touch the floor with any part of your body or open your eyes. You will be timed from the moment you lift your foot from the floor until you open your eyes or touch the floor, you may have one practice with your right foot and three test trials, and then one practice with your left foot, and three test trials. Then, there will be three more trials on each foot. Your score will be the total time on 12 trials.[3]

One demonstration was given while giving instructions. The total score was recorded in seconds.

(2) Arm Raising. The subject was given the following verbal directions:

> Close your eyes and raise your right arm out sideward to a horizontal position with the palm facing down.[4]

The instructor faced the subject whose back was pressed against the Deming posture chart. After the subject raised his arm to the angle he perceived to be 90^{o}, a mark was then made on the Deming posture chart even with the acromin process of the shoulder. A mark was also made even with the protruding condyle of the radius near the little finger. A straight line was then drawn connecting the above mentioned marks. A straight line parallel with the floor was then calculated using the mark made even with the acromin process and the squares on the Deming posture chart. A goniometer was then used to determine how far the subject deviated to the single degree in raising his arm to 90^{o}. The deviation was recorded as degree of deviation from the hortizontal. The right arm was then lowered and the test repeated. Then the test was given twice using the left arm. The total score was the sum of deviations on the four trials and was recorded in degrees. A score of zero was a perfect score.

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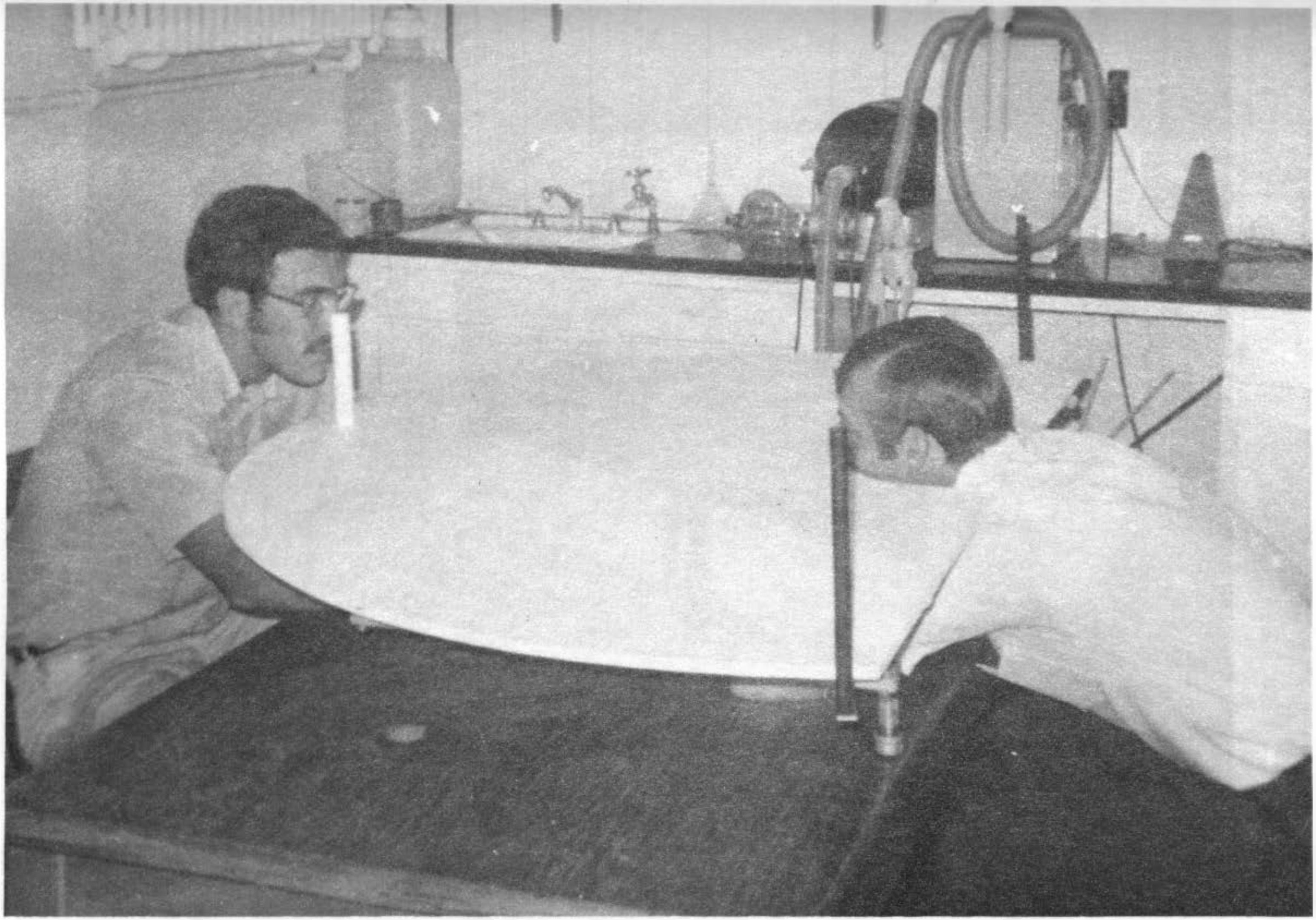
[3]Gladys M. Scott, Analysis of Human Motion (New York: F. S. Crofts and Co., 1942), p. 101

[4]Ibid.

