1967

The Relationship of Strength in Selected Muscle Groups to Agility and Forearm Performance Time

Val Gene McPeak
Eastern Illinois University

PAPER CERTIFICATE #3

To: Graduate Degree Candidates who have written formal theses.

Subject: Permission to reproduce theses.

The University Library is receiving a number of requests from other institutions asking permission to reproduce dissertations for inclusion in their library holdings. Although no copyright laws are involved, we feel that professional courtesy demands that permission be obtained from the author before we allow theses to be copied.

Please sign one of the following statements.

Booth Library of Eastern Illinois University has my permission to lend my thesis to a reputable college or university for the purpose of copying it for inclusion in that institution's library or research holdings.

7/28/77
Date

I respectfully req... ...brary of Ea... ...s University not allow my thes... ...duced because

Date

Au...

THE RELATIONSHIP OF STRENGTH IN SELECTED MUSCLE GROUPS TO AGILITY AND FOREARM PERFORMANCE TIME

(TITLE)

BY

VAL GENE McPEAK

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN EDUCATION

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

1967
YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

7/28/67
DATE

28 July 1967
DATE

ACKNOWLEDGEMENTS

I wish to thank Dr. William Groves, my advisor, Dr. Maynard O'Brien, and Dr. M. Thomas Woodall, members of my committee, for their sincere interest and constructive advice. Sincere appreciation is also extended to Dr. A. J. DiPietro for his assistance in the statistical analysis of this study. The writer would also like to express his appreciation to the graduate assistants in the Department of Physical Education (Men) for their assistance.

Appreciation is also extended to Mrs. Max Daugherty for her efforts in typing the final copy of this paper.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

AN INTRODUCTION TO THE PROBLEM

Introduction

Most definitions of the term "agility", in the field of physical education, imply that the trait is concerned primarily with shifting the total body about from one spot to a nearby spot. No attempt has been made to determine to what degree basic physical components are present in tests now used to measure agility.

Strength, derived from muscle sources, is considered to be a basic component of agility, for without a certain degree of strength the total body movement would be altered.

It would seem conceivable that the ability of certain body parts to shift positions from one place to another would aid total body movement or hinder it - depending on how such parts were used during an agility test. This movement of body parts would depend, no doubt, on a basic component of strength along with reaction time resulting in performance time.

The above hypotheses suggested to the writer that certain muscle groups could be tested for strength with the results intercorrelated with standard agility tests. In addition, it was thought that arm movement, involving an element of reaction time, resulting in performance time, might be measured and intercorrelations run be-

tween the strength tests. If any high intercorrelations were found between a number of the test items, it might suggest that basic components of a general total body agility test were available and could be isolated.

Purpose

This investigation was undertaken in an attempt to determine the degree of relationship, if any, between strength in the flexor and extensor muscle groups of the forearm and lower leg as compared with (1) components of total body agility, (2) total body agility, and (3) forearm performance time.

Need

If basic components of presently administered agility tests could be isolated a new and, perhaps, better approach to designing tests for total body agility and specific body-part agility may have been found.

Limitations

This study was limited by the fact that only thirty students were involved in the testing procedure, and that an equal distribution of body builds, heights and weights of subjects were not available to the writer.

Subjects were not evaluated as to physical fitness level prior to the time of testing and were not required to enroll in any off-

Definitions

The writer believes that the following definitions are necessary in order to attain a clearer understanding of the study.

1. Agility -- Agility is that quality which allows an individual to maintain balance, change body positions quickly, and have the speed to change body directions.[1]

2. Strength -- Strength is the capacity of an individual to exert muscular force.[2]

3. Performance time -- Performance time is defined as the time required for a subject to execute a prescribed and voluntary movement. No auditory stimulus was involved. Performance time should not be confused with reaction time.

---

[1] Douglas Lee Tschetter, "The Effects of Selected Football Drills on Agility," (M.S. Thesis, South Dakota State University, 1965), p. 3.

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

CHAPTER II

A REVIEW OF RELATED LITERATURE

A review of the literature related to agility revealed that the definition of agility varied according to the author or researcher. By examining the various definitions of agility, a broader scope of the term was established.

Clarke[1] defined agility as the speed in changing body positions or in changing directions. Barrow and McGee[2] thought of agility as the ability of the body or parts of the body to change directions rapidly and accurately. Tschetter[3] stated a complete and concise definition of agility in his study concerning agility. He defined agility as that quality which allows an individual to maintain balance, change body positions quickly, and have the speed to change body directions.

A variety of definitions appear in the literature associated with strength. Barrow and McGee[4] defined strength as the capacity of an individual to exert muscular force or the ability to apply force.

---

[1] H. Harrison Clarke, Application of Measurement to Health and Physical Education. (Englewood Cliffs: Prentice-Hall, Inc., 3rd. ed., 1959), p. 222.

[2] Barrow and McGee, loc. cit., p. 118.

[3] Tschetter, loc. cit.

[4] Barrow and McGee, op. cit., p. 115.

Hooks[1] said that strength of a muscle was the amount of force that a muscle was capable of exerting, such as pushing, pulling, gripping, or lifting. Clarke[2] discussed muscular strength as the maximum strength applied in a single muscular contraction. Morehouse and Miller[3] said that strength may be defined as the ability to exert tension against force.

In a study related to physical traits and agility, Jennett[4], in testing male athletes and non-athletes on twenty-five (25) different agility tests, concluded that performances in agility tests were accounted for, in part, by reaction time, speed of movement, strength, balance, change of positions, change of directions, and body size and form. Agility appeared to be comprised of many traits.

Tschetter[5] conducted an investigation to determine if agility was affected by an agility training program employing an agility maze, two man sled drills, and reaction drills. The conclusion from this study showed that the method of agility training employed was an effective method of increasing dynamic balance, but had no effect

---

[1]Gene Hooks, Application of Weight Training to Athletics, (Englewood Cliffs: Prentice-Hall, Inc., 1962), p. 12.

[2]Clarke, op. cit., p. 313.

[3]Laurence E. Morehouse and Augustus T. Miller, Physiology of Exercise. (St. Louis: The C. V. Mosby Company, 4th ed., 1963), p. 59.

[4]Clair W. Jennett, "An Investigation of Tests of Agility", (Ph. D. thesis, State University of Iowa, 1959).

[5]Tschetter, op. cit.

upon speed in changing body directions or quickness in changing body positions.

Keller[1] investigated the relation of quickness of bodily movement to success in athletics and concluded that there was a positive relationship between the ability to move the body quickly and success in athletic activities.

In reviewing the literature, the writer was not able to find studies that attempted to determine the degree of relationship, if any, between strength and agility. The above studies have suggested that agility probably consists of more than one trait, but to what degree remains unknown.

---

[1]Louis F. Keller, "The Relation 'Quickness of Bodily Movement' to Success in Athletics," Research Quarterly, XIII, (May, 1942), pp. 146-157.

CHAPTER III

PROCEDURE FOR OBTAINED DATA

Pre-Testing Considerations

The following procedures were considered important in conducting the tests involved in this study.

Pre-testing warm-up. Each subject should be required to execute a series of exercises prior to being tested. The exercises were as follows:

Jumping jacks
Bend and reach
Sit-ups
Push-ups
Stationary run

Testing sequence. Each subject should be tested in the following sequence in deference to fatigue factors.

