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Richard Dane Howell

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Vernal D. Seefeldt
Major professor

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THE RELATIONSHIP BETWEEN MOTOR PERFORMANCE, PHYSICAL GROWTH, AND SKELETAL MATURITY IN BOYS NINE THROUGH TWELVE YEARS OF AGE

By

Richard Dane Howell

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ABSTRACT

THE RELATIONSHIP BETWEEN MOTOR PERFORMANCE, PHYSICAL GROWTH, AND SKELETAL MATURITY IN BOYS NINE THROUGH TWELVE YEARS OF AGE

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This investigation examined the relationship of motor performance and physical growth with skeletal maturity. The data were obtained over a ten year period from 9 through 12 year-old boys who were enrolled in the longitudinal Motor Performance Study at Michigan State University. Within each chronological age group the subjects were subdivided into three levels of skeletal maturity; advanced, normal, and delayed.

With skeletal maturity as the independent variable, motor performance scores and physical growth measurements were analyzed using multivariate and univariate techniques. Follow-up analyses were applied when warranted. Only the motor performance scores of the nine-year-old age division were significantly related to the skeletal maturity of the subjects ($p < .05$). Within their respective age divisions, the advanced maturity group was consistently larger in physical size than were the normal and delayed groups. Many of these differences in physical size were statistically significant at the .05 level.

This work is dedicated to the memory of a friend, David Hird, whose fate did not allow him to know the joy of seeing a completed Master's Thesis. Dave was well liked by many, many people. I am very proud to have been one of them.

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Finally, I wish to say a very special thank you to the person who has been by my side throughout my days as a college student, my wife. Without Jean's support and encouragement, this educational pursuit would not have been possible.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

LIST OF FIGURES

CHAPTER I

THE PROBLEM

The existing criteria used for categorizing children into subgroups for optimal motor learning and/or athletic competition are not sufficient (Seefeldt, 1978; Martens, 1978; Griffin and Henschen, 1978). Chronological age and grade level, the criteria most often used, both imply that children's growth and readiness for learning depend on a rate of development that is consistent for all individuals. Organizations that use these criteria as guidelines indirectly express the belief that because two children have lived the same length of time, they are capable of learning at the same rate and competing at the same level. This is not necessarily true. It has been well established that children mature at different rates, which suggests that a measure of physiological development may be a more valid indicator of readiness than the two previously mentioned criteria.

It is essential that a method be devised to classify children for optimal learning and competition where motor skills are the basis for success. In an attempt to reach the goal of more suitable criteria for homogeneous grouping during motor skill performance, more research is needed to ascertain which characteristics of children correlate highly with the ability to perform motor skills. The

assessment of skeletal age as an indicator of physiological development may provide such a criterion.

The concept of assessing physiological development of children is not a new one. Crampton (1908) and Rotch (1908) began focusing on the need for measuring physiological development early in this century, however standards for estimating skeletal age were not available until 1937 (Todd). Between 1908 and 1937 other scientists devised various methods for making the assessment of skeletal age a reliable and objective way to determine skeletal development.

Much has been published concerning the significance of using skeletal age as an indicator of physiological development. It has been written that early maturers differ from late maturers in a variety of ways including academic achievement, physical growth, personality development and motor ability. A thorough review of the literature pertaining to physiological versus chronological age can be found in Chapter II of this report.

Need for the Study

Frequently children are categorized into what are supposedly homogeneous groups for learning and/or competition. For whatever reasons the groupings are made, be they academic, sport or social, the ultimate goal usually is to establish an optimal learning environment for each child. However, we often fail in achieving this goal, and our failure is manifested by the inability of some of the learners to attain certain knowledge or abilities. Why does this occur? Why does it always seem to be the same children who fail in their attempts to perform as well as the others? Obviously, there are many variables

that may prevent or assist children in their performances. For instance, some youth are endowed with physical capabilities that others will never have. In addition, teaching methods, parental motivation and learning resources play a vital role. However, in this paper the focus is on just one of many potential variables: physiological readiness for motor performance.

An obvious problem with the concept of readiness is the difficulty encountered when one tries to determine a child's readiness to learn. If the truth were known, it may be that different criteria for establishing optimal learning and competitive groups would exist for each situation that presents itself. This study is an attempt to determine if skeletal age is a valid indicator of motor performance ability. If so, perhaps skeletal age would be a better criterion for grouping children for motor skill learning and sports competition than chronological age. If this is the case, efforts would have to be made so that the assessment of skeletal age becomes a more practical measure.

