ANALYSIS OF THE RELATIONSHIP OF SELECTED ABILITIES TO PERFORMANCE ON A GROSS MOTOR TASK AT VARIOUS STAGES OF TASK PRACTICE

DISSERTATION

Presented to the Graduate Council of the North Texas State University in Partial Fulfillment of the Requirements

For the Degree of

DOCTOR OF EDUCATION

By

John P. Raducha, B. S., M. S.
Denton, Texas
December, 1970

The problem with which this investigation was concerned was that of determining the relationship of selected abilities to motor skill performance. Specifically this study analyzed the performance trend on a gross motor task to determine the degree of relationship between the abilities: agility, balance, depth perception, flexibility, reaction time and speed of arm movement, and strength and performance scores on a wall volley task at successive stages of task practice.

One hundred and two male freshman and sophomore students enrolled in physical education activity classes at North Texas State University served as subjects for this study. Each subject took six ability tests: The Side Step Test for agility, The Bass Stick Test for balance, The Howard-Dolman Depth Perception Apparatus for depth perception, Fleishman's Bend, Twist, and Touch Test for flexibility, The Hand Dynamometer for grip strength, and a reaction time and speed of arm movement test.

Each subject performed fifty trials of a wall volley task that involved hitting for speed and accuracy with a wooden paddle and a tennis ball. The scores collected from
the fifty trials were grouped into ten stages of practice. The score for each stage of practice consisted of the sum of the scores for each of five trials.

The data were analyzed for the total sample population and for four skill level groups. The four groups, quarters of the total sample population, were determined on the basis of the total score for the last five trials of the gross motor task.

A linear stepwise multiple regression was used to determine the relationship between the six abilities measured and performance on the wall volley task at the succeeding stages of practice to determine if there was a systematic change in the abilities that contributed to motor performance as task performance improved. The significance of a predictor as it was added to the regression equation was tested with an $F$ ratio and was accepted at the .05 level of significance. A Fisher's $t$ test was applied to determine the significance of the difference between the mean scores of the four skill level groups on the six ability measures and on the wall volley scores at the ten stages of practice. Differences were accepted at the .05 level of significance.

Based upon the findings of the study the following conclusions were drawn.

1. For college students the abilities that contribute to early stage performance are the same as those abilities that contribute to late stage performance on a wall volley task.
2. Knowledge of the abilities that are primary predictors of wall volley performance for the total sample population cannot be generalized to individual skill level groups within the total sample population. The abilities that are primary predictors of wall volley performance for a total sample population are not the primary predictors for specific skill level groups.

3. When individual ability level groups have been selected on the basis of their performance scores for the final stage of practice on a wall volley task, a convergence of the individual ability level performance curves does not take place. The curves will be similar in shape; however, significant differences will exist between the ability level groups at succeeding stages of task practice.
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CHAPTER I

INTRODUCTION

Two individuals can go through extensive sports skill practice. One may become a highly skilled athlete whereas the other person may never advance beyond the intermediate stage. Individual differences in motor performance do exist and physical educators have long been perplexed by the phenomenon, motor learning.

The progress in the physical educators' investigation of motor learning and skill acquisition has been somewhat sporadic, but a trend now appears to be evident. The past ten years have evidenced that physical educators are utilizing a multi-disciplinary approach in an effort to understand individual differences in motor skill performance and understand why these differences exist. One area which has received considerable attention is the relationship of human abilities to motor learning. A number of researchers have studied this subject but many of the studies deal with the relationship of abilities to performance on fine motor skills. It appears a more complete understanding of motor skill acquisition could be attained by investigation of the relationship of abilities with performance on gross motor tasks. This study was intended to provide additional
information about the relationship of abilities to performance on a gross motor task with extended practice on that task.

Statement of the Problem

The problem with which this investigation was concerned was that of determining the relationship of selected abilities to motor skill performance.

Purposes of the Study

The purpose of this study was to gain further information concerning the relationship of perceptual motor abilities to performance on gross motor tasks. Specifically, this study analyzed the performance trend on a gross motor task in order to determine the degree of the relationship between selected abilities and gross motor task performance scores at successive stages of task practice in an attempt to answer these questions:

1. Will there be a change in the combination of abilities contributing to task performance with extended task practice?

2. Will the change of abilities contributing to task performance be systematic and progressive?

3. Will there be a systematic change in the proportion of variance unaccounted for at each stage of task performance as practice continues?
4. Will the relationships between abilities and task performance follow the same trend for individuals at four different levels of performance as determined by performance scores on the last stage of task practice?

To accomplish the purpose of this study the following relationships were determined. The relationship was determined between the performance score on each successive stage of practice on a gross motor task and the following ability measures:

1. Agility as measured by the Side Step Test.
2. Balance as measured by the Bass Stick Test.
3. Depth Perception as measured by the Howard-Dolman Depth Perception Apparatus.
4. Flexibility as measured by Fleishman's Bend, Twist, and Touch Test.
5. Reaction time and speed of arm movement as measured by the Marietta Apparatus Company 11-1 Reaction Time Box and Timer.
6. Strength as measured by the Narragansett Hand Manometer.

Background and Significance

Motor learning and motor performance are very important factors in the educational setting today and their importance is recognized by many academic disciplines. Students are frequently required to perform motor tasks in typing classes,
industrial arts, music, and in physical education. In the educational setting today a large percentage of the student's academic day is spent in classes where the learning and performing of motor skills is essential.

The field of physical education is primarily concerned with gross motor learning, learning that involves movement of the large skeletal muscles. Considerable research in physical education has been conducted in an effort to find solutions to the problems involved in the learning of motor skills. Brace\(^1\) initiated an approach to motor learning with an investigation that was concerned with identifying the basic abilities which appeared to contribute to performance of gross motor tasks. It was his concept that an individual's aptitude for motor performance was approximately the same for all types of motor skills. The viewpoint espoused was that such general abilities were basic prerequisites needed to perform motor tasks and individuals who held high degrees of these abilities could learn to successfully perform any motor task.

Several authors have utilized factorial studies in an effort to isolate these basic motor abilities. Although there is some variation in the names given to these abilities there is some agreement as to the abilities that appear

to be contributing to motor performance. McCloy surveyed the early factorial studies, analyzed the abilities that were reported and concluded that ten abilities contributed to gross motor performance. He concluded these factors were strength, dynamic strength or energy, ability to change direction, flexibility, agility, peripheral vision, good vision, concentration, understanding the mechanics of movement, and absence of disturbing emotional complications. Cumbee identified five factors which he called balancing objects, tempo, two-handed agility, speed of change of direction of the arms and hands, and body balance. Guilford evolved seven psychomotor factors he felt would underlie gross motor performance and these he classified as strength, impulsion, speed, static precision, dynamic precision, coordination, and flexibility. Fleishman, Thomas, and Munroe in a factor analysis study identified six primary


5 Edwin A. Fleishman, Paul Thomas, and Philip Munroe, "The Dimensions of Physical Fitness--A Factor Analysis of Speed, Flexibility, Balance, and Coordination Tests," The Office of Naval Research, Department of Industrial Administration and Department of Psychology, Technical Report No. 3 (Yale University, New Haven, Conn., September, 1961).
factors of gross motor performance; speed-of-change-of-direction, gross body equilibrium, balance with visual cues, dynamic flexibility, extent flexibility, and speed of limb movement. Clarke identified nine abilities that underlie motor ability which he entitled arm-eye coordination, muscular power, agility, muscular strength, muscular endurance, circulo-endurance, flexibility, speed, and foot-eye coordination.

A multiplicity of research has been conducted with these abilities to learn more about their relationship to motor performance. Gagne and Fleishman state some of the abilities are the products of environment and may develop at differential rates while others depend more upon hereditary influences. The role of environment as opposed to heredity upon the development of abilities cannot be clearly dichotomized but it is assumed most abilities depend upon both to some degree. The abilities appear to be fairly enduring traits. Most of these abilities can be improved and improvement of these abilities will result in improved motor performance.

Continued research on the nature of motor learning in the past twenty years has uncovered information that further explains the complexity of motor performance. Studies


conducted by Fleishman, dealing entirely with fine motor tasks, suggest that the pattern of abilities determining proficiency in perceptual motor skills changes as a function of practice. Abilities that contribute a larger percentage of variance at one stage of practice may have a smaller percentage of variance at another stage. The same abilities are probably present in all stages of practice but there is a systematic change in the importance of their contribution in the successive stages of practice.

Many of the studies relating to analysis of abilities contributing to performance of motor skills at various stages of practice have been conducted with fine manipulative motor tasks. Scores obtained for the abilities analyzed in these studies were obtained by tests designed to measure manipulative and manual abilities. Hempel and Fleishman conducted a study in which the findings may reflect the need for research specific to gross motor skill performance. In an effort to determine the interdependence of abilities contributing to individual differences in skill performance they used a factor analysis technique to analyze forty-six tests that fall into three general categories: manipulative

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tests, printed tests, and gross physical performance tests. They found that abilities contributing to performance on gross motor tasks were independent of abilities contributing to performance on fine manipulative tasks. There were no overlapping factors.

If physical educators are to understand the phenomenon of gross motor learning, the structure of gross motor performance based upon measures of gross motor abilities should be analyzed. Information gained from research of this nature should be valuable in the development of skill tests for physical education. The tests currently used for measuring sports skills have not been successful in predicting playing ability at advanced levels. In most cases the current skill tests have been standardized using novice or intermediate players. This could account for their lack of predictive ability. If the abilities contributing to task performance in early stages of skill proficiency are different from those abilities contributing to later stages of skill proficiency it can be understood why the existing tests lack predictive ability. The test items that are discriminatory in early skill acquisition may not contain or sample the abilities that are necessary for discrimination at later stages. Similarly, those test items excluded from the test battery because of insignificant validity evidence when measured against immediate criteria measures may contain significant validity evidence for proficiency at advanced skill levels.
Understanding skill structure of motor tasks in motor learning has an important implication for the classroom teacher. At the time when certain abilities are contributing to performance on a motor task the educator can place emphasis on developing those proper abilities. Supplemental skills which would further develop these abilities could be provided. The educator should also have knowledge about the length of time to be spent on developing certain abilities. Overemphasis or underemphasis on some abilities may not be deleterious to skill learning but it could cause wasted efforts for the educator.

Additional information concerning the relationship of selected abilities to performance on a gross motor task at various stages of task practice should provide a more complete understanding of motor performance. The results of the present study should provide information which can serve as a basis for further comprehensive investigation of the problem.

Definition of Terms

The terms used in this study are defined as follows:

1. **Ability** refers to a basic trait of motor skills which has appeared to be consistently related to motor performance.

2. **Agility** refers to the rapidity with which a person can make repeated lateral movements of the body. For this study, agility was measured by the Side Step Test.
3. **Balance** is the ability to maintain a stationary position for a length of time while standing on one leg. For this study static balance was measured by the Bass Stick Test.

4. **Depth Perception** is the ability to discriminate the third dimension, to judge distance, and to orient oneself in relation to other objects within the visual field.\(^{10}\) Depth perception was measured by the Howard-Dolman Depth Perception Apparatus.

5. **Flexibility** refers to the ability to make repeated trunk stretching and twisting movements. For this study flexibility was measured by Fleishman’s Bend, Twist and Touch Test.

6. **Gross Motor Skill** is a skill that involves movement of the large muscle groups. The gross motor skill in this study was the wall volley task.

7. **Motor Performance** is movement behavior that is immediate and short term in nature and is goal directed.

8. **Motor Skill** refers to the level of proficiency that is attained on a specific motor task.

9. **Reaction Time and Speed of Arm Movement** refers to the time required for a person to react to a visual stimulus and the time required for the arm to move a given distance. In this study reaction time and speed of arm movement were

reported as a combined score. Measurement of reaction time and speed of arm movement was recorded by using the Marietta Apparatus Company 11-1 Reaction Time Box and Timer.

10. Strength is the muscular force exerted against a measuring instrument. Strength was measured by the Narragansett Hand Manometer.

Limitations of the Study

This study was limited to male freshman and sophomore students enrolled in the physical education activity classes at North Texas State University meeting on Tuesday and Thursday of each week during the 1970 spring semester.

Basic Assumption

It was assumed that the subjects involved in this experiment would cooperate and provide an honest effort on the test items and practice trials of the gross motor task.

Procedures

The study was conducted during the spring semester of 1970, at which time six sections of Physical Education 116 at North Texas State University were utilized in obtaining subjects to participate in the study. The students selected for the study met for the testing session and skill practice sessions during their regularly scheduled class time. To insure adequate contact time only those students enrolled in Tuesday and Thursday physical education classes were considered as subjects for the study.
Tests used to measure the abilities selected for the study were administered to the subjects. These tests were: the Side Step Test for agility, the Bass Stick Test for balance, the Howard-Dolmen Depth Perception Apparatus for depth perception, Fleishman's Hand, Twist and Touch Test for flexibility, Harracassett Hand Manometer for grip strength, and the Marietta Apparatus Company 11-1 Reaction Time Box and Timer for reaction time and speed of arm movement.

The subjects then met with the investigator for two separate sessions. During the two meetings each subject performed a total of fifty trials of a novel gross motor task that involved hitting for speed and accuracy. Each subject completed twenty-five trials of the motor task in each session. The novel gross motor task performed by the subjects was a wall volley task.

The scores collected from the fifty trials were then grouped into ten stages of practice. The score for each stage of practice consisted of the sum of the number of seconds for each of five trials. Stage one was the first five trials, stage two was the second five trials, and so on to stage ten which constituted the last five trials.

In addition to analyzing the data for the total group, the relationship between ability measures and task performance scores was analyzed for four ability groups. The four groups were determined on the basis of the total score for the last five trials of the gross motor task.
The combined action of the abilities in predicting performance on the gross motor task was determined by utilizing a stepwise multiple regression analysis. The regression analysis was computed at each stage of practice. The statistical findings for each stage of practice are reported in appropriate tables.
CHAPTER II

REVIEW OF THE LITERATURE

This study was concerned with the relationship of selected abilities to performance on a gross motor task at successive stages of task practice. In this chapter a review of the literature is covered for seven areas. Initially investigations dealing with the relationship of abilities to performance on motor tasks and motor skills are presented. This is followed by a review of the research for the six abilities: agility, balance, depth perception, flexibility, reaction time and speed of arm movement, and strength, and their relationship to motor performance. Only a cursory review of the literature for the six abilities is presented. However, the emphasis is placed upon providing information that shows the importance of each of these abilities individually in their relationship to motor performance.

Relationship of Abilities to Performance on Motor Tasks

An approach that is used to understand motor skill acquisition is through the study of the relationship of human abilities to motor performance. Human abilities are studied by analyzing individual differences in motor performance and then the structure of abilities is studied by
examining the correlation between abilities and performance on various skills or tasks. The examination of these correlations makes it possible "... to determine what latent structure lies behind the correlation, and it is possible to interpret this latent structure as the structure of ability."\(^1\)

Adams indicates the problem is one of identifying the abilities required for performance on a given task.\(^2\) However, once the abilities have been identified the contribution of these abilities to performance on tasks at succeeding stages of practice can be found.\(^3\)

Results of research tend to show both quantitative and qualitative patterns of abilities contributing to skill acquisition may change as practice continues. The individual differences in task performance after extended practice are more likely to depend upon abilities different than those that were required in early stages of practice.\(^4\)


\(^3\)Deese and Hulse, op. cit., p. 446.

Using a sample of airman basic trainees, Fleishman and Hempel\textsuperscript{5} analyzed their performance at different stages of practice on a criterion task, the Complex Coordination Test, with the results of eighteen reference tests. Using a factor analysis technique with the reference tests the authors identified nine factors, numerical facility, psychomotor speed, perceptual speed, mechanical experience, spatial relations, rate of movement, psychomotor coordination, and specific complex coordination. Their findings indicated that factorially the criterion task was most complex during the first stage of practice and less complex during the last stage of practice. In the first stage of practice seven different factors contributed significantly to performance whereas in the last stage of practice only three factors, rate of movement, psychomotor coordination, and complex coordination, appeared to make a significant contribution to performance on the task. There was a systematic change in the increasing or decreasing contribution of each factor to task performance.

Fleishman\textsuperscript{6} analyzed the performance of pilot-cadets on two forms of the Rudder Control Test, the Standard Rudder

\textsuperscript{5}Edwin A. Fleishman and Walter E. Hempel, Jr., "Changes in Factor Structure of a Complex Psychomotor Test as a Function of Practice," Psychometrika, XIX, No. 3 (September, 1954), 239-252.

Control, and the Experimental Six-Target Rudder Control Tests. He found that three primary factors account for performance on the standard and experimental models of the Rudder Control Test. The experimental model appeared to be least complex factorially with nearly all the variance accounted for by the factor, precision of movement. The other two factors, steadiness-control and strength, accounted for low variance at each stage of practice. The standard model was more complex and performance on this test was accounted for by all three factors. On the first three trials two factors accounted for nearly all the variance; but, beginning at trial four through trial six the third factor, strength, began to show a relationship to performance. For the last three trials of the standard model test all three factors had substantial loadings. The findings indicate that when there are different forms of a criterion task, different abilities may be required for performance on each separate task.

Fleishman used airman basic trainees in another study to do a cross sectional and longitudinal comparison of abilities contributing to early and late stages of proficiency scores on seven complex psychomotor tasks. The subjects were given a battery of eight reference tests and

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the same subjects were given extended practice sessions on the seven criterion (complex psychomotor) tasks. His findings indicate that systematic changes in the patterns of abilities contributing to performance occurred as a function of practice and increased proficiency on the task. Some abilities remained stable at all stages of practice, while the contribution of other abilities increased in importance and still others decreased. Fleishman also concluded prediction of late proficiency based on independent measures may be difficult.