Forearm Flexion Strength Test
Lower Leg Flexion Strength Test
Forearm Extension Strength Test
Lower Leg Extension Strength Test
Change of Direction Test
Quickness of Body Movement Test
Balance Test
Forearm Performance Time Test

Uniform. Each subject should be required to wear a uniform consisting of a T-shirt, gym shorts, athletic socks, and gym shoes.

Training of testers. All assistant testers should be given several training sessions, in order to familiarize them with all testing equipment and procedures that were to be followed.

Angle of testing. The angle at which each muscle group should be tested was considered along with the mechanical efficiency of muscles. Several studies were considered in determing the proper angle for each muscle group.

In the area of angle of testing and mechanical efficiency of muscles, Rasch[1] reported that muscle strength was the greatest during elbow flexion when the angle between the humerus and forearm was from eighty (80) to ninety (90) degrees. In elbow extension, the angle of one hundred and twenty (120) degrees produced the highest results. Rasch also found that subjects in the erect position showed the greatest strength of elbow flexion with the forearm in the mid-position, the least in the pronated position, and the intermediate in the supinated position.[2] Hunsicker and Greey[3] stated that the position of the body was an important consideration when administering strength tests. Morehouse and Miller[4] discussed the mechanical efficiency of muscles, stating that the angle of the pull by a muscle was affected by its attachment to the lever (bone). A pull at a right angle to the lever gives maximum mechanical efficiency. The closer

---

[1]Philip J. Rasch, "Effect of Position of Forearm on Strength of Elbow Flexion," Research Quarterly, XXVII, (June, 1956), pp. 333-37.

[2]Ibid.

[3]Paul Hunsicker and George Greey, "Studies in Human Strength," Research Quarterly, XXVIII, (March, 1957), pp. 109-22.

[4]Morehouse and Miller, op. cit. p. 81-2.

a load was placed to the fulcrum, the greater was the mechanical advantage.

The above pre-test considerations were deemed advisable and were so implemented.

Subjects

Subjects for the study were thirty (30) in number and members of the Eastern Illinois University varsity and non-varsity football squads. Subjects were volunteers and had participated in football during the 1966 seasons. The average group weight was 198 pounds and the average height was 71 inches.

Description of Test Administration and Test Apparatus

Forearm Flexion Strength Test. Forearm flexion was tested by the Elgin "Multiple Angle Testing Unit" (Figure 1). The individual was in a standing position, feet flat on the floor and spread about shoulder width. The elbows were in close proximity to the sides of the body. The hands grasped a six-pound bar to permit the subject to exert pressure against the Force Gauging System. A bevel square was used to check and adjust the angle of flexion between the humerus and the forearm prior to starting each trial. This angle was maintained at ninety (90) degrees. Each subject received three trials. The effort was read and recorded by the tester. The indicator on the Force Gauging System dial permitted scores to be recorded in increments of two pounds.

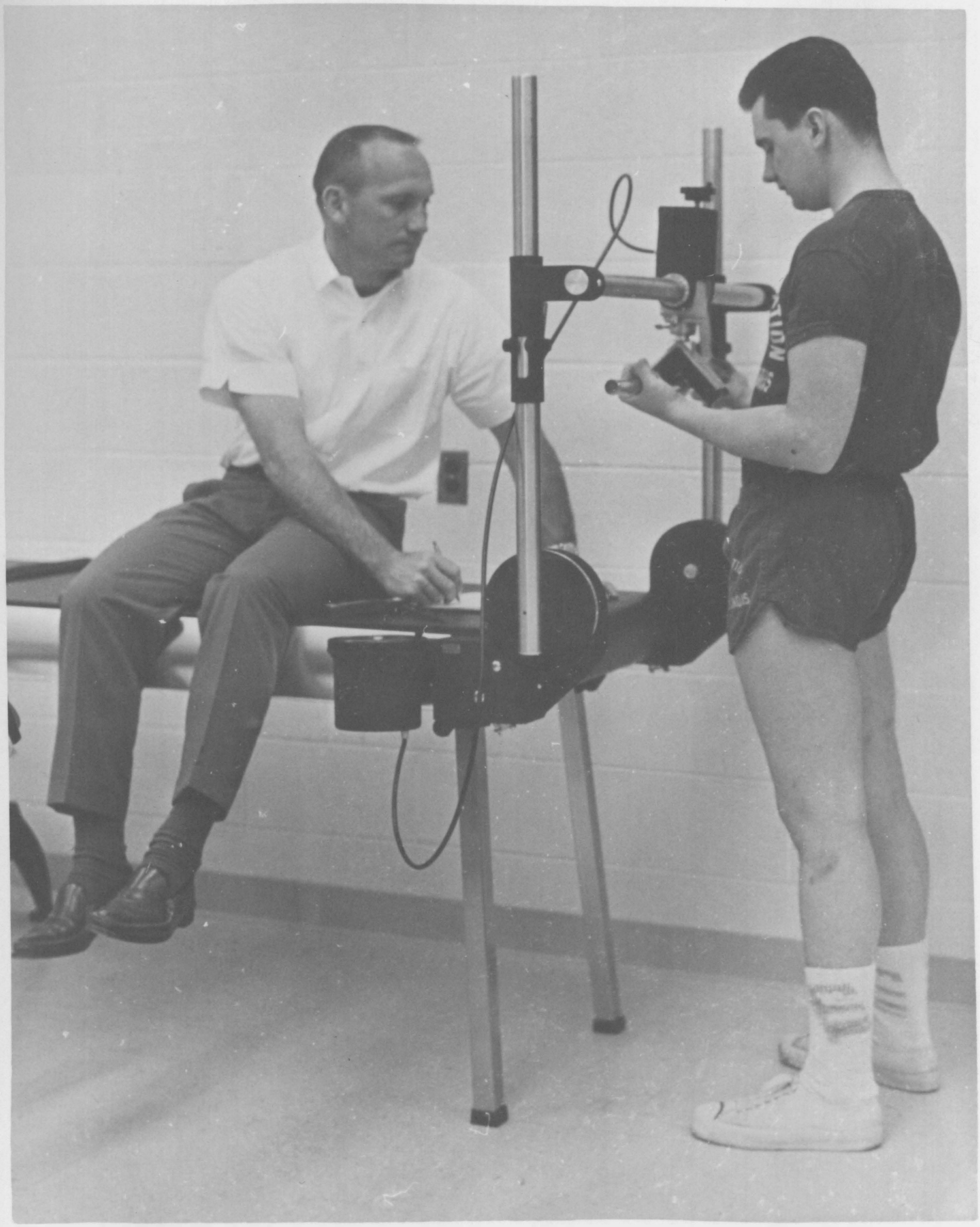

FIGURE 1. Strength Test: Forearm Flexion

Forearm Extension Strength Test. Forearm extension was tested on the Elgin "Multiple Angle Testing Unit" (Figure 2). The individual was tested in the supine position. The neck of each subject was placed over the end of the table in order that the subject's neck muscles could not be used. The arms of the testing unit were placed over the shoulders of the subject and the angle of extension between the forearm and humerus was adjusted at one hundred and twenty (120) degrees. The tester stood at the head of the subject and restricted the subject's elbows from abducting from the body and insure true extension of the forearm. Scoring was the same as in forearm flexion.

Lower Leg Flexion Strength Test. Lower leg flexion was tested by the Elgin Quadricep's and Hamstrings's Dynamometer (Figure 3). The subject was placed upon the table resting on his hands and knees. The Achilles tendon area was placed in the strap of the testing device. The angle between the femur and the lower leg was ninety degrees. The tester stood at the head of the subject, preventing the subject from leaning forward and destroying the testing angle. The scoring procedure remained the same.