Purpose of the Study

The primary purpose of this study was to determine if boys, when classified according to levels of skeletal maturity, differ from each other on selected measures of motor performance. A secondary purpose of this study was to describe the growth measurements of the boys when classified according to levels of skeletal maturity. The independent variable, skeletal maturity, was subdivided into three levels; namely advanced, normal and delayed. The selected motor performance tasks were: (a) the flexed arm hang, (b) jump and

reach, (c) agility shuttle run, (d) standing long jump, (e) 30-yard dash, (f) sit and reach, and (g) 400-foot shuttle run (see Appendix A). The selected growth measurements were: (a) standing height, (b) sitting height, (c) acrom-radiale length,(d) radio-stylion length, (e) bi-acromial breadth, (f) bi-cristal breadth, (g) arm-biceps girth, (h) thigh girth, (i) calf girth, (j) triceps skinfold, (k) subscapular skinfold, (l) umbilical skinfold, (m) ponderal index, and (n) weight (see Appendix B).

Research Hypotheses

The primary purpose of this study was to examine the relationship of skeletal maturity and selected motor performance test scores. Research has revealed that skeletal maturity is generally not a major factor in the ability of an individual to perform motor tasks prior to puberty (Seils, 1951; Rarick and Oyster, 1964; Jordan, 1966). However, experiential evidence with other boys in this age group suggests that those with advanced skeletal maturity seem to perform better athletically than those who mature within the normal range, who, in turn, seem to perform better than those who mature later. Data provided by Krogman (1959) and Clarke (1971) lend support to this notion. Thus, the following hypotheses were considered.

Significant differences were expected for four of the events that were included in this study. It was expected that the boys with advanced skeletal maturity for each chronological age group would perform significantly better than the normal maturers who would perform significantly better than the late maturers for the vertical jump, the agility shuttle run, the standing long jump, and the thirty-yard

dash. These events were chosen because power, agility, and speed are believed to be beneficial characteristics of successful athletes.

No differences were expected among the three skeletal maturity groups for the Wells sit and reach, the flexed-arm hang, or the 400-foot endurance run. These predictions were made for various reasons. Experience has shown that individuals become less flexible as they get older, so skeletal maturity may have the same effect. The flexed-arm hang is a measure of relative upper body strength and may depend heavily on the size of the individual rather than the raw strength that he possesses. Not enough is known about the 400-foot enddurance run to make predictions about how the individuals of the same chronological but of differing biological ages might perform on the task.

Research Plan

Boys who were enrolled in the Motor Performance Study at Michigan State University from ages 9-12 years chronologically served as subjects for this investigation. Data on fourteen physical growth measurements were obtained to clearly identify the average body sizes of the groups. Data on seven motor performance tests for these boys also were obtained, so that the abilities of boys with advanced, normal, and delayed skeletal maturity could be compared.

The three groups mentioned were the three levels of the independent variable, skeletal maturity. The subjects in each age division (9 years, 10 years, 11 years, and 12 years) were classified into one of the levels.

Inferential statistics were used to analyze the data. For each age division the MANOVA procedure of the Statistical Package

for the Social Sciences - SPSS (Nie, Hull, Jenkins, Steinbrenner and Bent, 1975) was used to determine if skeletal maturity had an overall effect on motor performance. Multivariate and univariate follow-up statistics were used when warranted to further examine the relationship between the levels of skeletal maturity and motor performance. The research plan is explained in detail in Chapter III of this report.

Delimitations

The population for this study was delimited to males who were enrolled in the Motor Performance Study at Michigan State University while they were from 9-12 years of age chronologically. All of the boys for whom skeletal age assessments and motor performance data were available were included in the sample. Nine through twelve year old males (chronologically) were chosen, because the literature concerning this age group related to maturation and motor skills is sparse. Also, this age group is extensively involved in competitive youth sports competition, and more needs to be known about the effects of physiological development on motor skill performance.

The study was further delimited by the test battery of the Motor Performance Study from which the data are taken. Seven motor performance measures were included as the dependent variables in this investigation. The test battery measures leg power, flexibility, relative upper body strength and endurance, cardiovascular endurance, speed, and agility. Originally, these tests were not chosen to differentiate between the various levels of maturational development.

Limitations

The investigator was aware of the following potential weaknesses in the study.

1. Motivation of subjects is difficult to control when testing for motor performance. The degree of exertion by individual subjects during the measurement period was not evaluated, although all subjects were urged to perform with maximum effort on all of the tests.
2. The effect, if any, of the various facilities used for testing on the motor performance of the boys is unknown.
3. The average chronological age for each level of skeletal age within an age group could not be controlled. That is, it may be that one level of skeletal age for the 10 year-old group had an average chronological age of 10.8 years, while another level of the same age group had an average chronological age of 10.1 years.
4. Human error in the measurement of motor performance and skeletal age was operating to an unknown degree.
5. Instrument bias may have been a possibility.
6. Sample size was limited by the amount of data that were available.