A sample of airmen basic trainees was used in a study by Adams to analyze initial and advanced stages of performance on the Discrimination Reaction Time Test. Adams administered the Airman Classification Battery and a simple reaction time test to the subjects and then gave the subjects extended practice on the Discrimination Reaction Time Test in an effort to determine the relationship between the abilities measured in the Airman Classification Battery and performance on the Discrimination Reaction Time Test. In the initial stage of practice four abilities: numerical, perceptual speed, rote memory, and visualization were important predictors of performance on the Discrimination Reaction Time Test. However, in the final stage of practice

three abilities: mechanical, perceptual speed, and reaction time were the best predictors. As practice on the criterion task was continued there was a change in the abilities contributing to performance.

In a study conducted by Fleishman and Rich, male undergraduate students at Yale University were administered two ability measures, a standardized test of spatial orientation and a test of kinesthetic sensitivity. Each subject practiced the Two-Hand Coordination Apparatus for forty one-minute trials. The forty Two-Hand Coordination Test scores were grouped into ten stages of four trials each and correlations were computed between the scores on the ten stages of practice and the scores on the ability measures. They found spatial orientation to be significantly related to the first three stages of practice on the criterion task and the correlation tended to systematically decrease for the last seven stages. Kinesthetic sensitivity had low correlations for the first six stages of practice on the criterion task and then became significantly related to the final four stages. The results of this study show different abilities to be related to performance at succeeding stages of task practice.

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Parker and Fleishman hypothesized that since there is a systematic shift in abilities contributing to performance, when an ability is important at a point in the practice schedule, verbal emphasis of that ability at that point will facilitate learning. They formed three groups: a control group with no formal training, a common sense group that received some training before task practice, and an experimental group that received verbal emphasis on a particular ability at a point when that ability contributed to task performance. All three groups had extended practice on a complex tracking task. Parker and Fleishman found the experimental group had significantly better task performance scores and a decrease in the within-groups variability. They also concluded the experimental group continued to exhibit superior task performance scores in later stages of practice when the experimental verbal emphasis was no longer given.

The review of the research on the relationship of human abilities to task performance indicates most of the studies have been conducted with fine manipulative motor tasks. No studies of this nature were found to be related to gross motor skill performance. Based upon the review of the literature it was concluded there is a need for research.

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to determine if a similar phenomenon between human motor abilities and gross motor skill acquisition can be established.

Agility

Clarke states, "The neuromuscular coordination of the individual, which includes his ability to learn new skills and . . . to achieve competency in physical activities, is essential to all phases of physical education."\(^{11}\) Agility is one of the factors of neuromuscular coordination and its importance in the performance of motor skills should not be overlooked. Early researchers identified agility as a basic component of motor ability and it was believed that agility was almost entirely dependent upon heredity. Subsequent research has revealed that agility can be improved by providing activities designed for developing it.

Bennett\(^{12}\) examined the effects of the contribution of four gross motor activities upon the development of agility in college women. She found that participation in four activities for one semester improved agility. In a similar


\(^{12}\)Colleen L. Bennett, "Relative Contributions of Modern Dance, Polk Dance, Basketball and Swimming to Motor Abilities of College Women," The Research Quarterly, XXVII, No. 3 (October, 1956), 256-257.
study, Lafuze\textsuperscript{13} analyzed women students who were classified as low motor and as high motor ability subjects. She found the high motor subjects to score significantly higher than the low motor subjects on a test of agility. She also found both groups to improve their performance after participation in a special conditioning program.

Experimental programs providing individual and team sport type activities are not the only programs that have been beneficial in improving agility. Calvin\textsuperscript{14} experimented by using a progressive resistive weight training program on a group of high school boys. He found that those students who participated in a weight training program improved their performance on measures of coordination and agility equal to or better than those students who participated in a sports activity program. Maseley, Hairabedian, and Donaldson\textsuperscript{15} found that a six week program of weight training improved agility and speed more than volleyball of inactivity for a like period of time. In


\textsuperscript{14}Sidney Calvin, "Effects of Progressive Resistive Exercises on the Motor Coordination of Boys," The Research Quarterly, XXX, No. 4 (December, 1959), 387-397.

\textsuperscript{15}John W. Maseley, Ara Hairabedian, and Donald N. Donaldson, "Weight Training in Relation to Strength, Speed, and Coordination," The Research Quarterly, XXIV, No. 3 (October, 1953), 308-315.
similar studies, Kurt\textsuperscript{16} and Braley\textsuperscript{17} found weight training to improve agility and coordination.

While weight training can improve agility, one study reports findings that indicate the best way to improve agility is through specific agility training. Hilsendager, Strow, and Ackerman\textsuperscript{18} grouped eighty-three male college freshmen students into five groups: agility, speed, strength, speed and strength, and control, to determine whether exercises designed to improve strength and speed were as effective for improving agility as those exercises designed specifically to develop agility. At the end of a six week experimental program the agility group performed better on measures of agility than the other four groups. They concluded that agility can best be improved by programs designed specifically for that purpose.


\textsuperscript{17}James A. Braley, "Effects of Isometric Exercises Done With a Belt Upon the Physical Fitness of Students in Required Physical Education Classes," The Research Quarterly, XXXVII, No. 3 (October, 1965), 291-301.

The relationship between physical growth and body build, and agility has been researched. Soils analyzed motor ability performance for a sample of grade school children in the first, second, and third grades. He found that the boys' performance improved significantly by age while the girls' did not. His findings did show both boys' and girls' performance scores to be related to skeletal maturity. In measuring the motor performance of 300 girls, aged 12 to 18, Vincent found the girls made gradually improved agility scores at each age level. These findings are in conflict with Espenschade who tested a sample of students aged ten to sixteen years. She concluded that both boys and girls improved in agility up to the age of fourteen. After the age of fourteen the girls' performance in agility was somewhat retarded while the boys made rapid gains.


Bookwalter studied 1900 elementary school boys to determine the relationship between physique and motor fitness developmental level. He concluded there was a relationship between physique and performance on the Indiana State Physical Fitness Tests. The obese boys were poorer performers than the medium and thin built boys. Sills analyzed the performance of college age students on motor tests and he found students with the mesomorph physique to be the superior performers followed by the ectomorph and endomorph physiques, respectively. Other researchers, Cureton, Carruth, and Perbis have supported the findings that individuals with the obese type physique have the least potential for performance on measures of agility.

Agility is highly related to motor ability and sports ability. To determine the relationship of agility to motor

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22Karl W. Bookwalter and others, "The Relationship of Body Size and Shape to Physical Performance," The Research Quarterly, XXIII, No. 3 (October, 1952), 276-280.


performance, Hoskins tested all members of the freshman class at the University of Virginia. He found agility, as measured by the Burpee Test to be highly related to success in basketball, boxing, and tap dancing. Beise and Peasely found agility in college women to be highly related to performance in archery, golf, and tennis. Other researchers have supported these findings. Mohr and Haverstick have found a relationship between agility and volleyball skill. Johnson found agility to be important in basketball performance. A study by Lehsten supported Johnson's findings. Also, Merrifield and Walford, and Doroschuk and


29 Dorothy R. Mohr and Martha L. Haverstick, "Relationship Between Height, Jumping Ability, and Ability to Volleyball Skill," The Research Quarterly, XXVII, No. 1 (March, 1956), 68-74.


Marcotte\(^{33}\) have found agility to be related to performance in ice hockey.

**Balance**

Two types of balance have been identified, static balance and dynamic balance, both of which are being measured in physical education today. Nicks and Fleishman state static balance is the ability to maintain the body in a fixed position while dynamic balance is the ability to maintain balance while performing a task\(^{34}\). A body that is in balance is in a state of rest, indicates Bunn, and thus a body may be in any one of a number of positions yet still be in a state of balance in each position. The body maintains its balance when the center of gravity falls within the area of its supporting base\(^{35}\).

The importance of balance ability to performance in physical activity has led researchers to include measures.

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\(^{34}\)Delmar Nicks and Edwin A. Fleishman, "What Do Physical Fitness Tests Measure?," Educational and Psychological Measurement, XXII, No. 1 (Spring, 1962), 77-96.

of balance in different types of tests. McCloy\(^\text{36}\) includes balance in a test of motor educability while Fleishman,\(^\text{37}\) Johnson,\(^\text{38}\) Lafuze,\(^\text{39}\) Scott,\(^\text{40}\) Roloff,\(^\text{41}\) and Young\(^\text{42}\) have included measures of balance in tests assessing physical fitness, motor ability, and kinesthesis.

While it is difficult to determine how important inheritance is to balance ability researchers have found balance can be improved. Gunden\(^\text{43}\) found participation in an athletic program improves balance ability of college


\(^{39}\)Lafuze, op. cit., pp. 149-157.


women. Valentine\textsuperscript{44} also found a significant improvement in static balance of college women after they participated in programs of modern dance and ice skating. Garrison\textsuperscript{45} concluded there is an improvement in balance when the physical education program is designed to include balance activities. Other studies by Carter,\textsuperscript{46} Cheney\textsuperscript{,47} Espenshade, Darble, and Schoendube,\textsuperscript{48} Lafuze,\textsuperscript{49} and Smith\textsuperscript{50} support the findings that participation in physical education activities improves balance.


\textsuperscript{46}Frances H. Carter, "Selected Kinesthetic and Psychological Differences Between the Highly Skilled in Dance and Sports," unpublished doctoral dissertation, Department of Physical Education, University of Iowa, Iowa City, Iowa, 1965.


\textsuperscript{49}Lafuze, op. cit., pp. 149-157.

Balance is related to physical growth and Cumbee, Meyer, and Peterson concluded that different types of balance items for different age levels should be considered. Bachman analyzed balance ability of 320 male and female subjects, matched by age, and found differences in balance ability for different age groups from ages 6 to 26. Singer and Seils, in measuring elementary school children, found balance to improve with an increase in chronological age. Espenschade reported similar findings, however, she found that although balance ability improves, there is a noticeable retarded rate of gain for boys in the thirteen to fifteen year age range.

Research findings from studies relating balance to height and weight of the student are as conflicting as the findings of the studies relating sex of the performer to


54 Seils, op. cit., pp. 244-260.

balance ability. Espenschade, Darble, and Schoendube, 56 and Kahms 57 have found that balance is not related to height or weight whereas Travis, 58 in a study using college men and women, and Seils, 59 in a study using grade school children, found these physiological factors to be related to performance on measures of dynamic balance.

Bachman, 60 Goetzinger, 61 Kahms, 62 and Travis, 63 in separate studies have found no difference between boys and girls in balance ability. These findings do conflict with

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59 Seils, op. cit., pp. 244-260.
62 Kahms, op. cit..
63 Travis, op. cit., pp. 216-234.
reported findings by Hoffman, Singer, and Smith who report differences between the sexes in measures of balance. Singer found third grade girls to score higher than third grade boys on a measure of balance whereas at the sixth grade, boys scored significantly higher than sixth grade girls on the same measure of balance.

Estep conducted a study to investigate static equilibrium and success in gross motor activities. The subjects were chosen subjectively on motor ability in rhythm and sport, and on team skill classification in the after school athletic program. She found a positive relationship between balance and performance in gross motor activities. Greenlee found a high significant relationship between balance and bowling performance of college women. Other studies by Carruth.

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63 Smith, op. cit., pp. 220-228.


66 Carruth, op. cit.
Cheney,70 Cron and Pronko,71 Cumbee,72 Espenschade, Darble, and Schoendube,73 Scott,74 and Wiebe75 support the hypothesis that a positive relationship does exist between balance and ability in gross motor activity.

Balance as a component of physical performance is reported to be related to gross motor ability and therefore athletes should score higher than non-athletes on measures of balance. Slater-Hammel76 administered a dynamic balance test to athletes, physical education majors and liberal arts majors. He found significant differences between all three groups with athletes scoring the highest and physical education majors and liberal arts majors following in that order. Mumby77 investigated the balance ability of

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70 Cheney, op. cit., p. 30.
72 Cumbee, op. cit., pp. 100-108.
twenty-one wrestlers who were rated as intermediate or advanced wrestlers. He found good wrestlers scored higher than poorer wrestlers on tests of balance and then concluded balance is an important factor in this sport. Gross and Thompson analyzed a sample of male students enrolled in an advanced swimming class and found the persons who swam the fastest and who had better swimming ability scored the highest on the balance test. Similar results have been found by Campbell, Seashore, and Wiebe in favoring athletic over non-athletic persons in measures of balance. Several investigations have found that even athletes who compete in specific activities perform better than other athletes on tests of balance. Cheney measured skilled performers in dance, gymnastics, and sports and found those in dance and gymnastics to have better balance than the sports persons.


82 Cheney, op. cit., p. 30.
Carter and Estep both found dance performance and sports performance to be related to balance ability and also found the dance groups to score higher than sports groups on measures of balance.

Depth Perception

Investigations which have compared depth perception and perceptual motor activities are scarce. When investigations have been conducted the reported findings have been somewhat conflicting.

In an early study Bannister and Blackburn hypothesized that athletes would have greater interpupillary distance (distance between the eyes) than non-athletes. They felt this physiological factor would facilitate the establishment of depth perception cues and thus contribute to the athlete's superior sports ability. Upon admission to Cambridge University, England, each man completed a form upon which he stated his achievements at various games, both at secondary school and at the university. Based upon the information reported on this form each man was subjectively classified into one of two groups according to his ability at games. The interpupillary distance of 258

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^83^ Carter, op. cit., p. 58.

^84^ Estep, op. cit., pp. 5-15.

Cambridge undergraduates was measured. Measurements of interpupillary distance were compared with ability at ball games and the analysis showed that those who had greater interpupillary distance were, on the whole, better players. Bannister and Blackburn concluded this was probably due to the better stereoscopic vision which the greater width makes possible.

A similar study was conducted by Clark and Warren using 598 undergraduate students at the University of Southern California. Clark and Warren measured the interpupillary distance of students who were college varsity athletes and students who were not athletes. Their findings showed no significant relationship between interpupillary distance and depth perception, no significant difference in interpupillary distance between athletes and non-athletes, and no significant difference in depth perception between athletes and non-athletes as measured by the Howard-Dolman Apparatus.

MacGillivary used the Howard-Dolman Apparatus to measure the depth perception of twenty-eight college varsity

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hockey players. The twenty-eight players were grouped into two groups, inferior and superior, based upon ratings by experts. He found no significant differences between the two groups in depth perception ability. The correlation between depth perception and the criterion, hockey ability, was low and also not significant.

The relationship between depth perception and basketball free throw shooting for thirty-two women college students was analyzed by Shick. Each subject took a total of fifty free throws, with ten shots taken on each of five days. Depth perception was measured with the modified Howard-Dolman Apparatus and with the Bausch and Lomb Ortho-Rater. She found no significant relationship between either measure of depth perception and success in free throw shooting for women.

Several researchers have found a relationship between depth perception and motor performance, and in some cases have found a difference between categories of motor performance. Olsen tested three groups of male college students, one hundred in each group, athletes, intermediate

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athletes, and non-athletes for reaction time and depth perception. No significant difference was found between the athlete and intermediate athlete on the measure of depth perception. He reported the athletes and intermediate athletes had better depth perception than the non-athletes.

Graybiel, Jokl, and Trapp, in a study of Russian researchers, reported that Krestovnikov utilized an apparatus similar to the Howard-Dolman Apparatus to measure depth perception of tennis players, football players, soccer players, and a group of untrained controls. He found tennis players to have better depth perception than football players and a high correlation was found between the athletic efficiency of tennis and soccer players and their depth perception. As a group, athletes had better depth perception scores than untrained controls and the more skillful players perceived depth more accurately.

Tests of depth perception, peripheral vision, and reaction time were administered to ninety-one athletes and ninety non-athletes at the junior high school level in a study by Ridini. He compared the junior high school boys.

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performance on those three tests with their performance on eight sports skill tests. Ridini found the athletes to score significantly higher than the non-athletes on depth perception, peripheral vision, and reaction time. He later concluded these three tests could be used to predict sports skill performance.

One hundred sixty-two men and women subjects rated as champions, near champions, and low skilled performers in basketball, fencing, gymnastics, swimming, and volleyball were tested in a study by Miller. She found significant differences between high skilled and low skilled sports performers in depth perception. Miller also concluded there were differences between highly skilled and intermediate sports performers in depth perception but the differences were not significant.

Flexibility

Flexibility is referred to as the ability of an individual to move his body or parts of his body in a stretching manner through as wide a range of motions as possible without feeling muscular strain. It is difficult to know how much flexibility is needed to perform adequately in physical activities, but it is understood that the performer must

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have enough flexibility to be able to participate in an activity with ease.

Flexibility appears to be related to human growth with persons becoming more flexible from early childhood to adolescence. Phillips\textsuperscript{93} administered the Kraus-Weber Test to 1456 elementary school children in Indiana to compare their test scores with performance on the same test by European children. She found for the Indiana population, that with an increase in age there was a decrease in the percentage of failures on the test items, which was consistent with the results found for the European children. Forbes\textsuperscript{94} found that with boys, hip flexion and extension did not follow an improved performance trend with age but he did find that while some joint flexibility was lost in early adolescence, other joint flexibility measures improved in later adolescence. In a similar study conducted with girls, Hupprich and Sigerseth\textsuperscript{95} found girls eighteen years of age to be more flexible in specific joints than girls six years of age.