Lower Leg Extension Strength Test. Lower leg extension was tested by the Elgin Quadricep's and Hamstrings's Dynamometer (Figure 4). The subject assumed a sitting position on the table. The lower leg was positioned ninety (90) degrees from the femur. The back of the

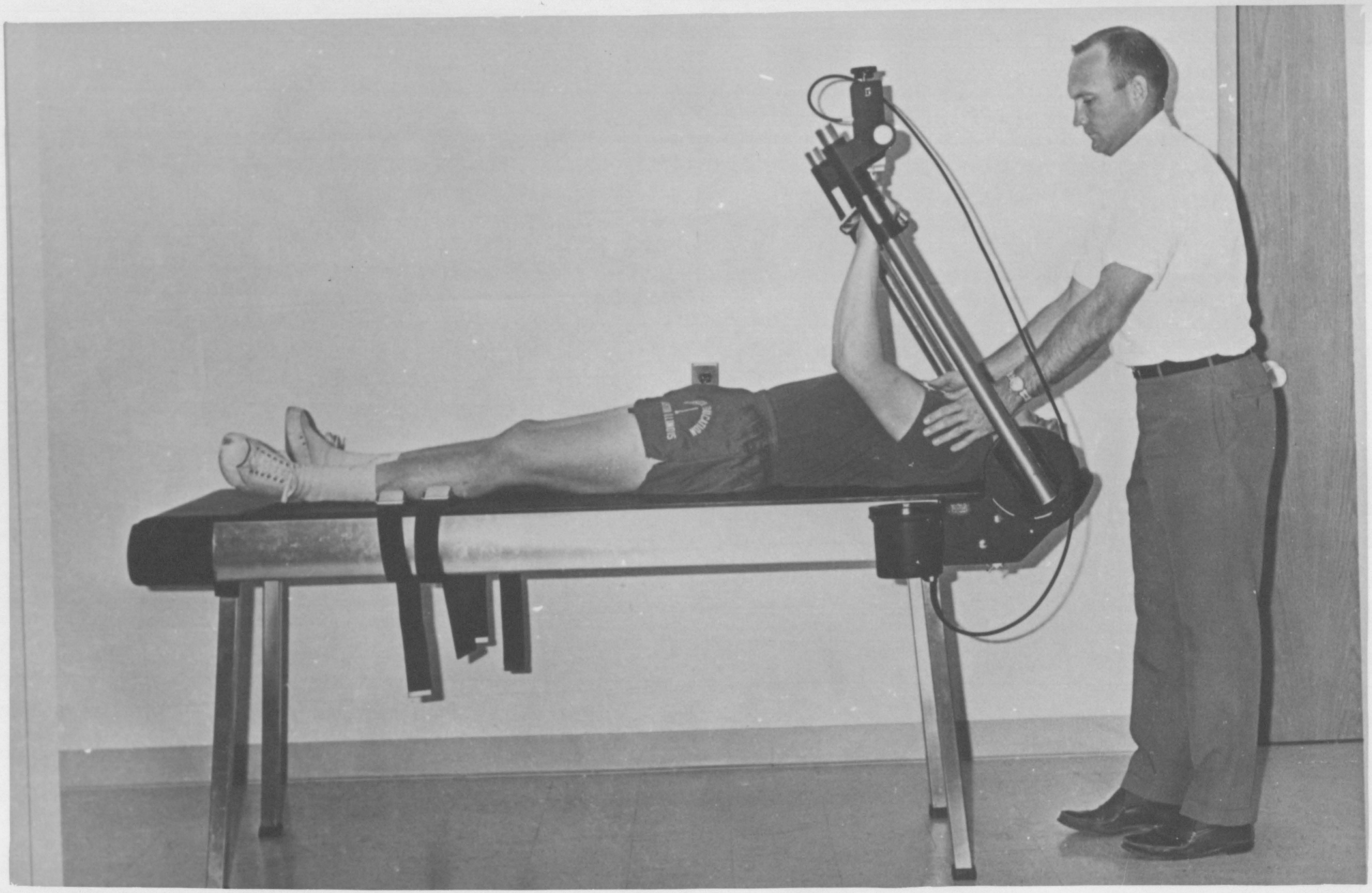

FIGURE 2. Strength Test: Forearm Extension

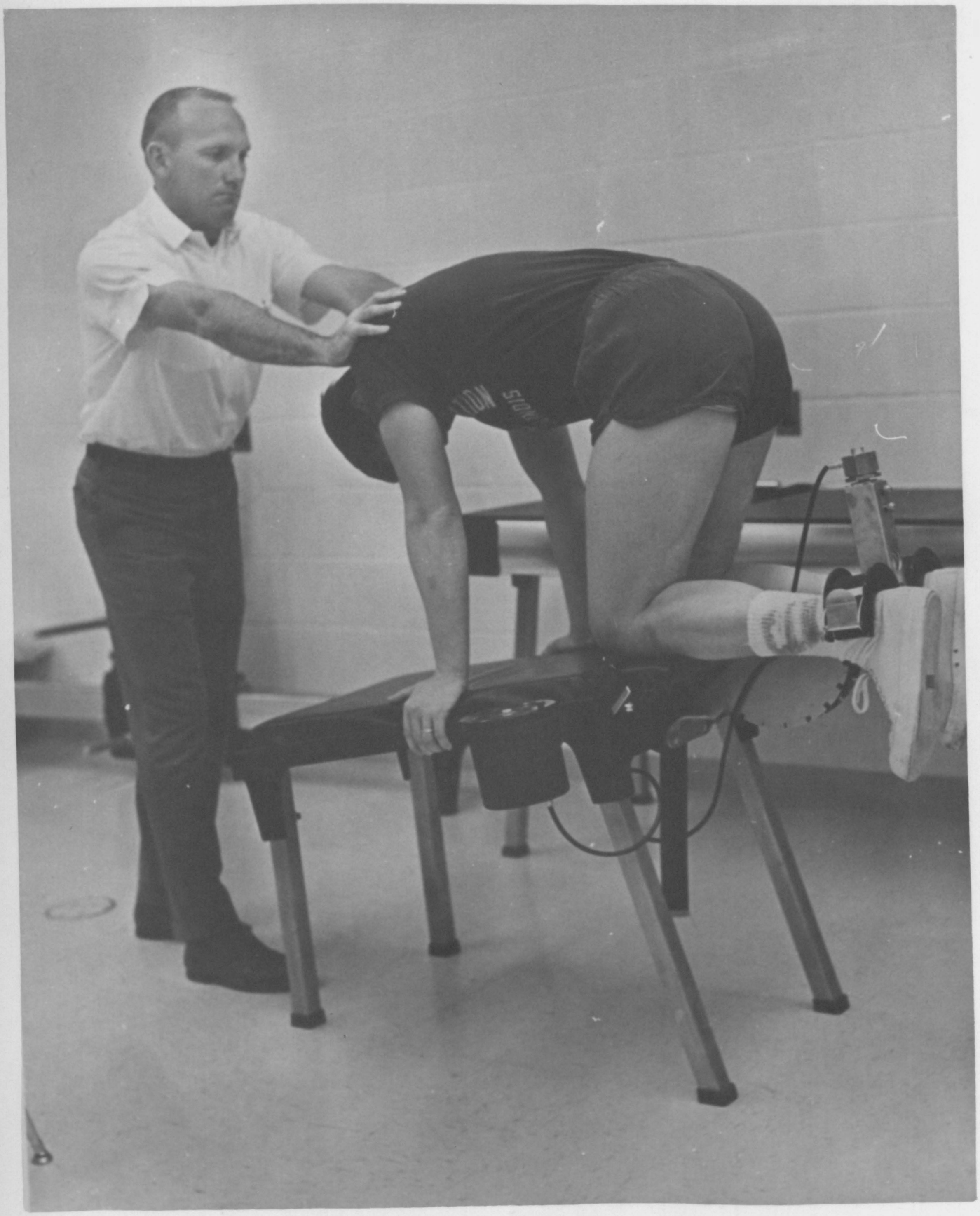

FIGURE 3. Strength Test: Lower Leg Flexion

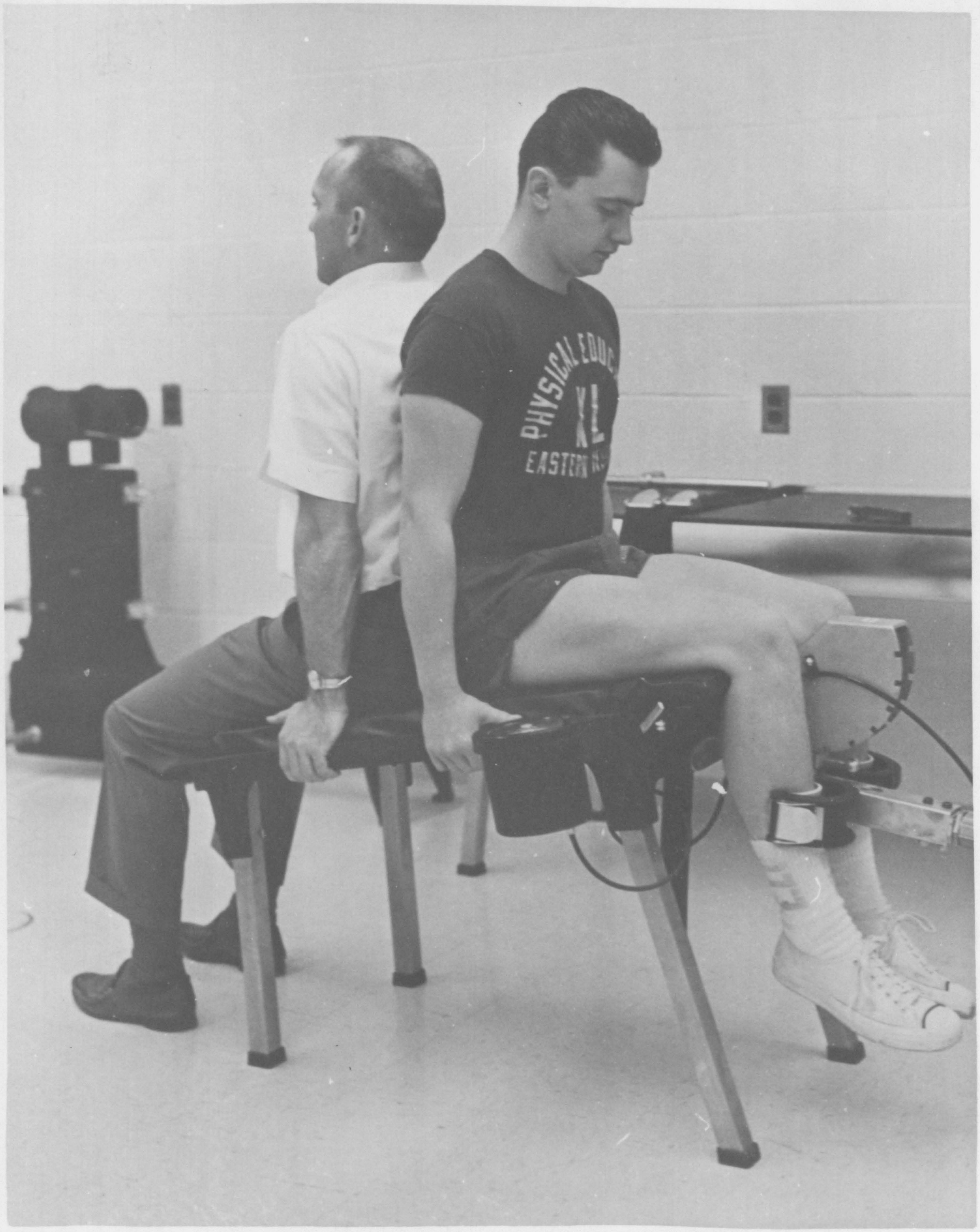

FIGURE 4. Strength Test: Lower Leg Extension

knee was flush with the edge of the table. Another person sat with his back against the back of the subject being tested to keep the subject from leaning backwards and using muscles other than those being tested. The hands could grasp the side edges of the table. The scoring procedure remained the same.

<u>Change of Direction</u>. The Penny Cup Test[1] was revised in order to measure direction change, one of the components of agility as defined in this study (Figure 5). The Penny Cup Test was converted to an electrically timed test and directional changes were given with a light stimulus controlled by a master control unit. In the test administration, the subject's performance time was measured by the Dekan Athletic Performance Analyzer and all readings were taken in hundredths of seconds. No auditory stimulus was used. Performers were allowed to start the test whenever ready. Direction lights, controlled by a three (3) position rotary switch, were placed behind each of three (3) termination pads and signified the direction the performer was to take. The termination pads were located with the center of the pad twelve feet straight ahead of the starting pad and the right and left pads at ninety degree angles to the center pad and eight feet away from the center pad. The tester, by use of a master control box, was able to control the functioning of the directional lights. The subject stood with his feet behind a starting line facing the direction of the test. When ready, the performer ran