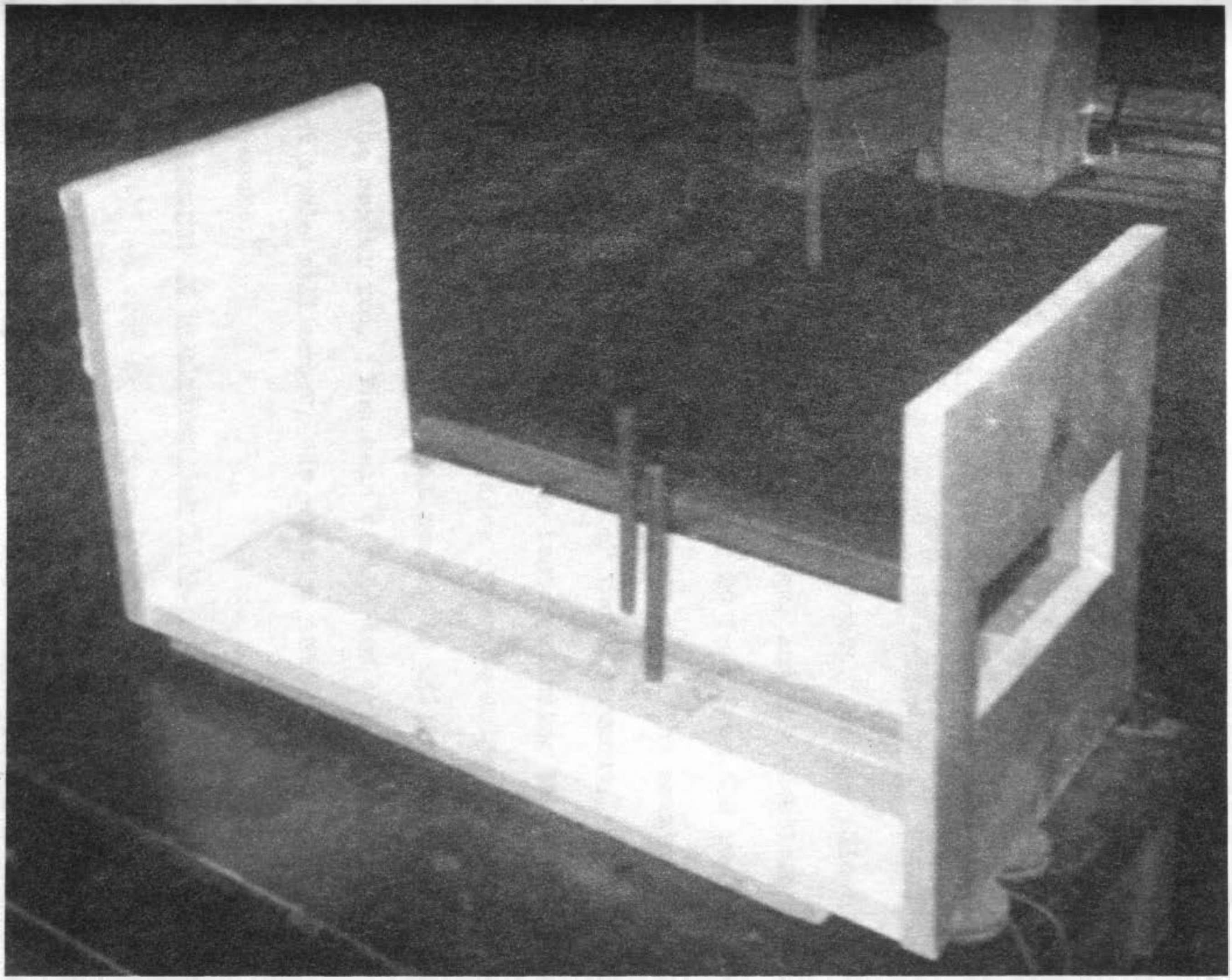
Measurement of Peripheral Vision. The apparatus used to measure peripheral vision consisted of a flat half-circle with a radius of thirty inches, placed on the horizontal eye-level of the subject being tested. Two rods, movable on levers, were fixed, one on each edge of the platform. The surface of the apparatus was painted a dull white and the rods a dull black. (See Picture 2) The subject was instructed to immobilize his head with his eyes fixed on a point thirty inches directly ahead of the eyes on the edge of the platform. The operator sat in front of the subject and had control of the levers. The operator moved one of the black rods very slowly toward the fixed point until the subject issued a command to stop as soon as he perceived the black rod in his periphery. The subject then indicated on which side he perceived the object. If he was correct the rod was left and the angle between the black rod and the eye level point was recorded in degrees. If he was incorrect, the operator returned the rod to its starting position, disregarded the trial, and began again. The subject was given ten trials, five on each side with the order on which side the rod moved being randomly selected.[5] His score was the mean angle of the ten trials.

Measurement of Depth Perception. The apparatus used to measure depth perception consisted of a box 24 inches long, 11-3/4 inches wide, and 12-1/2 inches high, open at the sides and top. (See Picture 3). The end of the box nearest the subject being tested, had a rectangular window 3 inches high and 7-1/2 inches wide. Inside the apparatus were two

[5]Robert A. Cobb, "A Comparative Study of Color Recognition in the Peripheral Field of Vision of Participants in Selected Sports," (Unpublished Master's thesis, Springfield College, Springfield, Mass., 1967), p. 22.



PICTURE II. APPARATUS FOR MEASUREMENT OF PERIPHERAL VISION



PICTURE III. APPARATUS FOR MEASUREMENT OF DEPTH PERCEPTION vertical black rods, one of which was fixed at the center of the box and the other 2 inches from the center rod and lengthwise movable on a track. The movable rod was controlled by strings, which were placed in the subject's hands at the beginning of the test. A millimeter scale was set along side of the movable rod's track. The center point of the scale directly opposite the fixed rod, was marked 0, and the scale's range was 0 to 200 mm. (away from the observer) and from 0 to 200 mm. (toward the observer).