\textsuperscript{93}Marjorie Phillips and others, "Analysis of Results from the Kraus-Weber Test of Minimum Muscular Fitness in Children," \textit{The Research Quarterly}, XXVI, No. 3 (October, 1955), 314-323.


In analyzing the relationship between chronological age and flexibility it is found that girls tend to be more flexible than boys. The trunk flexion and extension measures of over 6000 boys and girls who were 4-H Club members were recorded by Hall. He concluded that the test scores did not show a trend by age or body type, but that girls tended to have more flexibility than boys. One hundred boys and girls aged six to nine were used by Smith in a study to determine the relationship of selected physical abilities and the learning of certain motor skills. The boys were found to learn the motor skill faster than the girls, but the girls were found to score higher than the boys on measures of balance and flexibility. These findings were confirmed by Phillips when she administered the Kraus-Weber Test to elementary school children. She reported the girls were substantially superior to the boys at all age levels through the ninth grade. Phillips also concluded that while girls were more flexible than boys at the earlier age levels, as they both became older, the flexibility measures for the

96 D. M. Hall, "Standardization of Flexibility Tests for 4-H Club Members," The Research Quarterly, XXVII, No. 3 (October, 1965), 296-300.


sexes tended to converge. Fleishman, Kramer, and Shoup reported similar findings in their study of the physical fitness of boys and girls aged twelve to eighteen. This investigation shows that on the test of extent flexibility, in late adolescence the girls tended to become less flexible while the boys became more flexible. There was a convergence of their test scores.

Flexibility can be improved and it has been found that any number of physical activity programs can lend to improved flexibility. Kusinitz and Keeney used forty-six junior high school males, aged twelve to seventeen years to determine the effect of an eight week progressive weight training program on physical fitness. An experimental group participated in a weight training program while the control group participated in a regular physical education activities program. Both groups made gains on the trunk extension and flexion test but the weight training group made significant improvement in flexibility, over the control group. The effects of a longitudinal weight training

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program upon flexibility was investigated by Massey and Chaudet. They found that after six months of weight training, slight gains in flexibility were made. Bennett studied the contributions of programs of modern dance, folk dance, basketball, and swimming to general motor abilities of seventy-nine college freshman women. After a one semester program of activity she concluded all four activities improved flexibility but swimming and modern dance made the greatest contributions. McCue found that women students who scored in the lowest quarter on a group of flexibility tests made significant improvement in flexibility after three weeks of exercise. These findings are supported by Lefuze, Burley, Dobell, and Farrell, Kingsly, and


102 Bennett, op. cit., pp. 253-262.

103 Betty P. McCue, "Flexibility Measurements of College Women," The Research Quarterly, XXIV, No. 3 (October, 1953), 316-324.


Riddle, who all concluded that flexibility can be improved by implementing special programs.

Athletes participating in certain sports tend to be more flexible than those competing in other sports, and in a study by Haliski and Sigerseth, non-football players were found to be more flexible than football players. They compared 100 football players and non-football players on 21 tests of flexibility. The non-football players scored significantly higher on thirteen of the tests while the football players scored significantly higher on only one measure. However, in other studies the findings indicate athletes tend to be superior to non-athletes in flexibility.

Fisher analyzed flexibility measures of a cross sectional population comprised of 620 college students, elementary boys and girls, and Olympic swimmers. His findings show the superior swimmers to be most flexible and he also concluded that those students who are athletes are superior to non-athletes in measures of flexibility. Swimmers were


reported to be more flexible than non-athletes in a study by Pickens.\textsuperscript{110} He also found the swimmers to be more flexible than football players and basketball players. Von Ebers\textsuperscript{111} found the college varsity athlete to be more flexible than physical education majors, while Syverson\textsuperscript{112} found baseball players to be more flexible than non-athletes, and Williams\textsuperscript{113} found basketball players to be more flexible than students enrolled in activity classes.

Reaction Time and Speed of Arm Movement

Broer states that while reaction time is not an important factor in most tasks such as lifting, pushing, pulling, and carrying, it is extremely important in many sports such as tennis, basketball, and badminton.\textsuperscript{114} Its importance is

\begin{itemize}
\item \textsuperscript{112}Magnus Syverson, "A Study of Flexibility in Baseball Players," unpublished master's thesis, Department of Physical Education, University of Oregon, Eugene, Oregon, 1950.
\item \textsuperscript{113}Elvin T. Williams, "A Study of Flexibility in Basketball Players," unpublished master's thesis, Department of Physical Education, University of Oregon, Eugene, Oregon, 1950.
\item \textsuperscript{114}Marion R. Broer, Efficiency of Human Movement (Philadelphia, 1964), p. 13.
\end{itemize}
such that Oxendine says reaction time seems strategic in
distinguishing between outstanding, average, and poor per-
formers in many sports skills.  

During the developmental years reaction time improves
rapidly. As the peak is approached during the late teens
and early twenties, there is a leveling off of speed of
reaction, according to Ruch. Hodgkins conducted a
study concerned with the factors of age and sex in relation
to reaction time and speed of movement. Her findings warrant
the following conclusions: (1) Between the ages of twelve
and fifty-four, reaction time is faster in males than females;
(2) The fastest reaction time occurs between the ages of
eighteen and twenty-one years in both males and females; and
(3) After peak reaction time is obtained, females will main-
tain their peak reaction time longer than males.

Atwell and Elbel used male high school students
in the 14-17 year range to measure hand and body reaction

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115 Joseph B. Oxendine, Psychology of Motor Learning

116 Floyd L. Ruch, Psychology and Life (Chicago, 1948),
p. 308.

117 Jean Hodgkins, "Reaction Time and Speed of Movement
in Males and Females of Various Ages," The Research Quarterly,
XXXIV, No. 3 (October, 1963), 335-343.

118 William O. Atwell and Edwin R. Elbel, "Reaction Time
of Male High School Students in Fourteen to Seventeen Year
Age Groups," The Research Quarterly, XIX, No. 1 (March, 1948),
22-29.
They found the hand reaction time and body reaction time to improve with age and the variation of test scores to decrease with age. Similar findings are reported by Philip. He administered reaction time tests to 311 children, aged 9-16. Based upon the results, he concluded that reaction time improves with age and there is less variation in reaction time scores with the increase in age.

With the associated improvement of reaction time to developmental growth, it has also been shown that reaction time can be improved through special programs. Considerable research has shown that weight training programs used alone or in conjunction with sporting activities have contributed to improve reaction time and speed of movement. Zorbas and Karpovich used 150 college men who were weight trainers and 150 college men who were non-weight lifters to analyze the differences between the two groups in reaction time and speed of arm movement. They found the weight lifters to have significantly faster speed of arm movement and reaction time than the non-lifters. They also analyzed the speed of arm movement for two groups of non-weight lifters from two different colleges, Springfield College and a liberal arts


college. Zorbas and Karpovich found the Springfield students had faster speed of arm movement and they concluded this was a result of more physical education activities being required at Springfield than at the liberal arts school.

An effort to determine if an increase in strength was accompanied by an increase in speed of arm movement was investigated in separate studies by Masley, Hairabedian, and Donaldson, and Wilkin. Masley, Hairabedian, and Donaldson found that the college men enrolled in an eight week weight training program made significantly greater gains in speed of arm movement over a group of college students enrolled in a volleyball class and a group enrolled in a sports lecture class. Wilkin found those college students enrolled in an eight week weight training program made significant gains in speed of arm movement. He also found that weight training did not differ from swimming and golf in improving arm movement speed. Studies reported by Calvin, who used a population of high school boys aged fourteen to eighteen, Chui, who used a population of male

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121 Masley, Hairabedian, and Donaldson, op. cit., pp. 308-315.
122 Bruce M. Wilkin, "The Effect of Weight Training on Speed of Movement," The Research Quarterly, XXIII, No. 3 (October, 1952), 361-369.
college freshmen, and Michael,¹²⁵ who experimented with a group of college males in an isometric weight training program supported previous findings when they found progressive resistive weight training to improve reaction time and speed of arm movement.

Bates¹²⁶ used 108 male college students to determine the effects of isometric and isotonic weight training programs on the improvement of speed of movement and reaction time. Both groups made significant gains in speed of movement and reaction time, although Bates found no difference between isometric and isotonic weight training in the contribution to gains.

Similar findings are reported by Meadows¹²⁷ who found a ten week program of isotonic weight training to be as effective as a ten week program of isometric weight training in improving speed of movement, reaction time, and strength.


of eighty-four college football players, at St. Cloud State, Minnesota. He concluded there is no difference between isometric and isotonic programs in improving speed and reaction time.

Tweit, Gollnick and Hearne\textsuperscript{128} conducted a study in which they were concerned whether reaction time could be improved through a physical conditioning program. They found that reaction time could be improved in subjects of initially low physical fitness levels by subjecting them to a conditioning program. These writers concluded that the faster reaction time of athletes, as compared to non-athletes, may be due in part to the training programs to which they subject themselves.

Athletes do participate in an athletic environment that requires the performer to be in a constant state of readiness to react to various game situations. While it has not been clearly established what the cause-effect of reaction time, movement time, and athletic participation are to each other, it has been found that athletes are superior to non-athletes in reaction time and movement time studies.

Keller measured 755 university and high school athletes and non-athletes on a total body reaction time test. The athletes were found to be significantly faster than non-athletes in terms of large muscle reaction time. He also found those college athletes who participated in baseball, track, basketball, and football (in that order) had significantly faster reaction times than those participating in gymnastics, wrestling, and swimming.

Seven groups of college male subjects, non-letter winners in high school, high school letter winners, college football linemen, college football backs, college basketball men, college baseball men, and college swimmers were administered a simple and a complex reaction time test by Burley. He found all athletes to be significantly faster than non-athletes and he also found the high school letter winners to be significantly faster than the non-letter winners.

York measured two groups of seventy-two high school boys on simple hand-eye reaction time and simple foot-eye

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reaction time. One group consisted of subjects partici-
pating in interscholastic basketball and the other group
had not participated in any form of interscholastic ath-
letics. It was found that the basketball players were
significantly faster on both reaction time tests than the
non-athletic group.

Foot and hand reaction time and speed of movement of
seventy-five women students at the University of Michigan
were measured by Beise and Peaseley. The women selected
were grouped into four groups; those skilled in archery, in
tennis, and in golf, and a control group of non-athletes.
They found the athletes to be significantly faster than the
non-athletes in hand and foot reaction time. Within the
sports groups the tennis players recorded the fastest
reaction time followed by golfers and archers.

A study by Olsen is another experiment which had
subjects who had met with varying degrees of success in ath-
letics. The experiment involved measuring simple reaction
time, choice reaction time, and discriminatory reaction time
for varsity athletes, intermediate athletes (intramural
performers), and non-athletes. The results indicated the
varsity athletes had faster reaction times in each situation

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133Olsen, op. cit., pp. 79-89.
than the other two groups, while the intermediate athletes had faster times than the non-athletes in each situation.

Slater-Hammel\(^{134}\) tested the reaction time and movement time of eighty students who were grouped as varsity athletes, physical education majors, music majors, and liberal arts majors. Varsity athletes had significantly shorter reaction times and movement times than the other three groups and the physical education majors had shorter reaction times and movement times than the music majors and liberal arts majors.

The conclusion that individuals who are athletes or who participate regularly in physical activities exhibit faster reaction times and movement times has been supported in several other studies. Pierson\(^{135}\) found fencers to have quicker reaction time and speed of arm movement than non-fencers. Burpee and Stroll\(^{136}\) found men who participated in YMCA physical activity programs to have better reaction time than non-participants. And in four different studies


conducted at Indiana University, Cooper, Palmieri, Rangazas, and Wilkinson found that college athletes and former high school athletes have significantly faster reaction time and speed of arm movement time than non-athletes.

Strength

It is common knowledge that there are individual differences in capabilities to perform physical skills that require high levels of muscular strength. Age and sex are two variables that contribute to individual differences in strength development along with differences due to the genetic and environmental factors.

A person may not have the physical build to become a highly skilled performer in an athletic event. He can,


however, improve his strength and strength improvement has been shown to be related to improved athletic performance. Successful performance in most kinds of physical activities requires a certain amount of strength, regardless whether it is playing badminton or playing football.

Strength is a related factor in the growth and development of individuals. Various studies have shown that muscular strength is related to the muscular development from childhood to adolescence.

Following a review of research on strength, Hunsicker and Greey reported that strength gradually increases up to the age of twenty-five, remains at this level from five to ten years, then gradually decreases. This relationship between strength and age appears to be the same for both sexes. They also reported physical exercise could deter the onset of strength decrement.

Watt administered various structural, strength, and motor measures to 203 boys aged 7-17 years in the Medford, Oregon, public schools to analyze their growth patterns. He found there was a consistent increase in physical growth

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and strength at each succeeding year from age seven to age seventeen.

Kurimoto utilized sixteen measures of strength, structure, maturity, and motor performance to analyze the relationship between these variables and chronological age. He found that as the subjects increased in chronological age, their mean scores on strength measures increased on all tests. However, the increase in means became smaller with each year of advancement in age.

Kurimoto and Watt conducted their studies as part of the Medford, Oregon, growth project sponsored by H. Harrison Clarke. Investigations by Bailey, Berringer, and Orville Berringer. 

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2. Ibid.


Jordan,\(^{148}\) and Docherty\(^{149}\) as part of the Medford project, have supported the findings of Watt and Kurimoto that strength is related to growth and development.

The importance of strength in performing athletic skills was reported in a study by Hinton and Rarick.\(^{150}\) They administered the Rogers' Test of Physical Capacity and the Cubberly and Cozens Measurement of Achievement in Basketball to sixty-four women college students. Hinton and Rarich found a significantly high correlation between lung capacity, back strength, arm strength, and performance on the basketball achievement test. Lamp\(^{151}\) supported these findings in an investigation with participants in volleyball. She administered a volleyball skills test to 806 boys and girls in the seventh, eighth, and ninth grades and correlated their performance scores with the students' age, height, and sex.


\(^{151}\)Nancy A. Lamp, "Volleyball Skills of Junior High School Students as a Function of Physical Size and Maturity," The Research Quarterly, XXV, No. 2 (May, 1954), 189-199.
weight, and strength. Lamp reported no differences between boys and girls in their ability to perform the basic volleyball skills measured in this test. She did find there was a positive relationship between volleyball ability and strength for both sexes.

Kroll\(^{152}\) investigated the differences between twenty-four successful and sixty-eight unsuccessful high school varsity wrestlers in Illinois. He found the successful wrestlers to score significantly higher than unsuccessful wrestlers on right grip, left grip, and back lift strength measures.

Strength has also been found to be related to baseball playing ability. Hooks\(^{153}\) used fifty-six male freshmen students enrolled in basic physical education courses at Wake Forest College, North Carolina, to measure the relationship of nineteen selected strength and structural measures to baseball ability. He found strength to be the best predictor of baseball playing ability with left and right shoulder flexion strength as the two best predictors.

Athletes are constantly exhibiting athletic skills. Since strength has been shown to be highly related to athletic


performance it is also assumed athletes should score higher on strength measures than non-athletes. Peterson\textsuperscript{154} found this to be true when she measured maturational, structural, strength, and motor traits of upper elementary and junior high school boys with different levels of athletic abilities and also compared the same traits of these athletic boys with non-athletes. She reported strength was a consistent differentiation of athletic ability, with the athletes scoring significantly higher than the non-athletes.

Peterson's\textsuperscript{155} study involved using a population of upper elementary and junior high school athletes and non-athletes. Shelley,\textsuperscript{156} Olsen,\textsuperscript{157} and Wiley\textsuperscript{158} conducted

\begin{flushright}
\textsuperscript{154}Kay H. Peterson, "Contrast of Maturity, Structural, and Strength Measures Between Non-Participants and Athletic Groups of Boys Ten to Fifteen Years of Age," unpublished doctoral dissertation, Department of Physical Education, University of Oregon, Eugene, Oregon, 1959.

\textsuperscript{155}Ibid.


\textsuperscript{157}Arne L. Olsen, "Characteristics of Fifteen Year Old Boys Classified As Outstanding Athletes, Scientists, Fine Arts, Leaders, Scholars, or as Poor Students or Delinquents," unpublished doctoral dissertation, Department of Physical Education, University of Oregon, Eugene, Oregon, 1961.

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studies using the same age population as Peterson and their findings support her conclusions that the most distinctive characteristic between athletes and non-athletes was strength. The athletes scored significantly higher than non-athletes on measures of strength.

DiGiovanna\textsuperscript{159} and Wilhelm\textsuperscript{160} also found the male college athlete to be stronger than the male college non-athlete. Both men reported arm strength, total strength, and power were related to athletic success, and the athletes scored significantly higher than non-athletes in measures of strength.

Summary

For the six individual abilities measured in this study a considerable amount of research has been conducted to determine the relationship of these abilities to motor performance. A majority of the studies were found to have been conducted using subjects in elementary school through to college level. There is a paucity of research with these abilities on subjects beginning with the thirty year age bracket and above. Few studies are reported relating depth

\textsuperscript{159}Vincent DiGiovana, "The Relation of Selected Structural and Functional Measures to Success in College Athletics," The Research Quarterly, XIV, No. 2 (May, 1943), 199-215.

\textsuperscript{160}Arnold W. Wilhelm, "The Relationship of Certain Measurable Traits to Success in Football," unpublished doctoral dissertation, Department of Physical Education, Indiana University, Bloomington, Indiana, 1951.
perception to gross motor performance at any age level and only a limited number of studies are reported relating reaction time and movement time to performance for the lower elementary grade levels.