---

[1]Donald K. Mathews. <u>Measurement in Physical Education</u>, (Philadelphia: W. B. Saunders Company, 1963), p. 172.

FIGURE 5. Change of Direction Test

forward, stepping on the starting pad which was eight feet from the starting line. As a result of stepping on the starting pad, the timer was started and one of the directional lights flashed on. Once leaving the starting pad, the performer moved as quickly as possible in the direction of the signified termination pad. The performer ended the trial by stepping on a termination pad, thus stopping the performance clock. The time to complete the test was recorded in hundredths of seconds. The directions of the test were thoroughly explained to each performer and each performer was given as many trials as necessary to execute the test properly. Eight trials were given to each subject for score. The arrangement of the trials was assigned by a table of random numbers. Four groups of random numbers were used and rotated among the subjects.

Quickness of Body Movement Test. The test used for measuring quickness of body movement, another component of agility, was the Pennybaker Prone to Standing Movement Test[2] (Figure 6). The test began with the subject in the prone position on the floor, arms and legs fully extended with the arms above the head and the toes pointed behind. The performer rested his dominant hand on a micro-switch. After removal of the hand from the micro-switch, the subject stood up as quickly as possible, ran around a chair, and stopped the performance clock by stepping on the termination pad. The time to complete the test was recorded in one-hundredths of a second (1/100).

---

[2]Dale A. Pennybaker, "An Investigation of Speed of Movement," (Ph. D. thesis, State University of Iowa, 1961). p. 18.

FIGURE 6. Quickness of Body Movement Test

Subjects were given a thorough explanation of the test and were allowed as many trials as necessary to execute the test properly. Three trials for score were given to each subject.