The test was explained to each subject. He was allowed to look at the instrument, manipulate the strings, and ask questions about procedure. He was then seated in a chair 20 feet from the instrument and the test began. At the beginning of each trial the movable rod was placed at the extreme front or back of the instrument. This was done according to a set pattern with the tester standing in front of the instrument so that the rods were hidden from the subjects. The subject's score for each trial was the total number of millimeters the movable rod was from the center rod. The mean of the ten trials, rounded off to the nearest whole millimeter, was used as the individual's depth-perception score.[6]

Measurement of Hand-Reaction Time. The Nelson Hand Reaction Test (See Picture 4) was used to measure the speed of reaction of the hand to a visual stimulus. The subject was told to sit with his forearm and hand resting comfortably on the desk rop. The tips of the thumb and

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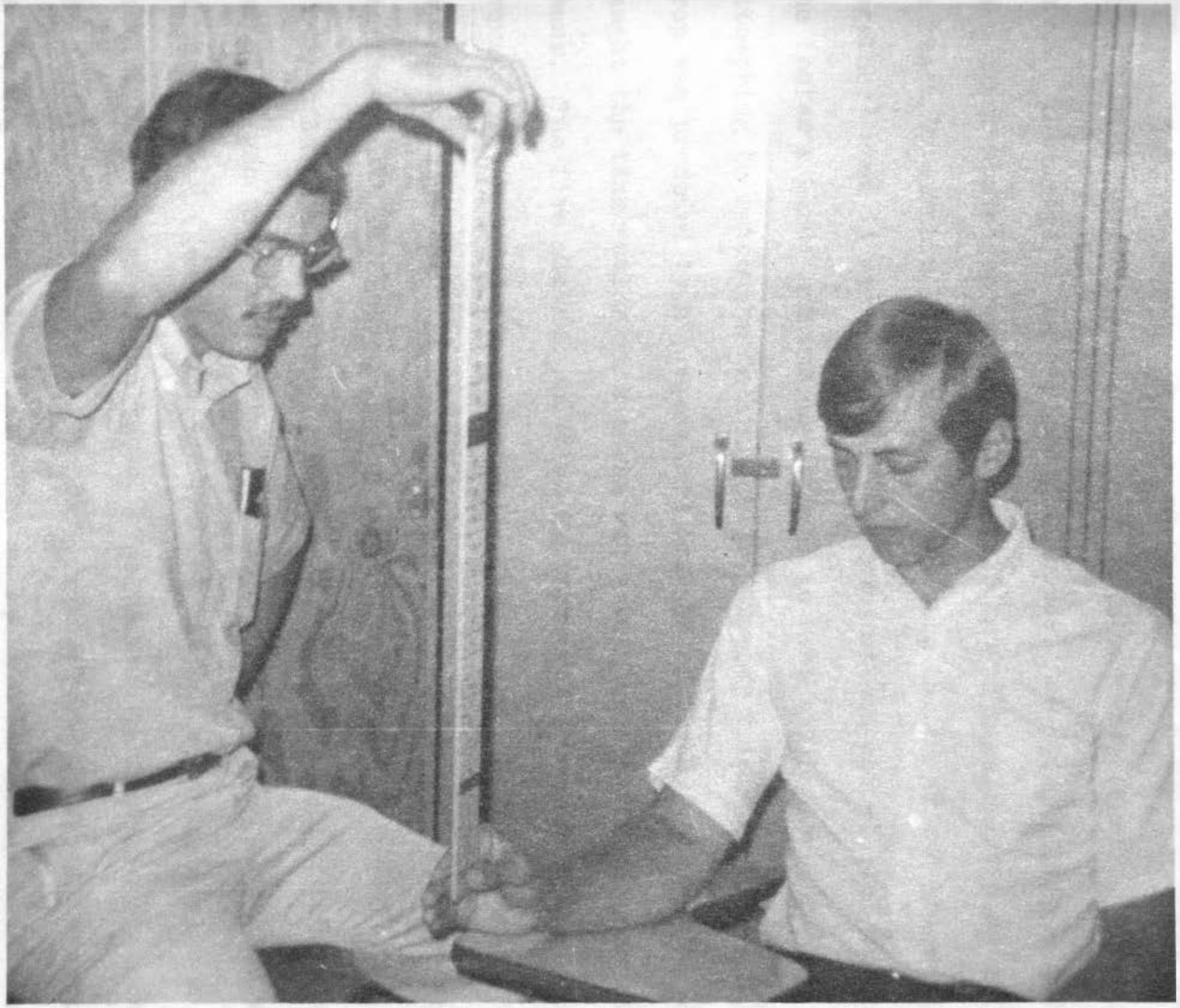
[6] H. W. Seiger, "Variation is Illumination of the Depth Perception Apparatus," Journal of Aviation Medicine, 15:401-403, December, 1955.



PICTURE IV. MEASUREMENT OF HAND REACTION index finger were held in a ready to pinch position about three or four inches beyond the edge of the table. The upper edges of the thumb and index finger were in a horizontal position. The tester held the stick-timer near the top, letting it hang between the subject's thumb and index finger. The Base Line was kept even with the upper surface of the subject's thumb. The subject was directed to look at the Concentration Zone (which is a black shaded zone between the .120 and .130 record lines) and was told to react by catching the stick (by pinching the thumb and index finger together) when it was released. The subject was not allowed to look at the tester's hand; nor was he allowed to move his hand up or down while attempting to catch the falling stick. Twenty trials were given. Each drop was preceded by a preparatory command of 'ready'. When the subject caught the timer-stick, the score was read just above the upper edge of the thumb. The five slowest and five fastest trials were discarded, and an average of the middle ten recorded as the score. Numbers on the timer represent thousandths of a second. Scores were recorded to the nearest one-thousandth of a second.[7]