A review of the literature indicates it is difficult to determine the effects of heredity versus environment in the possession of these abilities. The abilities are related to maturational growth. As individuals mature their performance on ability measures improves up to a point, then a decrement in performance begins due to the aging process. It has been shown that the abilities can be improved through specific practice and that improvement in abilities has led to improved motor performance. Individuals with high motor ability score better than persons with low motor ability and athletes tend to be superior to non-athletes on gross motor measures.
CHAPTER III

PROCEDURE OF THE STUDY

Selection of the Subjects

During the spring semester of 1970, six sections of Physical Education 116 at North Texas State University were utilized in obtaining subjects to participate in this study. The students selected for the study met for the testing session and skill practice sessions during their regularly scheduled class time. To insure adequate contact time only those students enrolled in Tuesday and Thursday physical education classes were considered as subjects for the study.

From each class section twenty-five male freshmen and sophomore students were selected by drawing to participate in the study. Of the 150 students selected for the study, 102 subjects completed all phases of the experiment. Those 102 subjects who formed the population for the study ranged in age from 17 years 8 months to 26 years 8 months with a mean age of 19 years 6 months, and a standard deviation of 1 year 2 months.

Testing of the Subjects

Each subject was required to take six ability tests to measure: agility, balance, depth perception, flexibility, reaction time and speed of arm movement, and strength.
Undergraduate and graduate physical education majors who were currently enrolled in, or who had taken, a physical education tests and measurements course were used as testing assistants in the data collection. Before the experiment began, in service training sessions were held to train the testing assistants in the testing procedures.

When the subjects reported for the testing session, each subject completed an individual score card (see Appendix A). The subjects were assigned to one of six groups and each group was assigned to a testing station. As each group completed its testing at a station, the members of the group then rotated to the next testing station. Station rotation was in numerical order. Those groups assigned to station six initially, rotated to station one and followed through the numerical sequence. The station assignments were as follows:

Station one—Test for agility
Station two—Test for grip strength
Station three—Test for balance
Station four—Test for reaction time and speed of arm movement
Station five—Test for flexibility
Station six—Test for depth perception.

As the students completed each of the given tests, the raw scores were recorded on their score cards.
Description of the Instruments

The measuring instruments used in the study were the Side Step Test, Bass Stick Test, Howard-Dolman Depth Perception Apparatus, Fleishman's Bend, Twist, and Touch Test, Marietta Apparatus Company #1 Reaction Time Box and Timer, and the Narragansett Hand Manometer.

Side Step Test

The Side Step Test is an agility test designed to measure rapid changes in lateral movement when traversing laterally across two lines twelve feet apart. This test is Johnson's modification of the side step test suggested by H. D. Edgren in the March, 1932, issue of the Research Quarterly. Johnson and Nelson indicate the test-retest reliability coefficient is reported to be .98 and the coefficient of concurrent validity to be .70. The test was administered according to the directions given in Appendix B.

Bass Stick Test

The Bass Stick Test was designed to measure static balance of an individual while he is supported upon a narrow surface on the ball of his foot. The subject places the ball of his foot lengthwise on a stick, one inch by one inch by

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2 Ibid., p. 103.
twelve inches in length, lifts the opposite foot from the floor and maintains his balance for as long as possible up to a maximum of sixty seconds. Each subject takes three trials with his left foot and three trials with his right foot. The subject's balance score for each trial is the number of seconds he maintains his balance. His balance score is the sum of the number of seconds for all six trials. 3 Bass 4 reports a test-retest reliability coefficient of .86. This test has been accepted for its face validity. Test administration directions are presented in Appendix C.

Howard-Dolman Depth Perception Apparatus

The Howard-Dolman Depth Perception Apparatus was used to measure stereoscopic depth perception. The Howard-Dolman Apparatus is a box forty inches long, twelve inches wide and is open at the sides and top. The end closest to the subject has a rectangular opening seven and one-quarter inches by five inches, through which could be seen two vertical black rods set sixty-four millimeters apart. These rods are set laterally and are against a white background. One rod is on a movable track and the other rod is fixed in the center of the box. The movable rod is controlled by two strings.

3 Johnson and Nelson, op. cit., p. 160.

twenty feet in length, and can be moved along the track, either toward or away from the subject. There is a millimeter scale along the track. The millimeter scale is from 0-200 millimeters along the track behind the stationary rod and also from 0-200 millimeters along the track in front of the stationary rod. The subject's score for one trial is the distance, recorded in millimeters, that is the amount of error in judgement of alignment between the movable rod and the stationary rod. The test-retest reliability coefficient for this measure is reported at .89 by Olsen⁶ and the split-half reliability coefficient is reported at .90 by Shick.⁷

Each subject receives twelve trials, two trials for practice and ten trials for score. The subject's depth perception score is the average millimeters of error in judgement of alignment for the ten trials. The test was administered according to the United States Air Force instructions, as outlined in Appendix D, which recommend ten trials, five trials with the movable rod placed in front and

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five trials with the movable rod placed in back of the sta-
tionary rod. The settings for the rod placement were
selected by drawing and the rod placement is shown in Appen-
dix E.

**Fleishman's Bend, Twist, and Touch Test**

*Fleishman's Bend, Twist, and Touch Test* is a test of
dynamic flexibility that measures the speed with which an
individual can flex, extend, and rotate the spine. This
test was one of thirty which Fleishman administered to 20 u.
Navy recruit subjects when he conducted a factor analytic
study of speed, flexibility, balance, and coordination tests.
The *Bend, Twist, and Touch Test* had a high factor loading of
.50 in the dynamic flexibility factor and Fleishman indicates
it is one of the best measures of dynamic flexibility. Procedures for administering the *Bend, Twist, and Touch Test* are
given in Appendix F. This test is accepted for its face
validity. Fleishman reports the test-retest reliability
coefficient of this test to be .92.

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8 *Air Force Manual, AFM 160-1, Medical Examinations and
Medical Standards*, Department of the United States Air Force,

9 Edwin A. Fleishman, *The Structure and Measurement of

Reaction Time and Speed of Arm Movement

The Marietta Apparatus Company 11 Reaction Time Box and Timer was used to measure reaction time and speed of arm movement. The reaction time box has three keys on the front of the box with a light above each key. These are numbered one, two, and three. The subject has his dominant hand resting on a line twelve inches from the reaction time box. In this test, simple reaction time is measured. At the presentation of a visual stimulus, a light, the subject moves his hand and depresses the lever that is below that light. Split-half reliability coefficient for measuring reaction time and speed of arm movement of this nature are reported as .7911 when the limb traveled twelve inches and .9612 when the limb traveled twenty-three and a half inches. Directions which were used for administering the test are listed in Appendix G.

Each subject receives twelve trials, two trials for practice and ten trials for score. His time is recorded in hundredths of a second. The subject's reaction time and speed of arm movement score is the average number of seconds for the ten trials.


Ruch\textsuperscript{13} indicates the state of readiness to react after a preparatory command lasts up to four seconds. Therefore the preparatory warning should come one to four seconds before the final stimulus. He also indicates a period of time is needed to prepare for readiness, therefore the lapsed time between the warning and stimulus should not be less than one second. In this test the maximum time lapsed between the preparatory command and the stimulus presentation was four seconds. The number of the stimulus light presented and the number of seconds between the preparatory command and the light presentation are listed in Appendix H.

**Grip Strength**

The Narragansett Hand Manometer was used to measure grip strength. The manometer consists of two heavy springs mounted between two steel bars that are curved to fit the hand grip. The scale on the manometer reads from 0-200 pounds. When testing strength the dial hand is set at zero manually.\textsuperscript{14} The test is administered according to Mathews'\textsuperscript{15} directions as listed in Appendix I.


\textsuperscript{15}Ibid., p. 65.
Rogers\textsuperscript{16} reports a test-retest reliability coefficient of .92 for the right hand and a test-retest reliability coefficient of .90 for the left hand. Fleishman\textsuperscript{17} reports the test-retest reliability coefficient to be .91 for static strength. This measure of grip strength is accepted for its face validity.

**Selection of the Gross Motor Task**

An important factor in this study was the selection of the gross motor task. Consideration needed to be given in selecting a motor task that could be related to sports activities, a task that would be similar to a sports skill, yet a task that would be novel enough to avoid influence from a previous task experience. Also, the task needed to be difficult enough to present an approximately normal distribution of performance scores, difficult enough so that a subject would not reach maximum performance in just a few trials, and yet not so difficult that less skilled subjects would not make some progress in performance.

Two pilot projects were conducted to establish the motor task. The first pilot study dealt with establishing a wall volley task that would yield a range of performance.


\textsuperscript{17}Fleishman, op. cit., p. 128.
scores that would provide an approximately normal distribution. The second pilot study involved experimenting with the number of trials that was needed to establish an acquisition curve. Results of the second pilot project showed that, on the average, little improvement in performance score was made after the fortieth trial on the wall volley task. However, some gradual improvement was made beyond the fortieth trial. It was arbitrarily decided to extend the number of practice trials to fifty. Since the improvement made was not as noticeable in the last stages of task practice, the possibility of the subject losing interest in performing the task was present. The task performance scores on any number of trials above fifty might be adversely affected by the subject's loss of motivation, since the subject was performing the same task for extended practice sessions.

Description and Administration of the Gross Motor Task

The subject stood behind a restraining line that was twelve feet from the wall. On the wall was a yellow, solid color, circular target which measured eighteen inches in diameter. The target was a gummed back plastic material that stuck to the wall. The distance from the floor to the top of the target was sixty-two inches. Using a wooden paddle sixteen inches in length and nine inches wide, and a tennis ball, the subject attempted to hit the target five times
during each trial. The score for a trial was the number of
seconds it took the subject to hit the target the required
number of times. To start the trial the ball had to be
bounced and hit at the target. The scorer started timing the
subject's attempts when he bounced the ball the first time
to begin each trial. As the ball rebounded from the wall
the subject could choose to hit it again as it bounced from
the floor or he could catch the ball and bounce and hit it
again each time. If the subject lost control of the ball he
had to retrieve the ball and resume the volley. A hit was
successful if the ball touched any part of the target. There
was a maximum time limit of three minutes for each trial.
If the subject did not hit the target five times within the
maximum time limit, he was stopped and the score of one
hundred eighty seconds was recorded on his score card for
that trial. All scores for each trial were recorded in
number of seconds. A low score, in terms of number of seconds,
was considered better task performance than a high score.

The wall volley task was performed in a room which was
sixty feet long, twenty-five feet wide and approximately
twenty feet high. The room had grey cement floor, ceiling,
and walls. The room was well lighted with both artificial
and natural light. There were ten overhead lights suspended
from the ceiling and on the back wall there were three large
windows.
Six targets were attached to the front wall. The distance from the center of the end targets to the side walls was five feet. All six targets were ten feet apart, measured from center to center of each target. Each target area was designated as a wall volley station. At each station was a scorer who had been trained to administer and score the test. Each scorer was provided with a paddle, several tennis balls, a stop watch, score cards, and pencils.

Three subjects were assigned to each wall volley station. At the station the subject was given a score card (See Appendix J) and instructions in performing the wall volley task. Each subject was given one warm-up trial the first day for familiarization with the task. No warm-up was given on the second day of testing. For uniformity the subjects were assigned to the same testing station for the data collection on both Tuesday and Thursday.

The subject performed five trials of the wall volley task at one time. The scorer timed each trial and recorded the score. The subject then rested until the other men in his group performed their trials. Benches were provided along the back wall for the subjects to sit upon when they were not performing the task. The subjects performed twenty-five trials of the wall volley task on each of two days, a Tuesday and the following Thursday, for a total of fifty trials.
Grouping of Data

The scores collected from the fifty trials were grouped into ten stages of practice. The score for each stage of practice consisted of the sum of the number of seconds for each of five trials. Stage one was the first five trials, stage two was the second five trials, and so on to stage ten which consisted of the scores of the last five trials.

Grouping of Subjects

In addition to analyzing the data for the total sample population the relationships between ability measures and task performance scores were analyzed for four ability groups. Research by Amsden, Cragin, and Norrie indicated that early in practice of a motor task the subject's performance scores are more diverse and more variable. But as practice continues the subjects become more consistent in their performance, and intra-individual variability in performance scores decreases. Therefore, the selection of four ability


groups based upon final performance scores on the gross motor task could provide a more accurate distinction between levels of performance. The four groups were determined on the basis of the total score for the last five trials of the gross motor task.

For statistical analysis the groups were as follows:

Group I, subjects who ranked in the first quarter
Group II, subjects who ranked in the second quarter
Group III, subjects who ranked in the third quarter
Group IV, subjects who ranked in the fourth quarter.

Table I presents a comparison of the four ability groups as designated by their final stage of task practice. Low scores indicate fewer number of seconds to complete the task.

**TABLE I**

COMPARISON OF THE FOUR ABILITY GROUPS ON N'S, MAXIMUM SCORES, MINIMUM SCORES, RANGES, MEANS, AND STANDARD DEVIATIONS FOR THE LAST STAGE OF MOTOR SKILL PRACTICE

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Maximum Score</th>
<th>Minimum Score</th>
<th>Range</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>25</td>
<td>61</td>
<td>36</td>
<td>25</td>
<td>51.92</td>
<td>6.52</td>
</tr>
<tr>
<td>II</td>
<td>26</td>
<td>85</td>
<td>63</td>
<td>22</td>
<td>72.04</td>
<td>6.79</td>
</tr>
<tr>
<td>III</td>
<td>25</td>
<td>101</td>
<td>66</td>
<td>15</td>
<td>93.16</td>
<td>5.27</td>
</tr>
<tr>
<td>IV</td>
<td>26</td>
<td>207</td>
<td>103</td>
<td>104</td>
<td>127.85</td>
<td>21.00</td>
</tr>
<tr>
<td>Total Population</td>
<td>102</td>
<td>207</td>
<td>36</td>
<td>171</td>
<td>86.51</td>
<td>30.64</td>
</tr>
</tbody>
</table>
and are therefore the best scores. Group I had scores that ranged from 36 to 61, Group II had scores that ranged from 63 to 85, Group III had scores that ranged from 86 to 101, and Group IV had scores that ranged from 103 to 207.

Procedures for Treating the Data

The design of this investigation was such that the subjects were administered six ability measures, after which they practiced a novel gross motor task for fifty trials. The scores from the fifty trials on the motor task were grouped into ten stages of practice. The combined action of the abilities in predicting performance on the gross motor task was determined by utilizing a linear stepwise multiple regression analysis. In the stepwise approach, the predictor that has the highest coefficient of correlation with the criterion is selected in the first step. The second best predictor is then added and this multiple correlation with the criterion is computed. The procedure continues to add the variable that will produce the next highest partial correlation when utilized in conjunction with the previously used predictors. As each predictor variable is added, an F test of significance is computed to determine the significance of the relationship of the variable when added as a predictor.

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The prediction equation was computed at each stage of practice for the total population and at each stage of practice for the four ability groups. The data were analyzed to determine the relationship between the six abilities measured and performance on the novel gross motor task at succeeding stages of practice to determine if there was a systematic change in the abilities that contributed to motor performance as task performance improved.

The significance of the differences between the mean scores for the four ability groups on the six ability measures and on the gross motor performance scores at ten stages of practice was computed. The difference was tested by application of the Fisher's t test. Differences were accepted at the .05 level of significance.

The statistical computations were performed at the North Texas State University Computer Center, Denton, Texas.
CHAPTER IV

ANALYSIS OF THE DATA

One hundred two students from six sections of physical activity classes were administered tests of agility, balance, depth perception, flexibility, reaction time and speed of arm movement, and strength. These same students then practiced a novel gross motor wall volley task for fifty trials. The fifty trials were then grouped into ten stages of practice and a multiple regression was computed between the scores on the ability measures and the scores on each succeeding stage of wall volley practice.

An analysis of the performance trend on the wall volley task was made to determine the strength of the relationship between the abilities and gross motor practice to seek answers to these questions:

1. Will there be a change in the combination of abilities contributing to task performance with extended task practice?

2. Will the change of abilities contributing to task practice be systematic and progressive?

3. Will there be a systematic change in the proportion of variance unaccounted for at each stage of task performance as practice continues?
4. Will the relationships between abilities and task performance follow the same trend for individuals at four different levels of performance as determined by performance scores on the last stage of practice?

Intercorrelational matrixes were computed for the following five groups:

1. The total population (see Appendix K)
2. Group I, subjects in the first quarter (see Appendix L)
3. Group II, subjects in the second quarter (see Appendix M)
4. Group III, subjects in the third quarter (see Appendix N)
5. Group IV, subjects in the fourth quarter (see Appendix O).

For the abilities, agility, balance, flexibility, and strength a high score is better than a low score, whereas for the abilities, depth perception and reaction time and for the ten stages of practice a low score is better than a high score. For this reason a negative correlation coefficient may be reported between agility, balance, flexibility, and strength, and the other variables, yet would still indicate a positive relationship between the variables.
Results of the Study

The data collected for the study are related to six ability measures and ten stages of practice. They were collected by the use of motor ability measures for the abilities and by the use of a novel gross motor wall volley task for the ten stages of practice. For interpretation purposes the data are reported as follows: (1) agility is in raw score units, (2) balance is in seconds, (3) depth perception is in millimeters of error in judgement of alignment, (4) flexibility is in raw score units, (5) reaction time and speed of arm movement is in hundredths of a second, (6) strength is in number of pounds, and (7) the score of each stage of practice on the wall volley task is in seconds.