Balance Test. The Bass Dynamic Balance Test[3] was employed to test balance, the third component of agility (Figure 7). Circles, eleven in number, and nine and one-half inches in diameter, were drawn on the floor in keeping with the test description. The performer stood with his right foot in the starting circle, leaped into the first circle with his left foot, into the second circle with the right foot, and completed the test by alternating the feet and leaping from circle to circle. The test required the subject to leave the floor entirely in leaping from one circle to another, landing upon the ball of the foot and not permitting the heel to touch the floor. Subjects were to remain in the circle for as long as he could up to a maximum of five seconds. The tester counted off the seconds for each circle. The test required that if the performer leaped into the next circle before the count of five, the count began anew. If the performer remained in the circle more than five seconds, the extra time was deducted from the total time. Each subject was given three trials for score. Practice trials were permitted. The score recorded was fifty plus the number of seconds taken to negotiate the test, minus three times the "errors". The "errors" included the following:

---

[1]Ruth I. Bass, "An Analysis of the Components of Tests of Semicircular Canal Functions and of Static and Dynamic Balance," Research Quarterly, X, (May, 1939), pp. 33-52.

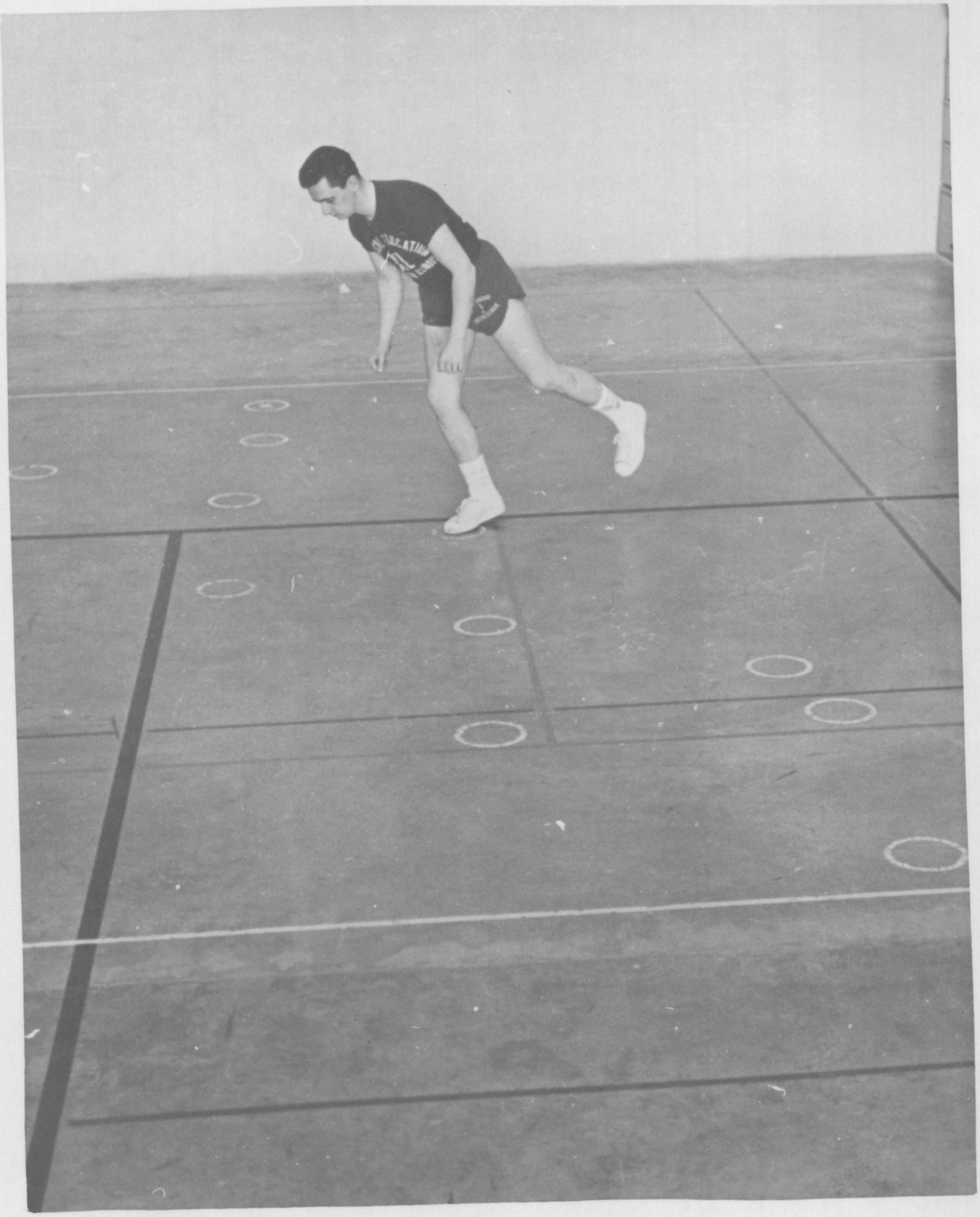

FIGURE 7. Balance Test

(1) touching the heel to the floor.
(2) moving the foot while standing in the circle.
(3) hopping upon the supporting foot.
(4) touching the floor outside the circle.
(5) touching the floor with the other foot.
(6) touching the floor with any other part of the body.

Three trials were given, and the average of the three was taken as the score. A minus score was recorded as zero. Each error counted as one point. Accumulative errors were computed by the use of a hand-tally register.

Forearm Performance Time (flexion and extension). Forearm performance time was tested in order to compare the time required to move the forearm from one position to another with the strength of that movement and the components of agility. Forearm performance time was measured by an apparatus constructed by the writer (Figures 8 and 9). The design of the apparatus permitted the tester to test both the left and right arms. The test itself consisted of depressing a switch, releasing it, and contacting another switch with the same hand. The timer did not start until the subject released the first switch and stopped whenever contact was made with the second switch. In the flexion test, the subject started with his forearm in the extended position and moved to the flexed position. Extension was tested by reversing two plug-ins on the Dekan timer. The subject then started in the flexed position and moved to the extended position. Each subject received as many practice trials as he desired. Three test trials in flexion and extension were recorded for each arm. Each trial was started by the subject whenever he was ready.