Measurement of Speed of Movement Time. The Nelson Speed of Movement Test was used to measure the combined reaction and speed of movement of the hands. (See Picture 5) The subject sat at a table with his hands resting on the edge of the table. The palms were facing one another with the inside border of the little fingers along two lines which were marked on the edge of the table twelve inches apart. The tester held the timer near its top so that it hung midway between the subject's palms. The

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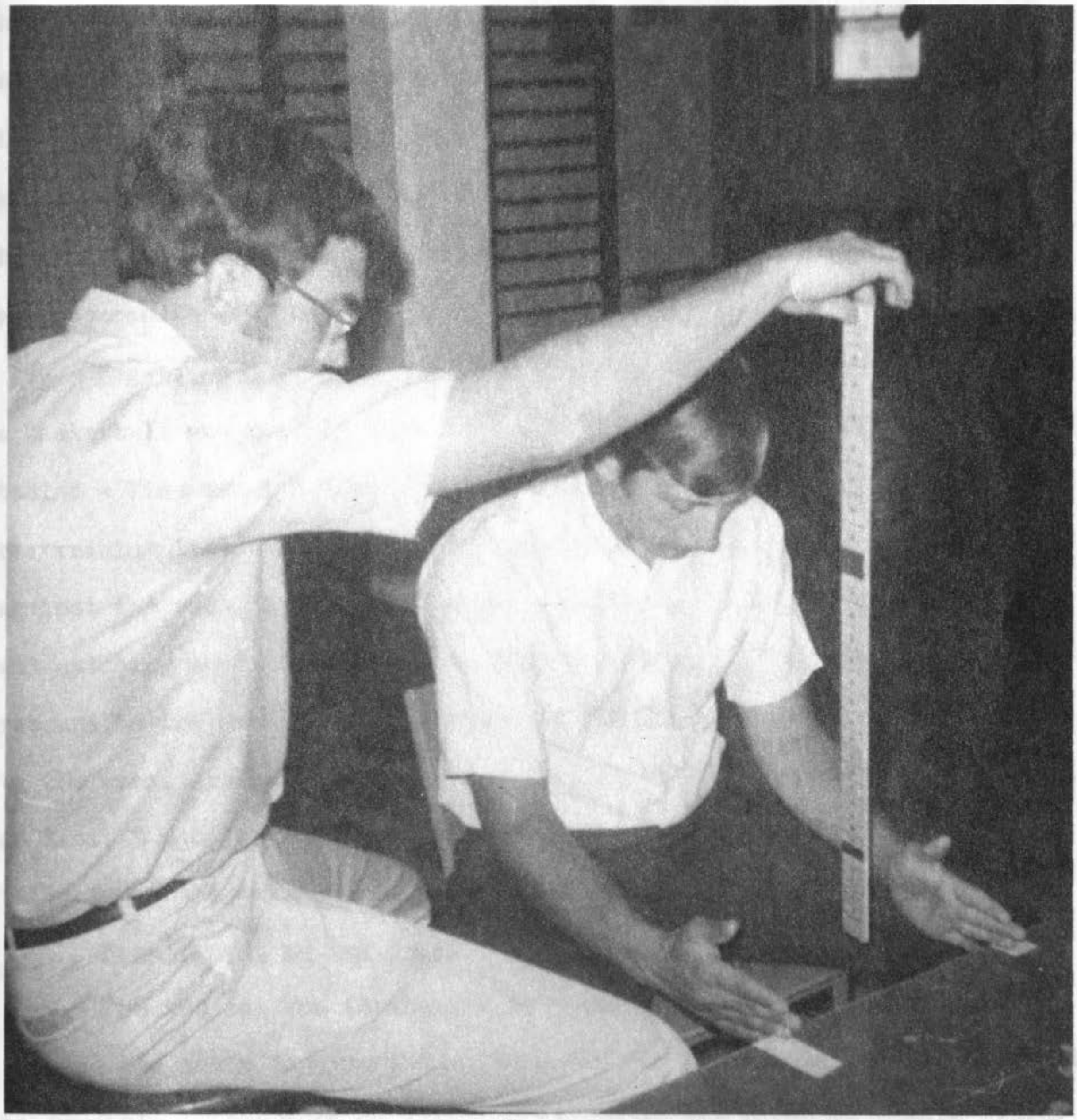
[7]Barry L. Johnson and Jack K. Nelson, Practical Measurements for Evaluation in Physical Education (Minneapolis, Minnesota: Burgess Publishing Company, 1970), p. 318.



PICTURE V. MEASUREMENT OF SPEED OF MOVEMENT

Base Line was positioned so it was level with the upper borders of the subject's hands. After the preparatory command 'ready' was given, the timer was released and the subject was careful not to allow his hands to move up or down as he clapped the hands together. Twenty trials were given. The score for the combined response-movement was read from the timer at the point just above the upper edge of the hand after the catch. The average of the middle ten trials, after the slowest and fastest five trials had been discarded, were recorded to the nearest one-thousandth of a second.[8]

Measurement of Hand-Eye Coordination. The wall-pass test with a basketball was used to test hand-eye coordination. The subject stood behind a line drawn 9 feet from the wall. Standing behind the 9-foot restraining line with the ball in his hand, the subject threw the ball against the wall, catching it as it rebounded, and continued throwing and catching until the signal to stop was given. If the ball did not rebound to the hands or was dropped, the subject recovered it, returned to the area, and continued.[9] Three trials of 30 seconds each were given, at least 3 minutes apart. The score was the mean number of times the ball struck the wall and successfully was caught in the three trials.