Table II contains the data collected for the total sample population on the six ability measures. For agility the highest score was 36 and the lowest was 13, which resulted in a range of 23. The mean score was 21.94 and the standard deviation was 4.77. On balance the range was 341 seconds, from 19 to 360 seconds with a mean of 188.32 seconds and a standard deviation of 109.54 seconds. The depth perception score range was 93 millimeters of error, from 6 to 99 millimeters, with a mean of 30.47 millimeters of error and a standard deviation of 21.71 millimeters of error.
TABLE II

MEANS, STANDARD DEVIATIONS, MAXIMUM SCORES, MINIMUM SCORES, AND RANGE FOR THE TOTAL POPULATION ON THE TESTS OF AGILITY, BALANCE, DEPTH PERCEPTION, FLEXIBILITY, REACTION TIME AND SPEED OF ARM MOVEMENT, AND STRENGTH (N = 102)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Highest Score</th>
<th>Lowest Score</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agility</td>
<td>24.94</td>
<td>4.77</td>
<td>36</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>Balance</td>
<td>188.32</td>
<td>109.514</td>
<td>360</td>
<td>19</td>
<td>341</td>
</tr>
<tr>
<td>Depth Perception</td>
<td>30.47</td>
<td>21.71</td>
<td>99</td>
<td>6</td>
<td>93</td>
</tr>
<tr>
<td>Flexibility</td>
<td>16.69</td>
<td>2.83</td>
<td>24</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Reaction Time and Speed of Arm Movement</td>
<td>.43</td>
<td>.05</td>
<td>.53</td>
<td>.33</td>
<td>.20</td>
</tr>
<tr>
<td>Strength</td>
<td>234.74</td>
<td>37.74</td>
<td>338</td>
<td>124</td>
<td>214</td>
</tr>
</tbody>
</table>

For flexibility the score range was 14, with the highest score being 24 and the lowest being 10. The mean score was 16.69 and the standard deviation was 2.83. The reaction time score range was .20 second, from a high of .53 to a low of .33 second. The mean score was .43 and the standard deviation was .05 second. Grip strength score range was 214 pounds, from a high of 338 pounds to a low of 124 pounds. The strength mean score was 234.74 pounds and the standard deviation was 37.74 pounds.
Tabulation of the results of the tests of agility, balance, depth perception, flexibility, reaction time and speed of arm movement, and strength for the four ability groups is presented in Table III.

### TABLE III

**N's, Means, and Standard Deviations for Ability Groups I, II, III, and IV on the Tests of Agility, Balance, Depth Perception, Flexibility, Reaction Time and Speed of Arm Movement, and Strength**

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Mean and Standard Deviation</th>
<th>Agility</th>
<th>Balance</th>
<th>Depth Perception</th>
<th>Flexibility</th>
<th>Reaction Time and Speed of Arm Movement</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>25</td>
<td>M 26.72</td>
<td>221.00</td>
<td>30.44</td>
<td>17.28</td>
<td>.41</td>
<td>236.96</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 4.34</td>
<td>100.84</td>
<td>19.77</td>
<td>2.88</td>
<td>.04</td>
<td>33.33</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>26</td>
<td>M 25.85</td>
<td>196.12</td>
<td>21.46</td>
<td>16.62</td>
<td>.43</td>
<td>231.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 4.23</td>
<td>111.87</td>
<td>6.87</td>
<td>2.64</td>
<td>.05</td>
<td>45.20</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>25</td>
<td>M 25.06</td>
<td>182.28</td>
<td>34.60</td>
<td>16.64</td>
<td>.45</td>
<td>230.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 4.05</td>
<td>113.27</td>
<td>27.79</td>
<td>2.53</td>
<td>.04</td>
<td>32.40</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>26</td>
<td>M 22.19</td>
<td>154.92</td>
<td>35.54</td>
<td>16.23</td>
<td>.44</td>
<td>239.38</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 4.86</td>
<td>107.67</td>
<td>24.09</td>
<td>3.28</td>
<td>.05</td>
<td>39.80</td>
<td></td>
</tr>
</tbody>
</table>

The significance of the difference between the mean scores on the agility test for Groups I, II, III, and IV is presented in Table IV. The Fisher's t value 3.57 for the
difference between the mean score of Groups I and IV is
significant at the .001 level of significance. The t value
of 2.91 for the difference between the mean scores of

TABLE IV

FISHER'S t TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE
BETWEEN THE MEANS OF THE SIDE STEP TEST OF AGILITY
FOR ABILITY GROUPS I, II, III, AND IV

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>.69</td>
<td>.61</td>
<td>2.28*</td>
</tr>
<tr>
<td>Group III</td>
<td>1.28***</td>
<td>2.91***</td>
<td>2.28*</td>
</tr>
<tr>
<td>Group IV</td>
<td>3.57***</td>
<td>2.91***</td>
<td>2.28*</td>
</tr>
</tbody>
</table>

*Significant at the .05 level.
**Significant at the .01 level.
***Significant at the .001 level.

Groups II and IV is significant at the .01 level of signi-
ficance. The t value of 2.23 for the difference between
the mean score of Groups III and IV is significant at the
.05 level of significance. No significant differences
exist between the mean scores of Groups I and II, between
Groups I and III, or between Groups II and III.

The significance of the difference between the mean
scores on the balance test for Groups I, II, III, and IV is
presented in Table V. The t value of 2.17 for the difference
between the mean score of Groups I and IV is significant at
the .05 level of significance. No significant differences
TABLE V

FISHER'S t TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MEANS OF THE BASS STICK TEST FOR BALANCE FOR ABILITY GROUPS I, II, III, AND IV

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>1.26</td>
<td>.46</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>2.17*</td>
<td>1.37</td>
<td>.90</td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

exist between the mean scores of Groups I and II, Groups I and III, Groups II and III, Groups II and IV, or between Groups III and IV.

The significance of the difference between the mean scores on the depth perception test for Groups I, II, III, and IV is presented in Table VI. The t value of 2.20 for

TABLE VI

FISHER'S t TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MEANS OF THE HOWARD-DOLMAN DEPTH PERCEPTION APPARATUS FOR ABILITY GROUPS I, II, III, AND IV

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>1.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>.69</td>
<td>2.20*</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>.86</td>
<td>2.38*</td>
<td>.16</td>
</tr>
</tbody>
</table>

*Significant at the .05 level.
the difference between the mean scores of Groups II and III is significant at the .05 level of significance. The t value of 2.38 for the difference between the mean scores of Groups II and IV is significant at the .05 level of significance. No significant differences exist between the mean scores of Groups I and II, Groups I and III, Groups I and IV, or between Groups III and IV.

The significance of the difference between the mean scores on the flexibility test for Groups I, II, III, and IV is presented in Table VII. As can be viewed there were no significant differences between the mean scores for any of the group combinations.

The significance of the difference between the mean scores on the reaction time and speed of arm movement test for Groups I, II, III, and IV is presented in Table VIII.

<table>
<thead>
<tr>
<th>Group</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>.63</td>
<td></td>
<td>.03</td>
<td>.51</td>
</tr>
<tr>
<td>Group III</td>
<td>.79</td>
<td>.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>1.32</td>
<td>.49</td>
<td>.51</td>
<td></td>
</tr>
</tbody>
</table>
TABLE VIII

FISHER'S t TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MEANS OF THE REACTION TIME AND SPEED OF ARM MOVEMENT TEST FOR ABILITY GROUPS I, II, III, AND IV

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>1.52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>3.13**</td>
<td>1.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>2.21*</td>
<td>.70</td>
<td>.95</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the .05 level.
**Significant at the .01 level.

The t value of 3.13 for the difference between the mean scores of Groups I and III is significant at the .01 level of significance. The t value of 2.21 for the difference between the mean scores of Groups I and IV is significant at the .05 level of significance. No significant differences exist between the mean scores of Groups I and II, Groups II and III, Groups II and IV, or between Groups III and IV.

The significance of the difference between mean scores on the strength test for Groups I, II, III, and IV is presented in Table IX. As can be seen, there were no
TABLE IX

FISHER'S t TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE
BETWEEN THE MEANS OF THE NARRAGANSETT HAND
MANUOMETER GRIP STRENGTH TEST FOR ABILITY
GROUPS I, II, III, AND IV

<table>
<thead>
<tr>
<th>Group</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>.57</td>
<td>.08</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>.23</td>
<td>.73</td>
<td>.80</td>
</tr>
</tbody>
</table>

significant differences between the mean scores for any of
the group combinations.

The data presented in Table X are the mean scores, in
terms of number of seconds, at each stage of wall volley

TABLE X

MEANS AND STANDARD DEVIATIONS FOR THE TOTAL SAMPLE
POPULATION AT ALL TEN STAGES OF PRACTICE
ON THE WALL VOLLEY TASK
(N = 102)

<table>
<thead>
<tr>
<th>Stage of Practice</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>172.22</td>
<td>61.78</td>
</tr>
<tr>
<td>Stage 2</td>
<td>147.53</td>
<td>55.76</td>
</tr>
<tr>
<td>Stage 3</td>
<td>132.31</td>
<td>50.90</td>
</tr>
<tr>
<td>Stage 4</td>
<td>115.29</td>
<td>46.48</td>
</tr>
<tr>
<td>Stage 5</td>
<td>109.94</td>
<td>37.41</td>
</tr>
<tr>
<td>Stage 6</td>
<td>105.60</td>
<td>36.77</td>
</tr>
<tr>
<td>Stage 7</td>
<td>97.80</td>
<td>32.56</td>
</tr>
<tr>
<td>Stage 8</td>
<td>91.94</td>
<td>31.42</td>
</tr>
<tr>
<td>Stage 9</td>
<td>87.94</td>
<td>31.10</td>
</tr>
<tr>
<td>Stage 10</td>
<td>80.51</td>
<td>30.64</td>
</tr>
</tbody>
</table>
practice for the total sample population. As can be seen there was an improved performance score at each succeeding stage of practice.

Figure 1 shows the performance trend for the same total sample population. A visual examination of the performance curve reveals there was a steady improvement until about the last three stages of practice. From Stage 8 to Stage 10 of practice, the performance curve levels off and very gradual improvement is evidenced for the final three stages of practice.

The mean scores, in terms of number of seconds, at each succeeding stage of wall volley practice for the four ability groups are presented in Table XI. There was an improved performance score at each succeeding stage of practice for
TABLE XI

COMPARISON OF N'S, MEANS, AND STANDARD DEVIATIONS FOR ABILITY
GROUPS I, II, III, AND IV AT ALL TEN STAGES OF
PERFORMANCE ON THE WALL VOLLEY TASK

<table>
<thead>
<tr>
<th>Group</th>
<th>N's</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
<th>Stage 5</th>
<th>Stage 6</th>
<th>Stage 7</th>
<th>Stage 8</th>
<th>Stage 9</th>
<th>Stage 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 25</td>
<td>M</td>
<td>122.76</td>
<td>93.92</td>
<td>83.72</td>
<td>79.88</td>
<td>75.20</td>
<td>74.52</td>
<td>66.64</td>
<td>62.24</td>
<td>58.00</td>
<td>51.92</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>37.56</td>
<td>19.29</td>
<td>23.44</td>
<td>19.19</td>
<td>18.67</td>
<td>14.06</td>
<td>17.61</td>
<td>11.59</td>
<td>7.97</td>
<td>6.52</td>
</tr>
<tr>
<td>II 26</td>
<td>M</td>
<td>161.11</td>
<td>130.81</td>
<td>119.65</td>
<td>104.12</td>
<td>101.69</td>
<td>89.96</td>
<td>89.23</td>
<td>81.38</td>
<td>79.65</td>
<td>72.04</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>43.44</td>
<td>32.90</td>
<td>32.83</td>
<td>24.00</td>
<td>17.57</td>
<td>16.77</td>
<td>15.31</td>
<td>11.03</td>
<td>8.26</td>
<td>6.79</td>
</tr>
<tr>
<td>III 25</td>
<td>M</td>
<td>174.40</td>
<td>173.12</td>
<td>147.64</td>
<td>128.40</td>
<td>119.28</td>
<td>115.48</td>
<td>104.28</td>
<td>95.56</td>
<td>90.32</td>
<td>93.16</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>44.85</td>
<td>55.90</td>
<td>46.45</td>
<td>41.15</td>
<td>41.26</td>
<td>36.83</td>
<td>20.91</td>
<td>21.63</td>
<td>13.73</td>
<td>5.27</td>
</tr>
<tr>
<td>IV 26</td>
<td>M</td>
<td>228.77</td>
<td>191.19</td>
<td>176.96</td>
<td>159.69</td>
<td>142.62</td>
<td>141.62</td>
<td>130.12</td>
<td>127.58</td>
<td>122.73</td>
<td>127.85</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>65.87</td>
<td>43.16</td>
<td>44.18</td>
<td>51.02</td>
<td>30.00</td>
<td>40.42</td>
<td>34.01</td>
<td>41.89</td>
<td>36.95</td>
<td>21.04</td>
</tr>
</tbody>
</table>
all four groups, except for the last two stages of practice for Groups III and IV. At Stage 9, Group III had a mean score of 90.32 seconds which was lower than its mean score of 93.16 seconds at Stage 10. Group IV had a mean score of 122.73 seconds at Stage 9 and this score was also lower than its score at Stage 10 which was 127.85 seconds.

Figure 2 shows the performance trend for the four ability groups. Visual inspection of the curves reveals

<table>
<thead>
<tr>
<th>Score in Seconds</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>140</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>160</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>170</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>190</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>210</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>220</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>230</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2—Performance curve for the wall volley task of four ability groups of college men classified according to final stage of practice scores.

there was an appreciable separation between the four groups from Stage 1 to Stage 10 of practice. It is noted also that
each group shows a constant and appreciable increase in task proficiency. As wall volley performance improved for all four groups there was no overlap of performance scores at any of the ten stages of practice for the four groups.

The results of the Fisher's t test for the significance of the difference between mean scores on the wall volley task at Stage 1 for the four ability groups are presented in Table XII. The t value of 2.78 for the difference

<table>
<thead>
<tr>
<th>Table XII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisher's t test for the significance of the difference between the means of practice Stage 1 on the wall volleyball task for ability groups I, II, III, and IV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
<th>Group IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>2.78**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>3.71***</td>
<td>.96</td>
<td>4.95***</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>7.68***</td>
<td></td>
<td>3.91***</td>
<td></td>
</tr>
</tbody>
</table>

**Significant at the .01 level.

***Significant at the .001 level.

between the mean scores of Groups I and II is significant at the .01 level of significance. The t values of 3.71 for the difference between Groups I and III and of 7.68 for the difference between Groups I and IV is significant at the .001 level of significance. A t value of 4.95 for the difference between Groups II and IV and a t value of 3.91 for the difference between Groups III and IV are significant at the
.001 level of significance. No significant difference was found between the mean scores of Groups II and III at the first stage of practice.

The significance of the difference between mean scores of the four ability groups in Stage 2 of practice is presented in Table XIII. The \( t \) value of 31.7 for the difference between Groups I and II is significant at the .01 level of significance. The \( t \) values of 3.17 for the difference between Groups I and III, and of 8.36 for the difference between Groups I and IV are significant at the .001 level of significance. The \( t \) values of 5.21 for the difference between Groups II and III, and of 5.24 for the difference between Groups II and IV are both significant at the .001 level of significance. No significance was found between Groups III and IV in mean performance at Stage 2 of wall volley practice.

**TABLE XIII**

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>3.17**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>5.74***</td>
<td>3.64***</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>8.36***</td>
<td>5.24***</td>
<td>1.55</td>
</tr>
</tbody>
</table>

**Significant at the .01 level.**

***Significant at the .001 level.**
The significance of the difference between the mean scores of the four ability groups at Stage 3 of practice on the wall volley task is presented in Table XIV. The $t$ values for the difference between Groups I and II is significant at the .01 level of significance. The $t$ values of 5.96 for the difference between Groups I and III, and of 8.79 for the difference between Groups I and IV are significant at the .001 level of significance. The $t$ value of 2.64 for the difference between Groups II and III is significant at the .05 level of significance and the $t$ value of 5.45 for the difference between Groups II and IV is significant at the .001 level of significance. A $t$ value of 2.76 for the difference between Groups III and IV is significant at the .01 level of significance.
The significance of the differences between the mean scores of the four ability groups at Stage 4 of practice is presented in Table XV. The \( t \) value of 2.39 for the difference between Groups I and II is significant at the .05 level of significance. The \( t \) values of 4.73 for the difference between Groups I and III and of 7.86 for the difference between Groups I and IV are significant at the .001 level of significance. The \( t \) value of 2.39 for the difference between Groups II and III is significant at the .05 level of significance and the value of 5.52 for the difference between Groups II and IV is significant at the .001 level of significance. A \( t \) value of 3.08 for the difference between Groups III and IV is significant at the .01 level of significance.

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>2.39*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>4.73***</td>
<td>2.39*</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>7.86***</td>
<td>5.52***</td>
<td>3.08**</td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

**Significant at the .01 level.

***Significant at the .001 level.
The significance of the difference between the mean scores of the four ability groups at Stage 5 of practice is presented in Table XVI. The t value of 3.32 for the difference between Groups I and II is significant at the .01 level of significance. The t values of 5.47 for the difference between Groups I and III and of 8.45 for the difference between Groups I and IV are significant at the .001 level of significance. The t value of 2.21 for the difference between Groups II and III is significant at the .05 level and the t of 5.18 for the difference between Groups II and IV is significant at the .001 level. A t value of 2.93 for the difference between Groups III and IV is significant at the .01 level of significance.