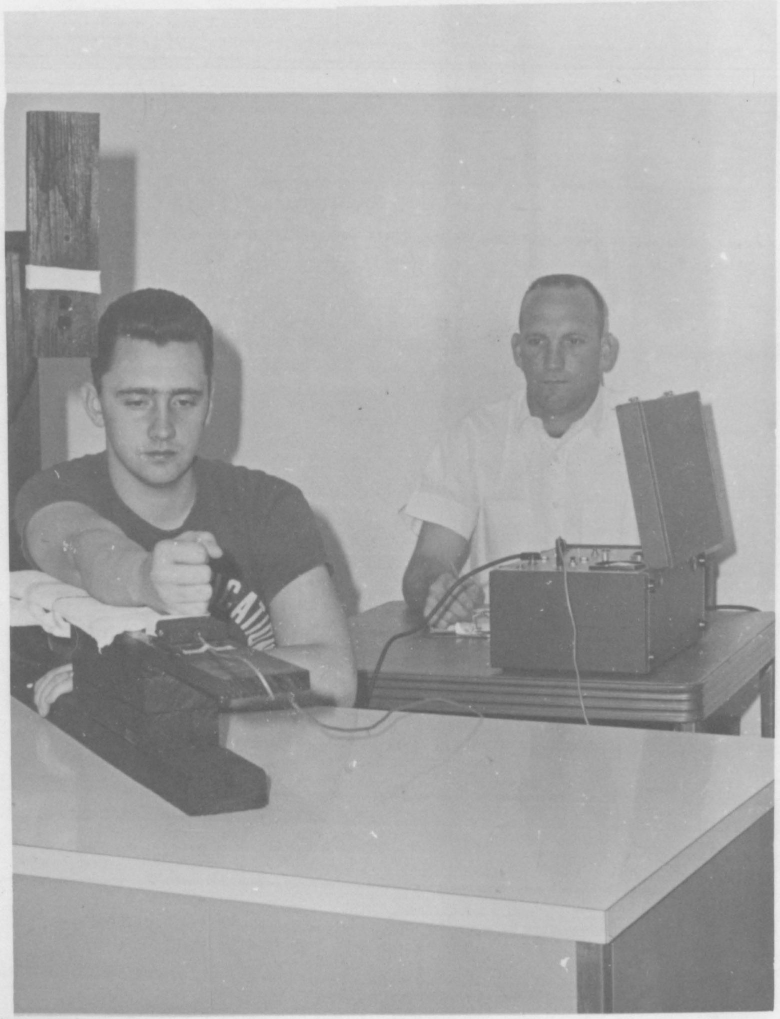

FIGURE 8

Forearm Performance Test: Flexion

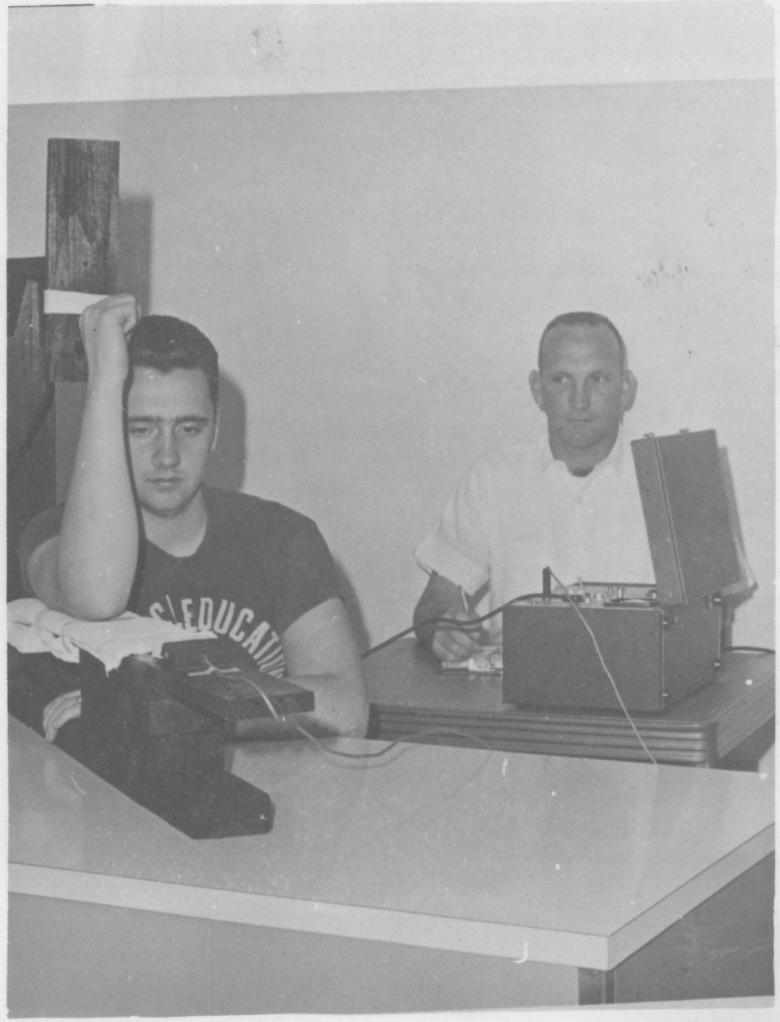

FIGURE 9

Forearm Performance Test: Extension

Subject Fatigue

The fatigue element from repeated maximal exertions of the forearm and lower leg muscles while possibly present, was minimized by spaced testing and, in addition, was equalized by systematically changing the muscle groups that were being tested. The three trials for each muscle groups were not considered severe enough to bring on fatigue.

CHAPTER IV

ANALYSIS OF DATA

Introduction

The purpose of this investigation was to determine the degree of relationship, if any, between strength in the flexor and extensor muscle groups of the forearm and lower leg as compared with (1) components of agility, (2) total body agility, and (3) forearm performance time.

Organization of Data

Strength tests. Each subject was given three (3) trials on each strength test. The highest score from each test was selected as the representative score for each subject. Data appears in Appendix A.

Total limb strength. Total limb strength was computed by adding the scores from each strength test. Data appears in Appendix A.

Change of direction test. Each subject was given eight (8) trials in this test. Three (3) trials were given to the left and right directional lights and two (2) trials were given to the center light. In the analysis of the data, the highest and the lowest score values were eliminated and the remaining six scores were averaged to determine a score for each subject. The raw scores were converted to z scores. The data appears in Appendix B.

Quickness of body movement test. Three (3) trials were given to each subject. In keeping with the test instructions, the scores were then added and the sum represented the score for each subject. The raw scores were converted to z scores. Data appears in Appendix B.

Balance test. Each subject received three trials. The scoring was fifty (50) plus the total number of seconds minus three times the "errors". The average of the three trials was computed for the statistical analysis. The raw scores were converted to z scores. Data appears in Appendix B.

Total body agility. The total body agility score was computed by finding the sum of the z scores from the change of direction test, quickness of body movement test, and the balance test. Data appears in Appendix B.

Forearm performance time. Three trials were given to each subject's right and left arm. The best effort for each forearm was selected and the average between the left and right arm was computed. The above procedure was applied to both extension and flexion. Data appears in Appendix C.

Reliability

The reliability coefficient for the Bass Balance Test[1] was

---

[1] Bass, op. cit. p. 38.

+.95 as reported by the orginal author. Another investigator, Tschetter[1], reported a reliability coefficient of +.87 for the Pennybaker Prone to Standing Movement Test. The original Pennyoup Test had a reliability coefficient of +.904[2]. Reliability coefficients for the remaining tests were not established. The following precautions and procedures were followed throughout the testing period in an attempt to obtain reliable results: training of assistant testers, written testing procedure for each testing station, standard score shoots for each testing station, practice trials, warm-up periods, electrical timers, and pre-arranged testing schedule.

Statistical Analysis

The data collected in this investigation were analyzed with a program developed by DiPietro, Meyerholtz, and LeDuc[3]. This program calculated the mean, standard deviation, and standard error of the mean for the variables and calculated the correlation coefficients between all variables and the number of sets of data used.

The scores representative of the variables were key punched on IBM cards and the IBM 1620 Computer calculated the correlation coefficients between the variables.

---

[1]Tschetter, _op_. _cit_. p. 20.

[2]Mathews, op. cit. p. 172.

[3]A. J. DePietro, Roy Meyerholtz, and Richard LeDuc, "Correlation Analysis for an Unfixed Number of Variables (Cards)." (Charlestion: Eastern Illinois University, July 15, 1964).

For the purpose of this study, the five (.05) per cent level of confidence with twenty-eight (28) degrees of freedom was used to determine if there was a statistically significant correlation between variables[1]. The coefficient correlation was required to be of greater magnitude than (+) or (-) .36 to be statistically significant.