Measurement of Leg Power. Leg power was measured by the vertical jump. The subject was instructed to stand with one side toward a wall keeping the heels together; the performer was instructed to stand as tall as possible on the toes so that the height of the extended middle finger

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[8]Barry L. Johnson and Jack K. Nelson, op. cit., p. 231.

[9]Barry L. Johnson and Jack K. Nelson, op. cit., p. 124.

of the raised arm could be recorded. The performer then jumped as high as possible and made another mark at the height of his jump. The number of inches between the reach and the jump marks, measured to the nearest quarter of an inch, was the score. Three trials were allowed and the best trial was recorded as the subject's leg power.[10]

Measurement of Agility. The shuttle run was used to measure agility. Two blocks of wood, 2 x 2 x 4 inches, a stop watch, and a 30-foot running area were needed for equipment for the shuttle run. The subject started from a standing position behind a line. Behind another line 30 feet away two blocks of wood were placed. At the starting signal the subject raced to the blocks, picked one up, and returned to the starting line. After placing (not throwing) the wooden block behind the starting line, he ran back and picked up the remaining wooden block, then carried it across the starting line. In all, the distance was crossed four times making a total distance of 120 feet, or 40 yards. Two trials were administered and the subjects score was the time to the nearest tenth of a second of the better of two trials.[11]

Procedure for Collecting the Data

The investigator was assisted in the testing by the coordinator of research for the Health, Physical Education and Recreation Department and eight graduate assistants from South Dakota State University. Each tester was instructed thoroughly on the mechanics of the test he

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[10] Barry L. Johnson and Jack K. Nelson, op. cit., p. 81.

[11] Barry J. Johnson and Jack K. Nelson, op. cit., p. 318.

administered. Each tester was given several trials until he was familiar with the testing procedures.

The tests were taken in two different orders, both of which were randomly selected. Half of the subjects took one and half the other. The testing forms were numbered from 1 to 23. Each subject was given a form with a number on it as he entered the testing environment. The front page of each form had the order which that subject was to follow. The subjects with odd numbered forms, (1 - 3 - 5 etc.) took the tests in the order of: hand reaction, shuttle run, hand-eye coordination, vertical jump, grip strength, hand size, peripheral vision, depth perception and kinesthetic perception. The subjects with even numbers took the tests in the order of: grip strength, hand size, peripheral vision, depth perception, kinesthetic perception, shuttle run, hand-eye coordination, vertical jump, and hand reaction time.

Measurement of the Criterion

Each subject was thrown 120 passes over a five-week period during the spring football practice session. Mondays and Wednesdays of each week were designated as pass receiving days since the team did not work out on these days. There were a total of 10 days used for catching passes. Three different quarterbacks were used with each throwing five passes to each subject at each pattern. There were eight different patterns (Figure I): Down-in right, down-in left, deep post right, down-out right, deep post left, down-out left, curl right, and curl left. All cuts were taken at 15 yards. For each pattern a total of fifteen passes were thrown. Each quarterback was allowed two warm-ups with the change