TABLE XVI

FISHER'S t TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MEANS OF PRACTICE STAGE 5 ON THE WALL VOLLEY TASK FOR ABILITY GROUPS I, II, III, AND IV

<table>
<thead>
<tr>
<th>Group</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>3.32**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>5.47***</td>
<td>2.21*</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>8.45***</td>
<td>5.18***</td>
<td>2.93**</td>
</tr>
</tbody>
</table>

*Significant at the .05 level.

**Significant at the .01 level.

***Significant at the .001 level.
The significance of the differences between the mean scores of the four ability groups at Stage 6 of practice is presented in Table XVII. No significant difference was found between Groups I and II at this stage of practice. However, the \( t \) values, 4.91 for the difference between Groups I and III and 8.13 for the difference between Groups I and IV are significant at the .001 level of significance. The \( t \) of 3.09 for the difference between Groups II and III is significant at the .01 level while the \( t \) of 6.32 for the difference between Groups II and IV is significant at the .001 level of significance. The reported \( t \) value of 3.17 for the difference between Groups III and IV is significant at the .01 level of significance.

The significance of the differences between the mean scores of the four ability groups at Stage 7 of practice is
presented in Table XVIII. The $t$ value of 3.48 for the
difference between Groups I and II is significant at the
.01 level of significance. The $t$ values of 5.74 for the

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>3.48**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>5.71***</td>
<td>2.32*</td>
<td></td>
</tr>
<tr>
<td>Group IV</td>
<td>9.77***</td>
<td>6.36***</td>
<td>3.98***</td>
</tr>
</tbody>
</table>

*Significant at the .05 level.
**Significant at the .01 level.
***Significant at the .001 level.

difference between Groups I and II, and of 9.77 for the
difference between Groups I and IV are significant at the
.001 level of significance. The difference between Groups
II and III is a $t$ value of 2.32, significant at the .05
level of significance and the $t$ of 6.36 for the difference
between Groups II and IV is significant at the .001 level
of significance. The $t$ of 3.98 for the difference between
Groups III and IV is also significant at the .001 level of
significance.

The significance of the difference between the mean
scores of the four ability groups at Stage 8 of practice is
presented in Table XIX. The t of 2.73 for the difference between Groups I and II is significant at the .01 level of significance and the t values of 4.71 for the difference between Groups I and III and of 9.32 for the difference between Groups I and IV are significant at the .001 level of significance. The t value of 2.02 for the difference between Groups II and III is significant at the .05 level of significance and the t of 6.66 for the difference between Groups II and IV is significant at the .001 level of significance. The t value of 4.57 is also significant at the .001 level of significance for the difference between Groups III and IV.

The significance of the difference between the mean scores of the four ability groups at Stage 9 of practice
is presented in Table XX. The \( t \) values of 3.74 between Groups I and II, of 5.53 between Groups I and III, and of 11.18 between Groups I and IV are all significant at the .001 level of significance. The \( t \) value of 7.51 for the difference between Groups II and IV is significant at the .001 level of significance. However, no significant difference was found between Groups II and III at this stage of practice. A \( t \) of 5.60 for the difference between Groups III and IV is significant at the .001 level of significance.

The significance of the difference between the mean scores of the four ability groups at Stage 10 of practice is presented in Table XXI. The \( t \) values of 6.03 between Groups I and II, of 12.24 between Groups I and III, and of 22.76 for the difference between Groups I and IV are all significant at the .001 level of significance. The \( t \) value
### TABLE XXI

**FISHER'S t TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MEANS OF PRACTICE STAGE 10 ON THE WALL VOLLEY TASK FOR ABILITY GROUPS I, II, III, AND IV**

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td>6.03***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group III</td>
<td>12.22***</td>
<td>6.33***</td>
<td>16.89***</td>
</tr>
<tr>
<td>Group IV</td>
<td>22.76***</td>
<td>16.89***</td>
<td>10.40***</td>
</tr>
</tbody>
</table>

***Significant at the .001 level.

A t of 6.33 for the difference between Groups II and III and the t of 16.89 between Groups II and IV are significant at the .001 level of significance. A t of 10.40 for the difference between Groups III and IV is also significant at the .001 level of significance.

### Findings Related to the Purposes of the Study

This section of the findings is a presentation of the order of the variable entered into the regression equation, the multiple correlation, the variance accounted for by the multiple correlation, an analysis of variance reported as an F ratio to determine the significance of the added variables as predictors, and the standard error of the estimate for the combination of predictors as each predictor is added to the equation. The multiple correlation is referred to as the multiple R and the variance accounted for is referred to
as $R^2$. These data are reported for the combination of the six abilities as predictors of performance on each succeeding stage on the wall volley task.

The multiple correlations and the significance of each added variable as a predictor to performance on the wall volley task for the total sample population at the ten stages of practice are presented in Table XXII. At Stage 1 for the total sample population, reaction time was the best single predictor of performance on the wall volley task with a multiple $R$ of .29, an $R^2$ of .08, and an $F$ ratio that was significant at the .01 level of significance. Agility, when combined with reaction time, increased the multiple $R$ to .38. The combined action of these two variables accounted for 15 per cent of the variance and had an $F$ ratio that was significant at the .01 level of significance. With depth perception added as a predictor, the multiple $R$ increased to .42 and the combined action of reaction time, agility, and depth perception accounted for 18 per cent of the variance. The $F$ ratio for these three predictors was 6.99, significant at the .01 level of significance.

The addition of the last three predictors, balance, flexibility, and strength did not increase the multiple $R$ noticeably. There was a slight increase in the $R^2$ to where the combined action of all six abilities accounted for 20 per cent of the variance of performance at Stage 1 of the wall volley task. Although there was a negligible increase
### TABLE XXII

**Order of the Variables Entered into the Regression Equation, Multiple R, R², F Ratio, and Standard Error of the Estimate for the Relationship of the Six Abilities to Wall Volley Performance on Each Succeeding Stage of Practice for the Total Sample Population**

<table>
<thead>
<tr>
<th>Entry Order of Variable</th>
<th>Stage 1 of Wall Volley Practice</th>
<th>Stage 2 of Wall Volley Practice</th>
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*Significant at the .05 level.

**Significant at the .01 level.

**"X1"--Agility, "X2"--Balance, "X3"--Depth Perception, "X4"--Flexibility.
"X5"--Reaction Time and Speed of Arm Movement, "X6"--Strength.*
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in the multiple R and the $R^2$ with the addition of the last three predictors, the $F$ ratio indicated the inclusion of balance, flexibility, and strength was significant.

Agility was the single best predictor of performance at Stage 2 for the total sample population with a multiple R of .24 which accounted for 6 per cent of the variance. An $F$ ratio of 6.11 was reported for agility which is significant at the .01 level of significance. Reaction time, when added to the equation, increased the multiple R to .33. The addition of reaction time accounted for 11 per cent of the variance. The $F$ ratio for these two variables as predictors was 5.92, which is significant at the .01 level of significance. When depth perception was added the multiple R increased to .37 and the combination of these three variables accounted for 14 per cent of the variance. The addition of balance, flexibility, and strength did not produce a significant increase in the size of the multiple R or a sizeable increase in the $R^2$. Although there was just a slight increase in the multiple R and the $R^2$ with the addition of balance, flexibility, and strength as predictors, the $F$ ratio indicated the inclusion of these three abilities was significant.

At Stage 3 of practice for the total sample population agility was the best single predictor. It had a multiple R of .27 and accounted for 7 per cent of the variance. The
The F ratio for agility was 8.03 which is significant at the .01 level of significance.

Reaction time, when combined with agility, increased the multiple R to .35. The combination of these two variables accounted for 12 per cent of the variance. The F ratio for agility and reaction time was 6.80 which is significant at the .01 level of significance. Flexibility was the third variable added and it increased the multiple R to .38. The addition of flexibility increased the $R^2$ to 14 per cent and the combination of these three variables had an F ratio of 5.48 which is significant at the .01 level of significance. Depth perception was the fourth variable added. It increased the multiple R to .41 and the combination of these four variables accounted for 17 per cent of the variance. The F ratio of 4.99 for the four predictors indicated is significant at the .01 level of significance. The addition of the last two predictors, balance and strength, did not result in a significant increase in the multiple R nor in the variance accounted for. The combination of all six abilities as predictors at the third stage of practice did result in an F ratio of 3.35 which is significant at the .05 level of significance.

At Stage 4, reaction time was the single best predictor for the total sample population with a multiple R of .22 which accounted for 5 per cent of the variance. The F ratio for reaction time as a predictor was 4.91 which is
significant at the .05 level of significance. The addition of agility to reaction time as a predictor resulted in a multiple R of .26. Their combined $R^2$ was 7 per cent and the $F$ ratio for reaction time and agility was 3.47 which is significant at the .05 level of significance. Flexibility was the third variable added as a predictor and it increased the multiple R to .29. The combination of reaction time, agility, and flexibility accounted for 9 per cent of the variance, and the $F$ ratio for these three predictors was 3.06 which is significant at the .05 level of significance. The addition of the last three variables, balance, strength, and depth perception, did not produce a significant increase in the variance accounted for by the addition of these variables. A view of the $F$ ratio indicates balance, strength, and depth perception did not make a significant contribution to performance on the wall volley task at Stage 4 of practice.

At Stage 5 of practice for the total sample population reaction time was the best single predictor with a multiple R of .22. It accounted for 5 per cent of the variance and had an $F$ ratio of 4.98 which is significant at the .05 level of significance. Agility was the next variable added and it increased the multiple R to .27. The combined action of these two predictors accounted for 7 per cent of the variance and had an $F$ ratio of 3.83 which is significant at the .05 level of significance. Depth perception was the third variable added and it, in conjunction with reaction time and
agility, resulted in a multiple $R$ of .29. The combined action of these three variables accounted for 8 per cent of the variance and the reported $F$ ratio was 2.88 which is significant at the .05 level of significance.

The addition of flexibility, strength, and balance did not result in a significant increase in the multiple $R$ nor in the variance accounted for. The $F$ ratio indicates that flexibility, strength, and balance are not significant predictors at the fifth stage of task practice.

At Stage 6 of practice for the total sample population agility was the best single predictor. It had a multiple $R$ of .23, an $R^2$ of 6 per cent, and an $F$ ratio of 5.82 which is significant at the .05 level of significance. The addition of reaction time as the second variable increased the multiple $R$ to .32. The combination of these two variables accounted for 11 per cent of the variance and their $F$ ratio was 5.78 which is significant at the .01 level of significance. Flexibility was the third variable added to the prediction equation and it, in conjunction with agility and reaction time, increased the multiple $R$ to .37. These three variables accounted for 14 per cent of the variance and their $F$ ratio was 5.51 which is significant at the .01 level of significance. The fourth predictor added was depth perception which increased the multiple $R$ to .40, the $R^2$ to 16 per cent and the combined action of these four variables had an $F$ ratio of 4.61 which is significant at the .01 level of
significance. The addition of the two abilities, strength and balance, did not result in an increase in the multiple R or in the variance accounted for. The F ratio for all six variables indicated they made a significant contribution to performance at the sixth stage of practice.

Reaction time was the best single predictor of performance at Stage 7 of practice for the total sample population. It had a multiple R of .27 and accounted for 7 per cent of the variance. The F ratio between reaction time and practice was 7.56 which is significant at the .01 level of significance. Balance, when added to reaction time, increased the multiple R to .36. The combination of these two abilities accounted for 13 per cent of the variance and their combined F ratio was 7.17 which is significant at the .01 level of significance. Agility was the third variable added to the regression equation. Its addition resulted in the multiple R increasing .38 and the $R^2$ increasing to 14 per cent. The F ratio for these three abilities as predictors was 5.51 which is significant at the .01 level of significance. The fourth variable added was depth perception. Its inclusion resulted in the multiple R increasing to .39 and the $R^2$ increasing to 16 per cent. The F ratio for these four abilities as predictors was 4.44 which is significant at the .01 level of significance. Flexibility and strength were the fifth and sixth variables to be added. Their addition as predictors resulted in a slight increase in the
multiple R. All six abilities accounted for 17 per cent of the variance and the $F$ ratio of 3.33 indicated those six variables were significant predictors.

At Stage 8 of practice balance was the best single predictor for the total sample population with a multiple $R$ of .28. It accounted for 8 per cent of the variance and had an $F$ ratio of 8.24 which is significant at the .01 level of significance. Reaction time was the second variable added and it, in conjunction with balance, increased the multiple $R$ to .35 and the $R^2$ to 12 per cent. They had an $F$ ratio of 6.78 which is significant at the .01 level of significance. The third variable added was agility. The combination of balance, reaction time, and agility, resulted in a multiple $R$ of .39. They accounted for 15 per cent of the variance and had a combined $F$ ratio of 5.61 which is significant at the .01 level of significance. Flexibility was the fourth variable added to the regression equation and its inclusion resulted in the multiple $R$ increasing to .42. The four abilities accounted for 18 per cent of the variance and they had an $F$ ratio of 5.13 which is significant at the .01 level of significance. Depth perception and strength were the fifth and sixth variables added. Their inclusion increased the multiple $R$ to .45 and increased the variance accounted for to 20 per cent. The $F$ ratio for all six abilities as predictors at the eighth stage of practice was 3.98 which is significant at the .01 level of significance.
At Stage 9 of practice for the total sample population, agility was the best single predictor. It had a multiple $R$ of $.25$, accounted for 6 per cent of the variance, and its $F$ ratio of 6.70 is significant at the .05 level of significance. Reaction time was the second variable included and it increased the multiple $R$ to .35 and the $R^2$ to 12 per cent. The joint action of agility and reaction time as predictors had an $F$ ratio of 6.68 which is significant at the .01 level of significance. The third variable to be added was balance and it, in conjunction with agility and reaction time resulted in a multiple $R$ of .38, an increase in the $R^2$ to 14 per cent and an $F$ ratio of 5.37 which was significant at the .01 level of significance. Flexibility was added fourth and its inclusion increased the multiple $R$ to .40. The combined action of the four predictors increased the variance accounted for to 16 per cent and had an $F$ ratio of 4.43 which is significant at the .01 level of significance. Depth perception and strength were the last two variables added to the regression equation. Their inclusion increased the multiple $R$ to .40, however the variance accounted for remained at 16 per cent. The combined action of all six abilities as predictors at Stage 9 of practice had an $F$ ratio of 3.05 which is significant at the .05 level of significance.

Agility was the best single predictor at Stage 10 of practice for the total sample population on the wall volley task. It had a multiple $R$ of .32, an $R^2$ of 10 per cent, and
an F ratio of 11.10 which is significant at the .01 level of significance. The second variable added was reaction time. It increased the multiple R to .39 and the $R^2$ to 15 per cent. The combined action of agility and reaction time as predictors had an F ratio of 8.77 which is significant at the .01 level of significance. Balance was the third variable added to the regression equation. It increased the multiple R to .42. The variance accounted for increased to 18 per cent and the F ratio for the combination of agility reaction time, and balance as predictors was 6.99 which is significant at the .01 level of significance. The fourth variable added was flexibility. Its inclusion increased the multiple R to .43, the $R^2$ to 19 per cent, and the combination of the four abilities as predictors had an F ratio of 5.57 which is significant at the .01 level of significance. Depth perception and strength were the last two variables added to the regression equation. Their addition as predictors increased the multiple R to .45 and increased the variance accounted for to 20 per cent. The combined action of all six abilities as predictors at Stage 10 of practice resulted in an F ratio of 4.02 which is significant at the .01 level of significance.

The multiple correlations and the significance of each added variable as a predictor to performance on the wall volley task for Group I at the ten stages of practice are presented in Table XXIII.
TABLE XXIII

ORDER OF THE VARIABLES ENTERED INTO THE REGRESSION EQUATION, MULTIPLE R, R^2, 
F RATIO, AND STANDARD ERROR OF THE ESTIMATE FOR THE RELATIONSHIP OF THE 
six abilities to wall volley performance on each succeeding 
stage of practice for ability group 1

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**Significant at the .05 level.

***Significant at the .01 level.

**"X1"--Agility, "X2"--Balance, "X3"--Depth Perception, "X4"--Flexibility, 
"X5"--Reaction Time and Speed of Arm Movement, "X6"--Strength.
### TABLE XXIII--Continued

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** Note: The significance levels are denoted as * (p < .1), ** (p < .05), and *** (p < .01).
TABLE XXIII--Continued

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At Stage 1 of practice for Group I reaction time was the best single predictor with a multiple R of .48 and an $R^2$ of 23 per cent. The $F$ ratio of 6.81, for reaction time as a predictor, is significant at the .05 level of significance. Strength was the second best predictor at Stage 1. Combined with reaction time, it increased the multiple $R$ to .55. The variance accounted for increased to 30 per cent and the $F$ ratio of 4.75 indicates the predictors to be significant at the .05 level of significance. The third variable added was depth perception. The inclusion of depth perception with reaction time and strength increased the multiple $R$ to .58 and the $R^2$ to 33 per cent. The $F$ ratio for these three variables as predictors to wall volley performance was 3.50 which is significant at the .05 level of significance. Agility, balance, and flexibility were the last three variables added to the regression equation. Their combined action with reaction time, strength, and depth perception increased the multiple $R$ to .61 and increased the variance accounted for to 37 per cent. The inclusion of agility, balance, and flexibility did not result in a significant increase in predictive ability. The $F$ ratio was low and not significant.

At Stage 2 of practice the best single predictor for performance on the wall volley task for Group I was strength. It had a multiple $R$ of .41 and accounted for 17 per cent of the variance. The $F$ ratio was 4.65 which was significant at
the .05 level of significance. Reaction time, when combined with strength was the second best predictor. Reaction time increased the multiple $R$ to .50, the $R^2$ to .25 per cent, and when combined with strength, had a prediction $F$ ratio of 3.58 which is significant at the .05 level of significance. Depth perception, flexibility, agility, and balance, in that order, were the next four variables added to the regression equation. They increased the multiple $R$ to .54 and raised the variance accounted for to 29 per cent. A visual examination of the $F$ ratio for these four predictors indicated they did not make a significant contribution to wall volley performance.