Strength versus agility findings. Of the sixteen (16) correlations that were analyzed between strength and agility, only two produced coefficients of correlation beyond the .05 level of significance. The correlations are shown in Tables 1 and 2. Forearm strength flexion was correlated to quickness of body movement by a coefficient of +.44. The extensors of the lower leg had a correlation coefficient of +.41 with balance.

Forearm strength versus forearm performance time. When forearm strength was correlated with forearm performance time, the coefficients were not at the five percent level of significance or beyond. (Table 3)

Agility versus forearm performance time. When forearm performance time was compared with agility, there was a correlation coefficient of -.39 between forearm performance time (extension) and quickness of body movement. (Table 3) The correlation between forearm performance time (flexion) and change of direction was +.34. However,

---

[1] J. P. Guilford, *Fundamental Statistics in Psychology and Education.* (New York: McGraw-Hill Book Company, Inc., 1950), p. 610.

this coefficient was not large enough to be accepted at the five per cent level of confidence.

TABLE 1

CORRELATION COEFFICIENTS BETWEEN VARIABLES OF STRENGTH AND AGILITY

	F. F. STREN.	F. E. STREN.	L. L. FLEX. STREN.	L. L. EXTEN. STREN.	TOTAL LIMB STREN.	CHANGE OF DIRECT.	QUICK. OF BODY MOVE.	BAL-ANCE	TOTAL BODY AGILITY
Forearm Flexion Strength	----	+.38*	-.22	+.15	+.53**	-.16	-.44*	-.02	-.31
Forearm Extension Strength	+.38*	----	+.13	+.07	+.90**	-.08	+.14	-.03	+.04
Lower Leg Flexion Strength	-.22	+.13	----	+.13	+.31	+.20	+.29	-.07	+.24
Lower Leg Extension Strength	+.15	+.07	+.13	----	+.39*	-.24	+.15	+.41*	+.18
Total Limb Strength	+.53**	+.90**	+.31	+.39*	----	-.12	+.10	+.06	+.06

* = indicates statistically significant relationship at .05 level of confidence.

** = indicates statistically significant relationship at .01 level of confidence.

TABLE 2

CORRELATION COEFFICIENTS BETWEEN VARIABLES OF AGILITY AND STRENGTH

	F. F. STREN.	F. E. STREN.	L. L. FLEX. STREN.	L. L. EXTEN. STREN.	TOTAL LIMB STREN.	CHANGE OF DIRECT.	QUICK. OF BODY MOVE.	BAL-ANCE	TOTAL BODY AGILITY
Change of Direction	-.16	-.08	+.20	-.24	-.12	----	+.30	-.14	+.61**
Quickness of Body Movement	-.44*	+.14	+.29	+.15	+.10	+.30	----	+.14	+.61**
Balance	-.02	-.03	-.07	+.41*	+.06	-.14	+.14	----	+.51**
Total Body Agility	-.31	+.04	+.24	+.18	+.06	+.61**	+.61**	+.51**	----

* = indicates statistically significant relationship at .05 level of confidence.

** = indicates statistically significant relationship at .01 level of confidence.

TABLE 3

CORRELATION COEFFICIENTS BETWEEN VARIABLES OF FOREARM STRENGTH, AGILITY, AND FOREARM PERFORMANCE TIMES

	Forearm Performance (flexion)	Forearm Performance (extension)
Forearm Flexion Strength	-.03	+.25
Forearm Extension Strength	-.08	+.15
Change of Direction	+.34	-.01
Quickness of Body Movement	-.16	-.39*
Balance	+.24	+.04
Total Body Agility	+.06	-.20

* = indicates statistically significant realtionship at .05 level of confidence.

Summary of Findings

In summarizing the results obtained, it was noted that there was a significant relationship between strength in the extensors of the lower leg and dynamic balance, one of the components of agility. There was a significantly inverse relationship between strength in the flexors of the forearm and quickness of body movements, another component of agility.

Forearm performance time (extension) had a significantly inverse relation to quickness of body movement.

Discussion of Findings

The writer found that the relationship between strength in the extensors of the lower leg and balance to be significant, however; this relationship was expected due to the design of the experiment. The test for balance required the subject to leap from one circle to another and the ability to control one's balance seemed to depend upon his strength in the extensors of the leg.

The inverse relationship between strength in the flexors of the forearm and quickness of body movement may indicate that strength in this particular muscle group does not improve one's ability to move the body quickly. The writer did not expect the results to come out in this manner because upon analysis of the test employed to measure quickness of body movement, it appeared that the first group of muscles to be used would be the flexors of the forearm, therefore; an expectation that the relationship would be positive.

The inverse relationship between forearm performance time (extension) and quickness of body movement could be expected due to the techniques normally followed by the subjects whenever performing in the quickness of body movement test. The subjects appeared to be flexing the forearm first when moving their body from the prone position to an upright position.

An interesting relationship occurred between strength in the extensors of the forearm and total limb strength. Forearm extension, with a coefficient of +.90, appears to be the best single indicator of total limb strength.

All of the agility tests had a high coefficient of correlation with total body agility, possibly indicating that the tests were, in general, measuring similar abilities.

Although this study did not show a significant degree of relationship between strength, as measured, in the flexors and extensors of the forearm and agility, one should not assume that strength was not important to agility. This study considered only the strength in the limbs of the body and this suggests that (1) agility might be derived from strength provided in other parts of the body, and (2) strength might be important to agility to a degree beyond which it may not play a part.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was undertaken in an attempt to determine the degree of relationship, if any, between strength in selected muscle groups as compared with (1) components of agility, (2) total body agility, and (3) forearm performance time. Agility was defined as that quality which allows an individual to maintain balance, change body positions quickly, and have the speed to change body directions.

Thirty male subjects, volunteers from the Eastern Illinois University varsity and non-varsity football teams, were used for the study. Strength of the flexors and extensors of the forearm and lower leg was measured by the Elgin dynamometer. Agility was measured by three tests: (1) The Revised Pennycup Test was used to measure change of direction; (2) The Pennybaker Prone to Standing Movement Test was used to measure quickness of body movement; and (3) The Bass Dynamic Balance Test was used to measure balance. Forearm performance time was measured by an apparatus constructed for that purpose. The Dekan Automatic Performance Analyzer, accurate to one/one hundredth (1/100) of a second, was used in the time measurements.

The data presented in the Appendixes were key punched on IBM data cards. The statistical analysis was done by an IBM 1620 Computer with a program designed to calculate the correlation coefficients be-

tween the variables in the study. Level of confidence was set at five per cent with twenty-eight (28) degrees of freedom.

Conclusions

The following conclusions are presented as a result of the experiment:

1. There is a significant relationship between lower leg extension and balance, and there is a significant inverse relationship between (1) strength in forearm flexion and quickness of body movement, and (2) forearm performance (extension) and quickness of body movement.

2. There is not a significant relationship between strength as measured and total body agility. Nor is there a significant relationship between strength in the flexors and extensors of the forearm and forearm performance times (flexion and extension).

Recommendations

Further studies similar to the one presented by the writer should be undertaken using a larger number of subjects with an equal distribution of body builds, heights, and weights. Also, a control group should be used in a study using a combination agility and weight training program.