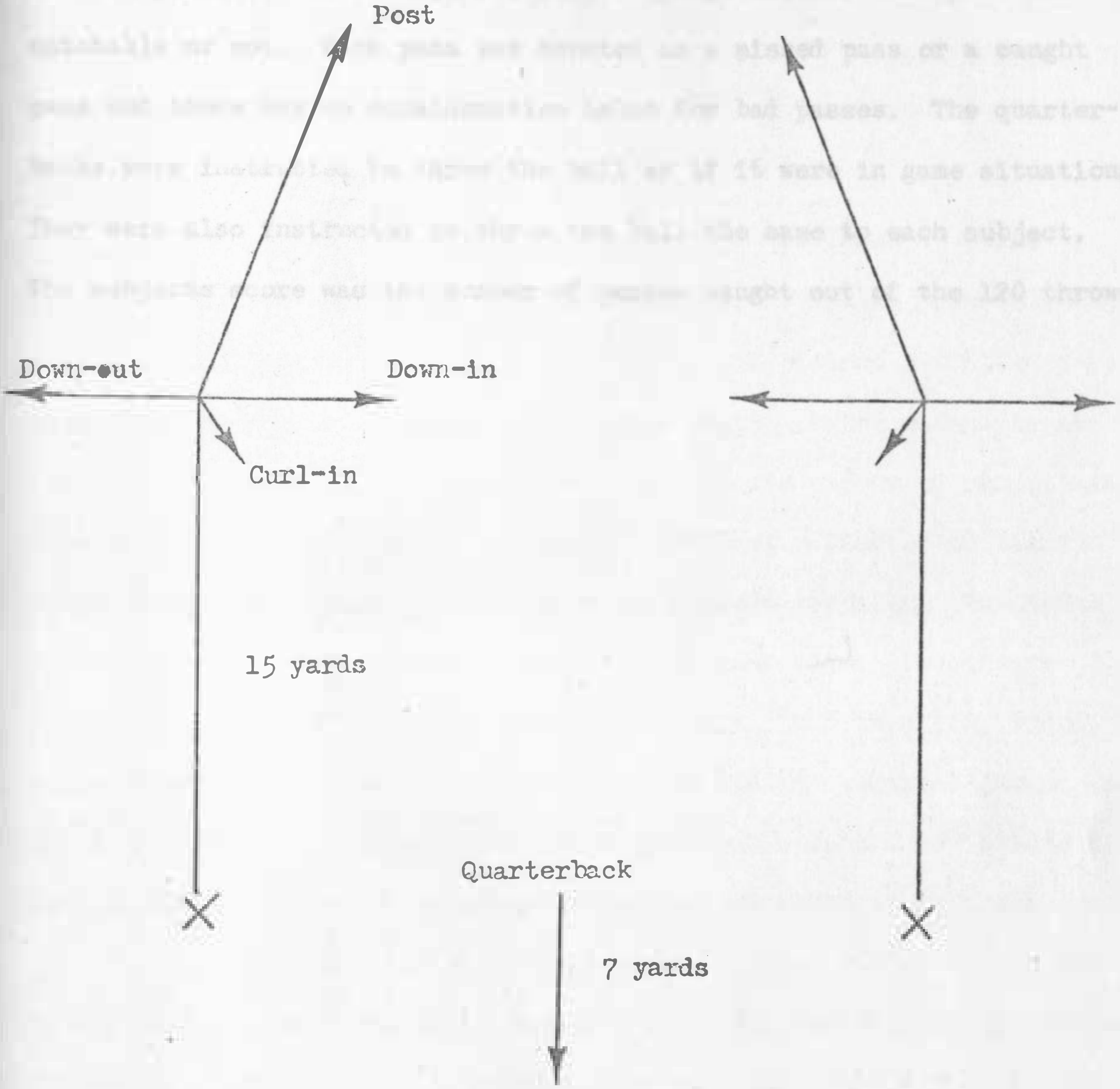

FIGURE I

PASS PATTERNS

of each pattern. No attempt was made to judge whether each pass was catchable or not. Each pass was counted as a missed pass or a caught pass and there was no consideration taken for bad passes. The quarterbacks were instructed to throw the ball as if it were in game situations. They were also instructed to throw the ball the same to each subject. The subjects score was the number of passes caught out of the 120 thrown.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

Organization of the Data for Treatment

Procedures and a statistical design were developed to formulate an objective tool to aid in the prediction of future pass catching ability of college football players. Eleven independent variables were identified by the investigator as making possible contributions to successful pass catching. The dependent variable was the number of receptions completed out of 120 passing attempts. Data were collected on the 23 subjects for the 11 independent and one dependent variable. The independent variables tested were grip strength, hand size, kinesthetic perception, peripheral vision, depth perception, hand reaction, speed of movement, hand-eye coordination, agility, and the vertical jump. The raw data are found in Appendix A. The means and standard deviations of the 11 independent and 1 dependent variables are found in Table II.

In order to be able to predict pass catching ability on the basis of the 11 selected independent variables, a multiple correlation and regression statistical procedure was employed.[1] The procedure first computed intercorrelations between all the independent variables and correlation between the independent variables and the dependent variable. Then multiple regression equations were developed beginning with a one variable equation and adding an additional variable in each succeeding step

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[1]Robert G. Steel and James H. Torris, Principles and Procedures of Statistics (New York-Toronto-London: McGraw-Hill Book Company, Inc., 1960), pp. 161-182.

TABLE II

MEANS AND STANDARD DEVIATION OF MEASUREMENTS FROM THE TWENTY-THREE FOOTBALL PLAYERS IN THE STUDY.

	Measurements	Mean	Standard Deviation
X_1	Grip Strength (pounds)	100.043	18.674
X_2	Hand Size (centimeters)	28.361	.947
X_3	Balance Stick (seconds)	44.413	10.238
X_4	Arm Raise (degrees)	12.609	6.099
X_5	Peripheral Vision (degrees)	93.461	2.976
X_6	Depth Perception (centimeters)	15.217	9.18
X_7	Hand Reaction (seconds)	.170	.015
X_8	Speed of Movement (seconds)	.223	.017
X_9	Hand-Eye Coordination (seconds)	32.843	3.078
X_{10}	Agility (seconds)	8.878	.366
X_{11}	Vertical Jump (inches)	20.13	2.785
Y	Receptions Out of 120	91.783	13.738

in order to increase the accuracy of the prediction. For each step a multiple correlation, standard error of estimate, and variance accounted for in that step were computed. An electronic computer was used to facilitate the speed and accuracy of the statistical process.

Analysis of the Data

This section provides results of the statistical analysis from the data and the developed regression equations.

The matrix of zero order correlations is presented in Table III. There was a low degree of relationship among the different pass catching variables, with only six out of fifty-five which were significant beyond the .05 level of confidence. Three of eleven independent variables showed a significant correlation with pass catching ability at the .05 level of confidence. Those three being hand-eye coordination, which showed a correlation of .66, vertical jump, which showed a correlation of .58, and agility, which showed a correlation of -.48.

The regression equations computed are shown in Table IV. This table includes the regression equations developed, their standard error of estimate, multiple correlation, and variance accounted for by the addition of each variable. The standard error of estimate showed gradual improvement through the fifth equation, but then grew larger in the sixth equation. The multiple correlations showed steady improvement through the fourth equation but thereafter approached the point of diminishing returns. According to the variance accounted for by the addition of each new variable to the equation, only the first variable made a significant contribution to the equation ($1783.61 > 513.61$). The variance

TABLE III

CORRELATION MATRIX

Variables*	1	2	3	4	5	6	7	8	9	10	11	Y
1	1.00	.29	.26	.41*	-.47*	-.01	-.06	-.23	.00	.25	.15	-.06
2		1.00	.05	.08	.05	.11	.00	-.06	.12	.23	-.15	.06
3			1.00	.20	-.18	.03	-.15	-.24	.45*	-.08	-.01	.33
4				1.00	-.07	.04	.07	-.33	.00	.04	.17	-.17
5					1.00	-.10	.35	.10	.01	.01	-.31	-.10
6						1.00	.15	.22	-.01	.13	-.01	-.23
7							1.00	.51*	.19	.39	-.12	-.21
8								1.00	.04	.07	.04	-.10
9									1.00	-.25	.41*	.66**
10										1.00	-.51*	-.48**
11											1.00	.58**
Y												1.00

* 1 Grip Strength
2 Hand Size
3 Balance Stick
4 Arm Raise
5 Peripheral Vision
6 Depth Perception
7 Hand Reaction
8 Speed of Movement
9 Hand-Eye Coordination
10 Agility
11 Vertical Jump
Y Receptions

** (.05 level of confidence = .41)

REGRESSION EQUATIONS DEVELOPED, THEIR STANDARD ERROR OF ESTIMATE, MULTIPLE CORRELATION, AND VARIANCE ACCOUNTED FOR BY THE ADDITION OF EACH VARIABLE.