For Group 1 depth perception was the best single predictor at Stage 3 of practice. It had a multiple $R$ of .56, an $R^2$ of 31 per cent, and an $F$ ratio of 10.22 which is significant at the .01 level of significance. Reaction time was the second best predictor and it increased the multiple $R$ to .62, the variance accounted for to 39 per cent, and when combined with depth perception had an $F$ ratio of 7.02 which is significant at the .01 level of significance. Strength, agility, balance, and flexibility, in that order, were the next variables added to the regression equation. They increased the multiple $R$ to .63 and accounted for 40 per cent of the variance. Strength and agility, when combined with depth perception and reaction time, had a prediction $F$ ratio of 3.23 which was significant at the .05
level of significance. Balance and flexibility did not make a significant contribution to performance at the third stage of practice.

At Stage 4 of practice, depth perception was the best single predictor for Group I. It had a multiple R of .44, accounted for 19 per cent of the variance, and had an F ratio of 5.49 which is significant at the .05 level of significance. Strength was the second variable added to the regression equation and it, in conjunction with depth perception had a multiple R of .53 and an $R^2$ of 28 per cent. The combination of depth perception and strength had an F ratio of 4.25 which is significant at the .05 level of significance. The third variable added in the equation was flexibility. Flexibility, in conjunction with depth perception and strength, increased the multiple R to .58, the $R^2$ to 34 per cent and these three variables as predictors had an F ratio of 3.61 which is significant at the .05 level of significance. Balance, reaction time, and agility were the next three variables added in the regression equation. The F ratio indicated their contribution was not significant. All six abilities resulted in predicting a multiple R of .61 and accounted for 37 per cent of the variance.

At Stage 5 of practice for Group I, depth perception was the best single predictor. It had a multiple R of .58, an $R^2$ of 34 per cent, and an F ratio of 11.71 which is significant at the .01 level of significance. Reaction time
was then added to the regression equation and it, in conjunction with depth perception increased the multiple $R$ to $.59$, the $R^2$ to $35$ per cent, and this resulted in an $F$ ratio of $5.82$ which is significant at the $.01$ level of significance. Flexibility was the third variable added. Its inclusion did not result in an increase of the multiple $R$ or the $R^2$, but the $F$ ratio of $3.83$ for flexibility, depth perception, and reaction time is significant at the $.05$ level of significance. Agility, strength, and balance were the last three variables added to the regression equation but their inclusion did not result in a significant $F$ ratio. All six abilities in combination had a multiple $R$ of $.60$ and they accounted for $36$ per cent of the variance.

At Stage 6 of practice for Group I none of the abilities made a significant contribution to performance on the wall volley task. Depth perception was the first variable entered, followed by strength, agility, balance, reaction time, and flexibility. The combined action of all six variables resulted in a multiple $R$ of $.39$ and they accounted for $15$ per cent of the variance. However, the $F$ ratio for the significance of the inclusion of a predictor variable indicates none of the predictor variables made a significant contribution.

Depth perception was the single best predictor for Group I at Stage 7 of practice. It had a multiple $R$ of $.68$, accounted for $46$ per cent of the variance, and had an $F$ ratio
of 19.29 which is significant at the .01 level of significance. Balance was the second variable added to the regression equation and it increased the multiple R to .73. The variance accounted for increased to 53 per cent and the combination of these two variables as predictors had an F ratio of 12.32 which is significant at the .01 level of significance. Reaction time was the third variable added and it, in conjunction with depth perception and balance, increased the multiple R to .74, increased the $R^2$ to 55 per cent and had an F ratio of 8.42 which is significant at the .01 level of significance. The fourth variable added was agility. Its inclusion in the regression equation increased the multiple R to .75, increased the $R^2$ to 56 per cent and had an F ratio of 6.27 which is significant at the .01 level of significance. Flexibility and strength were the last two variables added to the regression equation. Their inclusion did not increase the multiple R nor the variance accounted for. All six variables had a prediction F ratio of 3.78 which is significant at the .05 level of significance.

At Stage 8 of practice for Group I there were no significant predictor variables of performance on the wall volley task. Balance was the first variable entered, although it had an F ratio of 3.76 it was not significant. Balance was followed by depth perception, strength, agility, reaction time, and flexibility in the regression equation. As a combined group these six abilities had a multiple R of .57.
They accounted for 33 per cent of the variance but the $F$ ratio at each level of inclusion of a variable indicated these predictors did not make a significant contribution to performance.

At Stage 9 of practice for Group I there were no significant predictors of performance on the wall volley task. Depth perception was the first variable added to the regression equation followed by agility, reaction time, flexibility, balance, and strength, in that order. For all six abilities their combined action resulted in a multiple $R$ of .42. They accounted for 17 per cent of the variance. The $F$ ratio at each level of addition of a predictor variable indicated these predictors did not make a significant contribution to performance at this stage of practice.

At Stage 10 of practice for Group I there were no significant predictors of performance on the wall volley task. Strength was the first variable added to the regression equation followed by balance, depth perception, reaction time, agility, and flexibility, in that order. For all six abilities their combined action resulted in a multiple $R$ of .37 and they accounted for 14 per cent of the variance. However, the $F$ ratio at each level of inclusion of a predictor variable indicated these predictors did not make a significant contribution to performance at the tenth stage of practice.

The multiple correlations and the significance of each added variable as a predictor to performance on the wall
volley task for Group II at the ten stages of practice are presented in Table XXIV.

At Stage 1 of practice for Group II there were no significant predictors of performance on the wall volley task. Depth perception was the first variable entered into the regression equation followed by flexibility, agility, reaction time, balance, and strength. The combined action of the six abilities as predictors resulted in a multiple $R$ of .43 and an $R^2$ of 18 per cent. The $F$ ratio indicated at each level of inclusion of a predictor variable that those predictors did not make a significant contribution to performance on the wall volley task.

For Group II at Stage 2 of practice there were no significant predictors of performance. Depth perception was the first variable entered into the regression equation, followed by balance, strength, flexibility, reaction time, and agility. All six abilities combined resulted in a multiple $R$ of .47 and they accounted for 22 per cent of the variance. The $F$ ratio indicated that at each level of inclusion of a predictor variable these predictors did not make a significant contribution to task performance at the second stage of practice.

At Stage 3 of practice for Group II there were no significant predictors of performance on the wall volley task. Flexibility was the first variable entered into the regression equation followed by reaction time, agility, balance,
**TABLE XXIV**

ORDER OF THE VARIABLES ENTERED INTO THE REGRESSION EQUATION, MULTIPLE R, R², F RATIO, AND STANDARD ERROR OF THE ESTIMATE FOR THE RELATIONSHIP OF THE SIX ABILITIES TO WALL VOLLEY PERFORMANCE ON EACH SUCCEEDING STAGE OF PRACTICE FOR ABILITY GROUP II

<table>
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<th>Entry Order of Variable</th>
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<th>Stage 3 of Wall Volley Practice</th>
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*Significant at the .05 level.

**Significant at the .01 level.

***"X1"--Agility, "X2"--Balance, "X3"--Depth Perception, "X4"--Flexibility, "X5"--Reaction Time and Speed of Arm Movement, "X6"--Strength.
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depth perception, and strength. All six abilities combined resulted in a multiple $R$ of .44 and they accounted for 19 per cent of the variance. The $F$ ratio indicated that at each level of inclusion of a predictor variable these predictors did not make a significant contribution to task performance at the third stage of task practice.

At Stage 4 of practice for Group II there were no significant predictors of performance on the wall volley task. Reaction time was the first variable entered into the regression equation followed by depth perception, strength, flexibility, agility, and balance in that order. All six abilities combined resulted in a multiple $R$ of .43 and they accounted for 19 per cent of the variance. The $F$ ratio indicated that at each level of inclusion of a predictor variable these predictors did not make a significant contribution to task performance at the fourth stage of practice.

For Group II at Stage 5 of practice there were no significant predictors of performance on the wall volley task. Agility was the first variable entered into the regression equation followed by depth perception, flexibility, reaction time, balance, and strength in that order. All six abilities combined resulted in a multiple $R$ of .34 and accounted for 11 per cent of the variance. The $F$ ratio indicated that at each level of inclusion of a predictor variable these predictors did not make a significant contribution to task performance at the fifth stage of practice.
At Stage 6 of practice for Group II depth perception was the best single predictor of performance on the wall volley task. It had a multiple $R$ of $0.41$ and accounted for $17$ percent of the variance. The $F$ ratio for depth perception as a predictor was $4.90$ which is significant at the $0.05$ level of significance. The other five abilities, reaction time, flexibility, agility, strength, and balance, were entered into the regression equation in that order. The $F$ ratio indicated these abilities did not make a significant contribution to prediction of performance on the wall volley task. All six abilities combined resulted in a multiple $R$ of $0.55$ and accounted for $31$ percent of the variance at the sixth stage of practice.

At Stage 7 of practice for Group II there were no significant predictors of performance on the wall volley task. Reaction time was the first variable entered into the regression equation followed by strength, depth perception, agility, balance, and flexibility. All six abilities produced a multiple $R$ of $0.32$ and accounted for $10$ percent of the variance. The low $F$ ratio indicated none of the abilities were significant predictors at the seventh stage of practice.

Depth perception was the best single predictor of performance on the wall volley task at Stage 8 of practice for Group II. It had a multiple $R$ of $0.39$ and an $R^2$ of $15$ percent. The $F$ ratio of $4.32$ indicated depth perception as a predictor was significant at the $0.05$ level of significance.
Strength, flexibility, agility, reaction time, and balance were added to the regression equation in that order. However, the F ratio for the combination of all six abilities as predictors for the wall volley task was not significant. The combination of the six abilities resulted in a multiple R of .54 and had an $R^2$ of 29 per cent.

At Stage 9 of practice for Group II there were no significant predictors of performance on the wall volley task. Balance was the first variable entered into the regression equation followed by reaction time, strength, agility, depth perception, and flexibility. All six abilities combined resulted in a multiple R of .48 and they accounted for 23 per cent of the variance. The F ratio indicated that at each level of inclusion of a predictor variable those predictors did not make a significant contribution to task performance.

For Group II at Stage 10 of practice there were no significant predictors of performance on the wall volley task. Strength was the first variable entered into the regression equation followed by depth perception, agility, reaction time, flexibility, and balance. The F ratio indicated that at each level of inclusion of a predictor variable those predictors did not make a significant contribution to task performance. The combined action of the six abilities resulted in a multiple R of .41 and they accounted for 17 per cent of the variance at the tenth stage of practice.
The multiple correlations and the significance of each added variable as a predictor of performance on the wall volley task for Group III at the ten stages of practice are presented in Table XXV.

At Stage 1 of practice for Group III there were no significant predictors of performance on the wall volley task. Strength was the first variable entered into the regression equation followed by flexibility, reaction time, depth perception, balance, and agility. The six abilities combined resulted in a multiple R of .33 and they accounted for 11 percent of the variance. The F ratio indicated that at each level of inclusion of a predictor variable these predictors did not make a significant contribution to task performance.

At Stage 2 of practice for Group III a low F ratio for the six predictor variables indicated these variables did not make a significant contribution to prediction of task performance. Flexibility was the first variable entered into the regression followed by strength, agility, reaction time, depth perception, and balance. The combined action of these six abilities resulted in a multiple R of .23 and they accounted for 5 percent of the variance at Stage 2.

For Group III at Stage 3 of practice there were no significant predictors of performance on the wall volley task. Agility was the first variable added into the regression equation followed by strength, reaction time, flexibility, balance, and depth perception. These six abilities had a
TABLE XXV
ORDER OF THE VARIABLES ENTERED INTO THE REGRESSION EQUATION, MULTIPLE R, R², F RATIO, AND STANDARD ERROR OF THE ESTIMATE FOR THE RELATIONSHIP OF THE SIX ABILITIES TO WALL VOLLEY PERFORMANCE ON EACH SUCCEEDING STAGE OF PRACTICE FOR ABILITY GROUP III

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*=Significant at the .05 level.

**="X1"--Agility, "X2"--Balance, "X3"--Depth Perception, "X4"--Flexibility, "X5"--Reaction Time and Speed of Arm Movement, "X6"--Strength.
<table>
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<tr>
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<td>.56</td>
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</table>
multiple R of .37 and an $R^2$ of 13 per cent. The F ratio indicated these six predictors did not significantly predict task performance at that stage of practice.

At Stage 4 of practice for Group III there were no significant predictors of performance on the wall volley task. Balance was the first variable included in the regression equation followed by strength, agility, depth perception, flexibility, and reaction time. The six abilities had a multiple R of .23 and they accounted for 5 per cent of the variance. The F ratio indicated these six predictors did not significantly predict task performance at the fourth stage of practice.

At Stage 5 of practice for Group III there were no significant predictors of wall volley task performance. Depth perception was the first predictor entered into the regression equation followed by balance, strength, reaction time, flexibility, and agility. The six abilities had a multiple R of .33 and they accounted for 11 per cent of the variance. The F ratio indicated these six predictors did not significantly predict performance at that stage of practice.

For Group III at Stage 6 of practice there were no significant predictors of wall volley task performance. Balance was the first variable selected in the regression equation and it was followed by strength, depth perception, reaction time, agility, and flexibility. These six abilities had a
multiple R of .27 and they accounted for 7 per cent of the variance. The F ratio indicated these six predictors did not significantly predict performance at that stage of practice.

The F ratio for the six predictor variables at Stage 7 of practice for Group III indicated the six abilities did not significantly predict task performance. Balance was the first predictor added to the regression equation followed by depth perception, strength, flexibility, agility, and reaction time. Combined, the six abilities had a multiple R of .36 and an $R^2$ of 13 per cent at the seventh stage of practice on the wall volley task.

At Stage 8 of practice for Group III, balance was the best single predictor of performance on the wall volley task. It had a multiple R of .45, an $R^2$ of 20 per cent, and an F ratio of 5.71 which indicated balance to be a significant predictor at the .05 level of significance. Depth perception was the second variable entered into the regression equation and it increased the multiple R to .58 and increased the $R^2$ to 33 per cent. Flexibility was the third variable entered as a predictor. Its presence increased the multiple R to .71 and the variance accounted for to 50 per cent. Agility, flexibility, and depth perception were entered as predictor variables in that order. They did not change the multiple R or the variance accounted for. The combined action of all
six abilities or predictors had an $F$ ratio of 3.08 which is significant at the .05 level of significance.

At Stage 9 of practice for Group III there were no significant predictors of wall volley task performance. Balance was the first predictor entered into the regression equation followed by reaction time, strength, agility, flexibility, and depth perception. The six abilities as predictors had a multiple $R$ of .56 and an $R^2$ of 31 per cent. The $F$ ratio indicated these six abilities did not significantly predict performance at the ninth stage of task practice.

At Stage 10 of practice for Group III there were no significant predictors of wall volley task performance. Agility was the first variable entered into the regression equation followed by balance, flexibility, strength, reaction time, and depth perception. The combined action of the six abilities as predictors resulted in a multiple $R$ of .40 and they accounted for 16 per cent of the variance. The $F$ ratio indicated these six abilities did not significantly predict task performance at the final stage of practice.

The multiple correlations and the significance of each added variable as a predictor to performance on the wall volley task for Group IV at the ten stages of task practice are presented in Table XXVI.

At Stage 1 of task practice for Group IV there were no significant predictors of wall volley performance. The order of the entrance of the six variables into the regression
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**Significant at the .05 level.

**Significant at the .01 level.

"X1"—Agility, "X2"—Balance, "X3"—Depth Perception, "X4"—Flexibility, "X5"—Reaction Time and Speed of Arm Movement, "X6"—Strength.
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TABLE XXVI--Continued

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equation was reaction time, depth perception, strength, agility, flexibility, and balance. The combined action of these abilities as predictors resulted in a multiple $R$ of .38 and they accounted for 15 per cent of the variance. The $F$ ratio indicated these six abilities did not significantly predict task performance for Group IV at the first stage of practice.

At Stage 2 of practice for Group IV no significant predictor of wall volleyball performance was found. Depth perception was the first variable entered into the regression equation followed by flexibility, reaction time, strength, agility, and balance. These six abilities combined for a multiple $R$ of .49 and an $R^2$ of 24 per cent, but the $F$ ratio indicated these abilities did not significantly predict performance at the second stage of practice.

The $F$ ratio for the six abilities as predictors of wall volleyball performance indicated there were no significant predictors of performance at Stage 3 of practice for Group IV. The order of entrance into the regression equation for the six abilities was flexibility, reaction time, balance, strength, agility, and depth perception. The combined action of these six abilities as predictors resulted in a multiple $R$ of .47 and they accounted for 22 per cent of the variance.

Depth perception was the single best predictor of performance on the wall volleyball task at Stage 4 of practice for Group IV. It had a multiple $R$ of .50, an $R^2$ of 25 per cent,
and an $F$ ratio of 8.08 which indicated depth perception to be a significant predictor at the .01 level of significance. Flexibility, when combined with depth perception, increased the multiple $R$ to .58 and increased the variance accounted for to 33 per cent. The $F$ ratio for depth perception and flexibility as predictors indicated they were significant at the .01 level of significance. Strength was the third variable added to the regression equation. With the inclusion of strength the multiple $R$ increased to .59, the $R^2$ increased to 35 per cent and the $F$ ratio for these three predictors was 3.89, significant at the .05 level of significance. Balance, reaction time, and agility were added to the regression equation in that order. Their inclusion did not increase the multiple $R$ or the variance accounted for.