APPENDIX

APPENDIX A

RAW DATA: STRENGTH SCORES (POUNDS)

SUBJECT	FOREARM FLEXION	FOREARM EXTENSION	LOWER LEG FLEXION	LOWER LEG EXTENSION	TOTAL LIMB STRENGTH
1	90	160	136	168	554
2	98	166	150	150	564
3	130	252	140	164	686
4	76	184	138	160	558
5	94	152	124	148	518
6	100	152	102	152	506
7	114	140	118	194	666
8	100	194	136	176	606
9	114	144	150	152	560
10	124	324	148	168	764
11	120	186	138	202	646
12	102	148	148	166	564
13	122	270	152	176	720
14	110	250	120	140	620
15	118	196	110	204	628
16	118	218	144	196	676
17	88	142	158	172	560
18	80	158	162	198	598
19	106	238	146	164	654
20	120	242	140	160	662
21	90	190	132	154	566
22	110	244	132	154	640
23	110	200	138	170	618
24	76	231	155	184	646
25	92	300	150	174	716
26	76	228	162	164	630
27	112	208	150	176	646
28	120	242	156	178	696
29	120	212	142	172	646
30	96	236	146	162	640

APPENDIX B

RAW DATA: SCORES AND Z-SCORES

SUBJECT	CHANGE OF DIRECTION SECONDS	CHANGE OF DIRECTION Z-SCORE	QUICKNESS OF BODY MOVEMENT SECONDS	QUICKNESS OF BODY MOVEMENT Z-SCORE	BALANCE TEST POINTS	BALANCE TEST Z-SCORE	TOTAL AGILITY Z-SCORE
1	.01:08	1.967	.01:92	.348	78	-.791	1.524
2	.01:13	1.274	.02:03	-.534	79	-.699	.041
3	.01:20	.305	.01:95	.107	82	-.422	-.010
4	.01:23	-.111	.01:96	.027	97	.963	.879
5	.01:23	-.111	.02:05	-.694	73	-1.253	-2.058
6	.01:18	.582	.02:02	-.454	95	.778	.906
7	.01:20	.305	.01:90	.508	96	.871	1.684
8	.01:22	.028	.01:98	-.133	93	.594	.489
9	.01:30	1.080	.02:09	-1.015	60	-2.453	-2.388
10	.01:25	-.388	.02:17	-1.657	79	-.699	-2.744
11	.01:24	-.249	.01:97	-.053	93	.594	.292
12	.01:30	-1.080	.01:99	-.213	87	.040	-1.253
13	.01:18	.582	.02:10	-1.095	89	.224	-.289
14	.01:29	-.942	.01:91	.428	66	-1.899	-2.413
15	.01:41	-2.604	.02:17	-1.657	96	.871	-3.390
16	.01:16	.859	.01:82	1.150	84	-.273	1.736
17	.01:20	.305	.02:02	-.454	100	1.240	1.091
18	.01:33	-1.496	.01:90	.508	87	.040	-.948
19	.01:17	.720	.02:04	-.614	73	-1.253	-1.147
20	.01:29	-.942	.02:06	-.775	100	1.240	-.477
21	.01:20	.305	.02:04	-.614	69	-1.622	-1.931
22	.01:25	-.388	.01:88	.669	93	.594	.875
23	.01:14	1.136	.01:90	.508	95	.778	2.422
24	.01:17	.720	.01:74	1.791	84	-.237	2.274
25	.01:18	.582	.01:75	1.711	88	.132	2.425
26	.01:13	1.274	.01:64	2.593	94	.686	4.553
27	.01:22	.028	.01:88	.669	100	1.240	1.937
28	.01:29	-.942	.01:92	.348	83	-.330	-.924
29	.01:13	1.274	.02:09	-1.015	97	.963	1.222
30	.01:30	-1.080	.02:08	-.935	81	-.514	-2.529

APPENDIX C

RAW DATA: FOREARM PERFORMANCE TIME (HUNDREDTHS OF A SECOND)

SUBJECT	FLEXION	EXTENSION
1	:13.0	:14.0
2	:12.0	:11.5
3	:11.5	:13.0
4	:14.5	:15.0
5	:12.0	:15.0
6	:14.0	:13.5
7	:13.0	:13.0
8	:10.5	:11.5
9	:12.0	:12.5
10	:12.5	:15.5
11	:10.5	:12.0
12	:12.5	:12.5
13	:12.5	:14.5
14	:11.5	:12.5
15	:12.5	:13.5
16	:12.0	:13.0
17	:12.5	:12.5
18	:12.5	:13.5
19	:12.0	:13.0
20	:12.5	:12.0
21	:12.0	:13.0
22	:12.0	:12.0
23	:14.0	:13.5
24	:11.5	:10.5
25	:13.0	:13.0
26	:11.0	:12.0
27	:12.0	:12.5
28	:14.0	:15.5
29	:13.5	:16.5
30	:12.0	:13.0

BIBLIOGRAPHY

BOOKS

Barrow, Harold M., and McGee, Rosemary. *A Practical Approach to Measurement in Physical Education.* Philadelphia: Lea and Fibiger, 1964.

Clarke, H. Harrison. *Application of Measurement to Health and Physical Education.* Englewood Cliffs: Prentice-Hall, Inc., 1959.

Guilford, J. P. *Fundamental Statistics in Psychology and Education.* New York: McGraw-Hill Book Company, 1950.

Hooks, Gene. *Application of Weight Training to Athletics.* Englewood Cliffs: Prentice-Hall, Inc., 1962.

Mathews, Donald K. *Measurement in Physical Education.* Philadelphia: W. B. Saunders Company, 1963.

Merriam and Webster. *Webster's Seventh New Collegiate Dictionary.* Springfield, Mass.: G. and C. Merriam, 1965.

Turabian, Kate L. *A Manual for Writers of Term Papers, Theses, and Dissertations.* Chicago: The University of Chicago Press, 1955.

PUBLISHED MATERIAL

Bass, Ruth I. "An Analysis of the Components of Tests of Semicircular Canal Functions and of Static and Dynamic Balance," *Research Quarterly*, X (May, 1939), 33-52.

Hunsicker, Paul, and Greey, George. "Studies in Human Strength," *Research Quarterly*, XXVIII (March, 1957), 109-22.

Jennett, Clair W. "An Investigation of Tests of Agility," Ph. D. Thesis, State University of Iowa, 1959.

Keller, Louis F. "The Relation 'Quickness of Bodily Movement' to Success in Athletics," *Research Quarterly*, XIII (May, 1942), 146-157.

UNPUBLISHED MATERIAL

DiPietro, A. J., Meyerholtz, Roy, and LeDuc, Richard. "Correlation

Analysis for an Unfixed Number of Variables (Cards)," Charleston, Illinois: Eastern Illinois University, July 15, 1964.

Pennybaker, Dale A. "An Investigation of Speed of Movement," Ph. D. Thesis, State University of Iowa, 1961.

Tschetter, Douglas Lee. "The Effects of Selected Football Drills on Agility," M. S. Thesis, South Dakota State University, 1965.

VITA SHEET

The writer was born in McLeansboro, Illinois on May 20, 1939. He attended Broughton Grade School in Broughton, Illinois and Moweaqua High School in Moweaqua, Illinois. The writer received his Bachelor of Science degree from Eastern Illinois University in May of 1962 with a major in physical education and a minor in social studies. In August of 1966, the writer entered graduate school at Eastern Illinois University. He received his Master of Science in Education degree in August of 1967. In August of 1967, the writer will be teaching and coaching at Kaneland High School in Maple Park, Illinois.