	Regression Equation	Standard Error of Estimate	Multiple Correlation	Variance Accounted*
1.	$Y = 2.925X_9 - 4.279$	10.62	.660	1783.61
2.	$Y = 3.221X_9 - 3.289X_7 + 41.993$	9.681	.741	493.95
3.	$Y = 2.615X_9 - 2.716X_7 + 1.487X_{11} + 22.222$	9.109	.788	298.00
4.	$Y = 2.506X_9 - 2.473X_7 + 1.725X_{11} - .478X_4 + 22.899$	8.814	.814	178.09
5.	$Y = 2.461X_9 - 2.201X_7 + 1.751X_{11} - .469X_4 - .268X_6 + 23.177$	8.640	.833	129.32
6.	$Y = 1.944X_9 - 1.635X_7 + 2.068X_{11} - .579X_4 - .289X_6 + .232X_3 + 15.551$	8.646	.844	72.82
7.	$Y = 1.737X_9 - 1.433X_7 + 2.274X_{11} - .628X_4 - 312X_6 + .268X_3 + 1.662X_2 - 32.862$	8.75	.851	47.81
8.	$Y = 1.445X_9 - 1.263X_7 + 2.565X_{11} - .529X_4 - .334X_6 + .354X_3 + 2.586X_2 - .130X_1 - 50.023$	8.712	.863	85.64
9.	$Y = 1.348X_9 - .668X_7 - 2.713X_{11} - .624X_4 - .311X_6 + .359X_3 + 2.592X_2 - .139X_1 - .881X_8 - 41.400$	8.933	.866	25.23
10.	$Y = 1.346X_9 - .770X_7 + 2.738X_{11} - .632X_4 - .304X_6 + .361X_3 + 2.592X_2 - .127X_1 - .846X_8 + .134X_5 - 52.337$	9.29	.866	1.89
11.	$Y = 1.350X_9 - .913X_7 + 2.841X_{11} - .269X_4 - .308X_6 + .368X_3 + 2.554X_2 - .134X_1 - .816X_8 + .169X_5 + .131X_{10} - 66.179$	9.693	.867	1.97

* Total Variance 4151.90
MS Variance 103.56
$F_{.05}$ (1/10) = 4.96; LSD = 103.56 x 4.96 = 513.64

accounted for by the addition of each new variable to the equation after the first variable, was not significant (493.95 < 513.64; 298.00 < 513.64, etc.)

Discussion of Results

In surveying the correlation matrix it is interesting to note that only six out of fifty-five correlations were significant at the .05 level of confidence. The significant correlations were between grip strength and arm raise (.41), grip strength and peripheral vision (.47), balance stick and hand-eye coordination (.45), speed of movement and hand reaction (.51), hand-eye coordination and vertical jump (-.57). Of the above only the correlations between speed of movement and hand reaction, and between agility and vertical jump were anticipated by the investigator. However, it is not surprising that there was a significant correlation between hand-eye coordination and the vertical jump since they both are considered to be excellent indicators of athletic ability.[2,3]

The investigator found no significant correlation between grip strength and hand size (.29). This is probably due to the fact that there were more small (backs, ends, etc.) football players tested than large (tackles, guards, etc.) and hence there were more football players with long narrow hands than with short thick hands. This mean and standard deviation for hand size of 28.361 ± .947 centimeter revealed little

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[2]Frederick J. McDonald, Educational Psychology (San Francisco: Wadsworth Publishing Company, Incorporated, 1959), p. 312.

[3]Charles Harold McCloy, Tests and Measurements in Health and Physical Education (New York: Appleton Century Crafts, Inc., 1954), p. 142.

variability among the hand sizes. The short thick hands of linemen would hold the definite advantage in grip strength.[4]

There was also a low relationship between the two vision tests measuring peripheral vision and depth perception. Vision, however, is a very complicated and integrated bodily function,[5] and it is not surprising that a person with good peripheral vision does not necessarily have good depth perception and vice versa. As an example, a person may have tunnel vision and therefore perceive depth with a certain amount of accuracy but be able to perceive very little in his periphery.

Hand-eye coordination as measured by the wall pass, showed the highest relationship with pass catching ability (.66). This would indicate that hand-eye coordination as measured by the wall pass is the leading variable, out of the eleven in this study, for prediction of pass catching ability.

The regression equations computed along with the standard error of estimate, multiple correlation, and variance accounted for by the addition of each variable are shown in Table IV. Several important conclusions can be drawn from the data in this table. First we note that the standard error of the estimate reaches its highest point in equation number five (8.640). Also we see that multiple correlation reaches its most significant rise in equation number five (.833). However, the variance accounted for by the addition of each variable is greatest in

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[4]Peter Everett and Frank Sills, "The Relationship of Grip Strength to Statue, Somatotype Components, and Anthropometric Measurements of the Hand," The Research Quarterly, 42, May, 1952.

[5]Hoyt Sherman, Drawing by Seeing (New York: Hinds, Hayden and Eldridg, 1947), pp. 1-77.

equation number one and there is no significant rise in those additions following equation number one.