Significance of the Study

It is important to learn more about the effect of physiological development on pre-adolescents. It is well established that children do not mature at the same rate, and yet it is not known how this variation on maturation affects them with regard to motor skills. If it

can be ascertained through studies such as this that skeletal development is an indicator of a child's ability to perform specific skills, perhaps another method by which children could be grouped for instruction in motor skills should be considered.

This study could have specific implications for teaching motor skills. If one of the skeletal maturity groups has a distinct advantage in the performance of motor skills, then physical educators should take notice and give consideration to grouping by physiological development instead of by grade level or chronological age. This would also apply to individuals who teach motor skills to children in other settings, such as youth sport groups and private clubs. It would be especially critical to those who provide competition for children and base their competitive divisions on chronological age alone.

Definitions

Chronological age. The amount of time one has existed as measured by sidereal time.

Skeletal age. An assessment of the degree to which maturation has occurred in skeletal ossification centers, as seen on x-rays.

Advanced maturer. One whose difference score, when obtained by subtracting his chronological age from his skeletal age, is greater than one standard deviation above the mean of the difference scores for his chronological age group.

Normal maturer. One whose difference score is within plus or minus one standard deviation of the mean of the difference

scores for his chronological age group.

Delayed maturer. One whose difference score is more than one standard deviation below the mean of the difference scores for his chronological age group.

Motor Performance Study. The study from which the data for this investigation were taken. The longitudinal study was initiated in January 1968 in the Department of Health, Physical Education and Recreation at Michigan State University and has enrolled over 1200 children through June 1978.

CHAPTER II

RELATED LITERATURE

The need for a developmental criterion based on physiological growth of human beings has been recognized since the beginning of this century. The early work of Crampton (1908) and Rotch (1908) emphasized the need for a biological criterion for the assessment of maturity and made suggestions for exploring the methods by which this could be accomplished. Carter (1926), Cattell (1934) and Flory (1936) made initial contributions in formalizing the objective measurement of human skeletal growth via x-ray. They were followed by Todd (1937), Greulich and Pyle (1950, 1959), Acheson (1954, 1957) and Tanner, Whitehouse and Healy (1959, 1962) who made great strides toward its popular use by establishing standards to which the x-rays could be compared and evaluated. Others whose names are prominent throughout the literature concerning skeletal age include Krogman (1954, 1959, 1970, 1972), Roche (1965, 1968, 1969, 1970, 1971, 1975) and Tanner (1955, 1961, 1962, 1971, 1975).

This chapter, a review of the literature pertaining to skeletal age, is written to inform the reader of the work that has been published in an effort to establish skeletal age as a valid form of developmental assessment. A need for its use will be established before discussing the overall concept of skeletal age. Then, an historical

perspective of the various methods of assessment and criticisms of the methods is presented. The next section is comprised of the relationship that skeletal development has with cognitive growth, somatic growth and the motor and affective domains. Finally, the differences in rate of skeletal development between males and females are outlined.

Physiological Age as a Developmental Criterion

Children develop at various rates. They do not proceed from one stage of development to the next at exactly the same pace. Nor do they advance systematically with the calendar. This presents problems in instances when an index of physiological development is desired. For example, parents like to know about the comparative growth of their children as they move through infancy, childhood and adolescence. In addition, governmental agencies and ethnic groups are frequently interested in knowing how a certain community stands with regard to maturational status of its youth. Thirdly, clinical medicine concerns itself with the normal physical growth of children in order that growth inducing or inhibiting remedies may be prescribed, if necessary. Finally, many educators agree that students should be grouped homogeneously if an optimum learning environment is to be established. Without comparative criterion available, these concerns can not be addressed.

These and other situations suggest that some form of development measurement be available. Although it is quite frequently used, the number of days that a child has lived (chronological age) is not an accurate developmental criterion. A more appropriate standard

(skeletal age) is available for this purpose. Greulich agreed with this opinion when he stated that there is a need for more ". . . precise information about the developmental status of the child than can properly be inferred from its height, weight and age alone." (1959, p. 1).

Although at present there is no practical method for its assessment by the layman, the concept of skeletal age as an indicator of development is a sound one. By making use of this developmental yardstick, one can eliminate some of the inherent deficiencies of chronological age. Numerous authors (Todd, 1937; Greulich and Pyle, 1950, 1959; Acheson, 1954, 1957; Tanner and Whitehouse, 1959; Tanner, Whitehouse and Healy, 1962) have published standards from which clinicians can assess, via x-ray, the maturational status of a child. The assessment of skeletal age, in conjunction with an accurate measurement of standing height can also be used to successfully predict the child's adult height (Baley and Pinneau, 1952). With these thoughts in mind, the review will further describe the physiological development creiterion of skeletal age and explain how it can be assessed.