At Stage 5 of practice for Group IV there were no significant predictors of wall volley performance. Strength, flexibility, depth perception, agility, balance, and reaction time were added to the regression equation in that order. These six abilities combined as predictors had a multiple $R$ of .39 and they accounted for 16 per cent of the variance. The $F$ ratio indicated these abilities did not significantly predict performance at the fifth stage of practice.

Flexibility was the best single predictor of performance on the wall volley task at Stage 6 of practice for Group IV. It had a multiple $R$ of .47, an $R^2$ of 22 per cent, and an $F$ ratio of 6.89 which indicated flexibility was a significant
predictor at the .05 level of significance. Reaction time was the second variable added to the regression equation and it increased the multiple R to .57, the variance accounted for to 32 per cent and it had an F ratio of 5.38, significant at the .05 level of significance. Depth perception was the third predictor added and its inclusion increased the multiple R to .58, the $R^2$ to 34 per cent and it had an F ratio of 3.73, significant at the .05 level of significance. Strength, balance, and agility were the last three variables added in the regression equation. Their inclusion did not change the multiple R or the $R^2$ significantly.

At Stage 7 of practice for Group IV on the wall volley task there were no significant predictors of task performance. Depth perception was the first variable entered into the regression equation followed by flexibility, reaction time, agility, balance, and strength. These six abilities combined as predictors had a multiple R of .50 and they accounted for 25 per cent of the variance. The F ratio indicated these combined abilities did not significantly predict task performance at the seventh stage of practice.

For Group IV at Stage 8 of practice, reaction time and flexibility combined to be the two best predictors of performance. Combined, these two variables accounted for 214 per cent of the variance and had a multiple R of .49. The F ratio of 3.70 indicated these predictors to be significant at the .05 level of significance. Agility, strength, balance,
and depth perception were added to the regression equation. Their presence did not significantly increase the multiple \( R \) or the \( R^2 \). The combined \( F \) ratio for these last four variables indicated they were not significant predictors of task performance.

At Stage 9 of practice for Group IV, flexibility and strength were the two best predictors of performance. When combined in the regression equation, these two variables had a multiple \( R \) of .50 and they accounted for 25 per cent of the variance. The \( F \) ratio of 3.80 indicated flexibility and strength to be significant predictors at the .05 level of significance. Agility, balance, depth perception, and reaction time were added to the regression equation. They did not significantly increase the multiple \( R \) or the variance accounted for. The \( F \) ratio indicated these last four variables were not significant predictors of performance.

At Stage 10 of practice for Group IV, flexibility, strength, and balance combined to be the best predictors of wall volley performance. Their combination resulted in a multiple \( R \) of .55 and they accounted for 30 per cent of the variance. The \( F \) ratio for these three predictors was 3.11, significant at the .05 level of significance. Agility, reaction time and depth perception were the last three variables added to the regression equation and their inclusion did not result in a significant increase in the multiple \( R \) or the variance accounted for. The \( F \) ratio for
the last three variables indicated they did not significantly predict task performance at the tenth stage of practice.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The problem under consideration was an investigation of the relationship of selected abilities to motor skill performance. Specifically, the study analyzed the performance trend on a gross motor task to determine the degree of the relationship between selected abilities and gross motor task performance scores at successive stages of task practice in an attempt to answer these questions:

1. Will there be a change of abilities contributing to task performance with extended task practice?

2. Will the change of abilities contributing to task performance be systematic and progressive?

3. Will there be a systematic change in the proportion of variance unaccounted for at each stage of task performance as practice continues?

4. Will the relationship between abilities and task performance follow the same trend for individuals at four different levels of performance as determined by performance scores on the last stage of task practice?

To accomplish the purpose of this study the following relationships were determined. The relationship between the...
performance score on each successive stage of practice on a gross motor task and the following abilities: agility, balance, depth perception, flexibility, reaction time and speed of arm movement, and strength.

During the spring semester of 1970, 102 male freshman and sophomore students from six sections of Physical Education 116 at North Texas State University were used as subjects in this study. The students selected for the study met for the testing session and skill practice sessions during their regularly scheduled class time. To insure adequate contact time, only those students enrolled in Tuesday and Thursday physical education classes were selected for the study. Each subject was required to take six ability tests. These tests were: The Side Step Test for agility, The Bass Stick Test for balance, The Howard-Dolman Depth Perception Apparatus for depth perception, Fleishman's Bend, Twist, and Touch Test for flexibility, The Hand Manometer for grip strength, and a reaction time and speed of arm movement test.

The subjects then met with the investigator for two separate sessions. During the two meetings each subject performed a total of fifty trials of a novel gross motor task that involved hitting for speed and accuracy. The novel gross motor task was a wall volley task. The subjects performed twenty-five trials of the wall volley task on each of two days, a Tuesday and the following Thursday,
for a total of fifty trials. A low score, in terms of number of seconds, was considered better task performance than a high score.

The scores collected from the fifty trials were grouped into ten stages of practice. The score for each stage of practice consisted of the sum of the number of seconds for each of five trials. Stage one was the first five trials, stage two was the second five trials, and so on to stage ten which consisted of the scores of the last five trials.

In addition to analyzing the data for the total sample population the relationships between ability measures and task performance were analyzed for four ability groups. The four groups, four quarters of the total sample group, were determined on the basis of the total score for the last five trials of the gross motor task.

The combined action of the abilities in predicting performance on the gross motor task was determined by utilizing a linear stepwise multiple regression analysis. The prediction equation was computed at each stage of practice for the four ability groups. The data were analyzed to determine the relationship between the six abilities measured and performance on the novel gross motor task at succeeding stages of practice to determine if there was a systematic change in the abilities that contributed to motor performance as task performance improved. An F ratio was applied as each predictor variable was entered into the regression equation to determine if the
predictor was a significant contributor to the regression equation. The .05 level of significance was arbitrarily set for the acceptance of a variable as a predictor.

The significance of the difference between the mean scores for the four ability groups on the six ability measures and on the gross motor performance scores at ten stages of practice was computed by utilizing Fisher's t-test. Differences were accepted at the .05 level of significance.

The following is a summary of the findings with respect to the questions asked:

1. Will there be a change in the combination of abilities contributing to task performance with extended task practice?

For the total sample population reaction time and agility were the two most consistent predictors of performance at all ten stages of practice. Beginning at stage one of practice and continuing through stage six of practice, reaction time and agility accounted for the greatest percentage of variance toward performance on the wall volley task. At stages seven and eight of practice balance replaced agility as a primary predictor. However, agility was the third variable added to the regression equation both times. Agility became a primary predictor again at stages nine and ten. The change that took place in the combination of abilities contributing to performance was not long lasting.
2. Will the change of abilities contributing to task performance be systematic and progressive?

With the exception of balance becoming a primary predictor at stages seven and eight of practice, no other variables replaced reaction time and agility as primary contributors to wall volley performance. Depth perception and flexibility accounted for a small percentage of the variance at all ten stages of practice, however neither became an important predictor of performance. Strength was not a significant predictor at any stage of practice. There was no systematic change of abilities contributing to task performance.

3. Will there be a systematic change in the proportion of variance unaccounted for at each stage of task performance as practice continues?

The per cent of variance accounted for was stable for the first three stages of practice, became low for the fourth and fifth stages of practice, and then raised again for the final five stages of practice. The change in the proportion of variance unaccounted for at each succeeding stage of practice did not systematically increase or decrease.

4. Will the relationships between abilities and task performance follow the same trend for individuals at four different levels of performance as determined by performance scores on the last stage of task practice?
For Group I reaction time and strength were the two primary predictors of wall volley performance in the first and second stages of practice. Starting at stage three and continuing through stage nine of practice, depth perception became the primary predictor of wall volley performance. For the first five stages of practice the variance accounted for was low but stable. At stage six it dropped to fifteen per cent, at stage seven it increased to fifty-five per cent, and then from stage eight to stage ten of practice it became increasingly lower. Also from stage eight to stage ten of practice, the multiple correlation coefficients between the predictor variables and wall volley performance scores were low and not significant. This would indicate abilities other than those measured were contributing to performance at those stages of practice.

For Group II, at stage six and at stage eight of practice depth perception was the single best predictor, but the other variables did not significantly contribute to performance on the wall volley task. At the other eight stages of practice the correlation coefficients between the scores of the abilities measured and wall volley performance scores were low and not significant. There was no systematic change either of increasing or of decreasing importance in contribution of the abilities to task performance.

The variance accounted for throughout the ten stages of practice was low and stable. This indicated that the
abilities measured in this study did not significantly contribute to performance for this group.

For Group III one stage of practice, stage eight, showed a significant multiple R between the scores on balance, depth perception, and flexibility, and the wall volley task performance score. At all other stages of practice the correlation of coefficients between the ability measure scores and the wall volley performance scores were low and not significant.

Balance appeared to be of increasing importance and strength appeared to be of decreasing importance as predictor variables in the succeeding stages of practice. It is difficult to assess the significance of this trend since the $F$ ratio indicated the variables measured were not significant predictors.

With the exception of stage eight where the $R^2$ was fifty per cent, the variance accounted for at each of the other nine stages of practice was low. There was no systematic change in the variance accounted for with Group III at each succeeding stage of practice.

For Group IV there were no systematic changes in the abilities that predicted wall volley performance from stage one to stage ten of practice. One variable, flexibility, was the most consistent predictor ability. It was a primary predictor at stage two of practice and remained so to stage ten of practice. However, at several stages, flexibility,
along with the other variables, did not significantly contribute to performance.

It was also found that there was no consistency in the contribution of the other five variables to performance on the wall volley task. The order of entry of the variables in the regression equation fluctuated from stage to stage of practice.

The variance accounted for also fluctuated from stage to stage of practice. There was no consistency at the succeeding stages of practice in the variance accounted for until the final three stages of practice. But since the combination of abilities that contributed to performance at these three stages changed, no particular trend was evidenced.

Conclusions

Based upon the findings of the study the following conclusions were drawn:

1. For college students the abilities that contribute to early stage performance are the same as those abilities that contribute to late stage performance on a wall volley task.

2. Knowledge of the abilities that are primary predictors of wall volley performance for the total sample population cannot be generalized to individual skill level groups within the total sample population. The abilities that are primary predictors of wall volley performance for
a total sample population are not the primary predictors for specific skill level groups.

3. When individual ability level groups have been selected on the basis of their performance scores for the final stage of practice on a wall volley task, a convergence of the individual ability level performance curves does not take place. The curves will be similar in shape; however, significant differences will exist between the ability level groups at succeeding stages of task practice.

Recommendations

The findings of this study suggest the following recommendations:

1. A similar study should be conducted using different measures of the abilities tested in this study.

2. A similar study should be conducted using measures of additional abilities not measured in this study.

3. A similar study should be conducted using several different measures of the same ability to determine which measure would be the best ability predictor for the wall volley task.

4. A similar study should be conducted using younger age groups where a more elemental stage of perceptual-motor level of ability is found.
5. A similar study should be conducted and stages of practice analyzed to determine if there are critical stages of performance on a perceptual-motor task.

6. A similar study should be conducted using other perceptual-motor, gross motor tasks where hand-eye foot-eye, and hand-foot learning is involved.
**APPENDIX A**

**TEST DATA SCORE CARD**

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<td>Time:</td>
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**SIDE STEP TEST**

**FLEXIBILITY TEST**

**BALANCE (Basch Stick Test)**
- Right Leg, Trial #1
- Right Leg, Trial #2
- Right Leg, Trial #3
- Left Leg, Trial #1
- Left Leg, Trial #2
- Left Leg, Trial #3

**STRENGTH (Hand Grip Test)**
- Right Hand, Trial #1, #2, #3
- Left Hand, Trial #1, #2, #3

**REACTION TIME-SPEED TEST**
- Trial #1
- Trial #2
- Trial #3
- Trial #4
- Trial #5
- Trial #6
- Trial #7
- Trial #8
- Trial #9
- Trial #10

**DEPTH PERCEPTION**
- Trial #1
- Trial #2
- Trial #3
- Trial #4
- Trial #5
- Trial #6
- Trial #7
- Trial #8
- Trial #9
- Trial #10
APPENDIX B

DIRECTIONS FOR ADMINISTERING
THE SIDE STEP TEST

1. The subject begins by standing astride the center line.

2. On the starting signal the subject side steps to the right until his right foot crosses the outside line six feet from the center line.

3. The subject then side steps to the left until his left foot crosses the left outside line that is six feet to the left of the center line.

4. A two foot counter mark is placed halfway between the center line and each outside line.

5. Each time the subject crosses one line he receives one point. For example, the subject moves to his right and crosses the right counter mark for one point, the outside line for two points, back across the counter mark for three
points, across the center line for four points, across the left counter mark for five points, across the left outside line for six points, back across the counter mark for seven points, and so on until the stop signal is given.

6. The subject continues these movements as rapidly as possible for ten seconds.

7. The subject's score is the number of lines crossed in the ten second period of time.

8. **Penalty** - There is a one point penalty for each time a crossover step is taken and for each failure to place the proper foot across the outside line.
APPENDIX C

DIRECTIONS FOR ADMINISTERING

THE BASS STICK TEST

1. The subject places his foot lengthwise on the balance stick and lifts the opposite foot from the floor, maintaining his balance for as long as possible, up to a maximum of sixty seconds.

2. Each subject is given three trials with the right foot and three trials with the left foot.

3. The subject alternates feet on each of the six trials of the test.

4. The subject places his foot on the balance stick and timing begins as soon as he lifts his opposite foot from the floor.

5. Timing is stopped as soon as any part of the subject's body touches the floor.

6. The score for each trial is the number of seconds the subject maintains his balance.

7. The subject's balance score is the sum of the times for all six trials.
APPENDIX D

DIRECTIONS FOR ADMINISTERING
THE HOWARD-DOLMAN DEPTH
PERCEPTION TEST

1. The rod on the left side is the movable rod.

2. The string in the right hand will move the rod backward and the string in the left hand will move the rod forward.

3. The subject is not permitted to move his head while adjusting the rod.

4. The subject may not draw the movable rod from end to end of the box.

5. The subject must drop the strings when he has aligned the rods.

6. The rods are screened from the subject's view while readjustments are being made.
APPENDIX E

ROD PLACEMENT FOR THE HOWARD-DOLMAN DEPTH PERCEPTION APPARATUS

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APPENDIX F

DIRECTIONS FOR ADMINISTERING FLEISHMAN'S

BEND, TWIST, AND TOUCH TEST

1. The subject begins by standing with his back toward the wall (eighteen inches from the wall) and his hands in front of his thighs.

2. The subject's feet are shoulder width apart.

3. An "X" mark is placed on the floor between the subject's feet and another "X" mark is placed on the wall directly behind the middle of the back at shoulder height.

4. On the starting signal the subject bends forward and touches the "X" mark between his feet with both hands. He then rises, turns to his left and touches the "X" mark behind his back that is placed on the wall. This constitutes one cycle. In the next cycle the subject repeats this movement except he twists to the right.

5. The subject continues to alternate the side to which he twists as rapidly as possible for twenty seconds.

6. The subject's score is the number of trials he completes in twenty seconds.
APPENDIX G

DIRECTIONS FOR ADMINISTERING THE
REACTION TIME AND SPEED OF
ARM MOVEMENT TEST

1. The subject's dominant hand is to rest on a line
twelve inches from the reaction box key.

2. A visual stimulus, a light, will be presented.
When the light is flashed the subject is to press the key
below the light.

3. A preparatory command, "Ready", will be given and
then the light will flash. The light will be presented at
varying intervals.

4. The subject is given two practice trials and ten
trials for score.

5. The score is the number of seconds, in hundredths,
that is recorded on the timer.
APPENDIX H

TRIAL NUMBER, STIMULUS LIGHT SETTING, AND SECONDS FOR THE REACTION TIME AND SPEED OF ARM MOVEMENT TEST

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#5 ..... 1 ..... 2
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#7 ..... 3 ..... 2
#8 ..... 2 ..... 3
#9 ..... 2 ..... 4
#10 ..... 3 ..... 3

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APPENDIX I

DIRECTIONS FOR ADMINISTERING

THE GRIP STRENGTH TEST

1. The subject should place the convex edge of the manuometer between the first and second joints of the fingers with the dial toward the palm.

2. The subject is allowed any movement while squeezing the instrument provided he does not hit any object with his fist. The most common movement is the upper cut.

3. The dominant hand is measured first.

4. Each subject has three trials with each hand.

5. The score for each trial is the number of pounds recorded on the manuometer.

6. The subject's grip strength score is the sum of the highest reading for the right hand and the highest reading for the left hand.

7. Allow thirty seconds rest between grip measurements.
**APPENDIX J**

**WALL VOLLEY SCORE CARD**

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APPENDIX K

INTERCORRELATION OF THE ABILITY MEASURES AND THE SCORES FOR TEN STAGES
OF WALL VOLLEY PRACTICE FOR THE TOTAL SAMPLE POPULATION

\( (N = 102) \)

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APPENDIX L

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APPENDIX M

INTERCORRELATION OF THE ABILITY MEASURES AND THE SCORES FOR TEN STAGES
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### APPENDIX N

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### APPENDIX O

**INTERCORRELATION OF THE ABILITY MEASURES AND THE SCORES FOR TEN STAGES OF WALL VOLLEY PRACTICE FOR GROUP IV**

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