This would seem to point to an equation between numbers one and five depending upon time and amount of accuracy desired. If a greater amount of accuracy is desired then it would appear that one should use either equation four or equation five. If, however, time is a factor then this investigator feels that one should lean toward equations two or three and it would appear that three has more to offer than two. If only one variable is to be tested then of course equation number one would be the most advantageous.

The hypothesis stated that a regression equation can be developed from selected anatomical measurements and motor responses that will predict success in football pass catching ability. The hypothesis was accepted because the computed F ratio for the first equation was above that necessary for significance at the .05 level of confidence ($17.12 > 4.96$).

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this investigation was to develop a multiple regression equation, employing selected anatomical measurements and motor responses, which would aid in predicting pass catching ability.

South Dakota State University varsity football players (N-23) of the 1970 football season, provided the data for the developed predictor variables of selected anatomical measurements and motor responses--grip strength, hand size, kinesthetic perception, peripheral vision, depth perception, hand reaction, speed of movement, hand-eye coordination, agility, and the vertical jump. From intercorrelations and correlation of the predictor variables and the dependent success criteria of individual receptions out of 120 attempted passes, regression equations were developed for the purpose of predicting pass catching ability.

An F value determined the significance of the regression equations at the .05 level of confidence. The final phase included testing the hypothesis. These testing procedures, then, examined the significance of the regression equations in terms of estimating individual pass catching ability from selected anatomical measurements and motor response variables.

Conclusions

Due to the results of this study and within its limitations, the investigator concludes:

1. That the variables of hand-eye coordination, agility, and vertical jumping relate significantly with pass catching ability.

2. Pass catching ability can be predicted from a combination of from one to eleven variables of grip strength, hand size, kinesthetic perception, peripheral vision, depth perception, hand reaction, speed of movement, hand-eye coordination, agility, and the vertical jump to predict pass catching ability.

Recommendations

Based on the findings of this study, the investigator proposes the following recommendations for further study:

1. That further study be conducted employing a similar statistical design and procedure, but that several tests be used to measure each independent variable.

2. That a study be conducted to determine the feasibility of using other predictor variables and objective success criteria in developing regression equations for football pass catching evaluations.

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APPENDIX A

TABLE V

THE RAW DATA, MEANS AND STANDARD DEVIATIONS OF THE ELEVEN INDEPENDENT VARIABLES AND THE ONE DEPENDENT VARIABLE FOR THE TWENTY-THREE SUBJECTS USED IN THIS STUDY.

Subjects	Hand Size	Grip Strength	Balance Stick	Arm Raise	Peripheral Vision	Depth Perception	Hand Reaction	Speed of Movement	Hand-Eye Coordination	Agility	Vertical Power	Reception
1	105	29.8	35.9	10.5	95.7	9.0	19.3	24.2	37.3	8.8	20.0	98
2	69	26.7	32.3	11.0	94.7	20.0	17.5	25.0	32.3	8.9	19.5	87
3	102	28.7	47.5	95.0	96.5	8.0	20.0	22.0	36.6	9.1	20.0	95
4	97	29.5	33.4	14.0	91.6	7.0	14.4	18.5	31.6	8.7	21.5	98
5	103	29.6	46.1	6.5	92.4	8.0	14.3	23.9	33.0	8.4	22.3	99
6	87	28.2	54.9	14.5	98.3	11.0	15.9	19.7	38.0	8.9	19.3	112
7	93	29.1	40.2	19.0	95.2	42.0	18.1	22.3	31.3	9.0	18.0	59
8	138	29.8	32.4	19.0	87.7	14.0	17.2	22.2	34.6	9.6	20.0	96
9	76	28.3	45.9	19.5	95.4	8.0	16.6	20.3	30.3	8.4	21.0	102
10	77	27.5	42.5	2.0	95.5	12.0	18.3	24.5	33.3	8.5	20.8	102
11	139	28.0	53.5	29.5	92.3	17.0	17.9	22.7	32.0	8.8	24.5	94
12	95	29.1	39.3	12.0	15.5	14.0	16.7	22.7	30.3	9.1	14.0	81
13	93	29.4	50.7	5.0	92.8	39.0	17.6	23.3	33.3	9.2	19.0	104
14	87	27.8	37.3	13.0	89.2	21.0	18.4	24.8	34.6	8.9	23.5	88
15	89	26.5	41.7	14.5	91.2	10.0	15.8	21.2	32.7	8.3	21.8	90
16	94	28.3	60.9	10.5	93.6	19.0	15.4	21.6	36.0	8.7	22.5	102
17	106	28.0	30.3	55.0	89.6	15.0	15.7	22.0	29.6	8.8	22.5	102
18	98	28.3	48.1	18.5	95.6	10.0	18.5	22.3	37.3	8.8	22.5	103
19	111	27.6	22.6	11.0	95.4	11.0	17.8	21.6	26.6	9.7	18.0	63
20	138	27.6	63.1	14.0	87.0	19.0	15.4	19.5	35.0	8.6	20.3	94
21	110	28.1	37.8	8.5	96.0	19.3	16.7	23.1	32.0	8.5	22.5	95
22	87	27.3	58.2	6.0	92.6	6.0	17.2	22.7	30.7	9.3	15.0	82
23	108	29.1	46.9	16.5	95.8	11.0	17.0	21.9	27.0	9.2	14.5	65
X	100	28.4	44.4	12.6	93.5	15.2	17.0	22.3	32.8	8.8	20.1	91.7
SD	18.7	.95	10.2	6.09	2.97	9.17	.015	.017	3.07	.36	2.78	13.7