Concept of Skeletal Age

Over the years many methods of assessing development in addition to chronological age have been suggested. As early as 1908 Crampton (1908) used the term physiological age and Rotch (1908) spoke of anatomic age as yardsticks of development. Other developmental ages have been suggested. Included in the list are dental age, maturational age, organismic age and skeletal age. Though assessments

of these measures were made in varied ways, they were all proposed for a common reason--to establish the physiological developmental level of children. Of these, chronological age is the most widely used, because it is readily obtained. This is a poor excuse for its use in many cases, however.

One of the most accurate indicators of a child's biological maturation is skeletal age. This is an evaluation of the maturational level of children which is made by assessing the degree of growth that the bones have undergone. These assessments are commonly made by subjecting a portion of the skeleton to x-irradiation and comparing the resulting x-ray film with established standards. This comparison yields a developmental level that provides a great deal of information about the growth of a child. It may be that the child is developmentally much older than its chronological age suggests, or he/she may be much younger. In many cases this disparity should not be overlooked and can be accounted for through the concept of skeletal age.

Though other measures may serve the purpose of estimating physiological maturity in some cases, Johnston lists ". . . several reasons why the skeleton offers the best evidence of progressive maturation in the growing child." (1962, p. 1)

1. The beginning and end points are established: only a few of the accessory centers of ossification are present in the newborn, while the attainment of adult morphology as well as completed epiphyseal union is found in everyone, save the grossly pathological.

2. Second, the skeleton changes continuously throughout the growing period--its appearance records the maturation level at all times.

3. Third, the hand-wrist area, by far the most commonly utilized, is easily x-rayed with minimum effort and with complete safety, providing the gonads are shielded.

4. Finally, the assessment of the maturational level is not difficult for an anatomically-trained person, and can be done in a relatively short time with the aid of reliable available standards.

The Evolution of Skeletal Age as an Estimate of Maturity

The emphasis of C. Ward Crampton (1908) on the puberty of children provided the idea which caused Rotch (1908) to propose the concept of skeletal age, which he chose to call anatomic age, as an indicator of maturation. Roentgenograms of the hands and wrists of children showed that their chronological ages meant very little in terms of biological development. Rotch concluded that:

1) Standards of development should be established to be used in athletic and educational reform.
2) The wrist is the most suitable area of the skeleton to be used for assessment.
3) Divisions of growth such as A, B, C, and D should be used instead of months and years.

Later, several methods of defining the size and ossification of the bones of the wrists were introduced. Freeman and Carter (1924) and Carter (1926) devised a way to determine the circumference of the carpal bones by taking planimeter measurements from roentgenograms. Cattell (1934) measured the diameters of the bones of the wrist, and Flory (1936) studied overall appearance of the carpals, metacarpals and epiphyses. Even with these methods, standards for comparison were still lacking, and it was not until 1937 that they were published.

By introducing standards of skeletal maturity of the hand, Todd

(1937) increased optimism for the use of skeletal age as a developmental indicator. The publication begins with a lengthy section defining the necessity of using skeletal development as a criterion for assessment of maturation. Also included in this section is the rationale for use of the hand as the area of the anatomy for study and standardization.

The last two-thirds of the book is devoted to providing plates for comparison to be used for skeletal age assessments. The 40 plates of hand x-rays of males displayed in the book cover the age range of three months through eighteen years and nine months. The 35 plates of hand x-rays of females cover the age range of three months through sixteen years and three months. From the age of three months through fifteen months, the plates appear in three-month intervals. After fifteen months, the plates are standardized at six month intervals. This is true for both sexes. The plates are based on roentgenograms from over 3500 White males and 3400 White females.

To this point in time the hand and wrist was the only segment of the skeleton for which standards had been established. In 1955, Pyle and Hoerr published an atlas of the knee joint containing 29 plates of bone maturation from neonatal to 18 years of age. Using records from the Brush Foundation, only children who were free from gross physical and mental defects and who volunteered for continued participation in the study were selected. Modal pictures from the 10,400 films studied were used as plates. This research team also published an atlas of standard plates of the foot and ankle in 1962 (Hoerr, Pyle and Francis) and revised their atlas of the knee in 1969 (Pyle and Hoerr).

Greulich and Pyle (1950, 1959) have published and revised their standards for the hand and wrist. The second edition, a final report of Todd's work of 1937, is quite similar to the first. Four new plates for males and one new plate for females have been added, but the suggested techniques of assessment are essentially the same. These standards remain in wide use almost twenty years subsequent to their final publication.

In 1954 a new method of assessing skeletal maturity was suggested (Acheson, 1954). This technique included a summation of units for each maturity indicator present in the developing child. It was proposed that the technique could be used at any time throughout the developmental period, and details of its use were given for the first five years of life. Another suggestion made by Acheson was that it may be better to discuss skeletal maturity as a percentage of the biological maturity attained, rather than relating biological to chronological age.

Acheson's Oxford method of evaluating skeletal maturity varied from the established form of assessment in two ways (1957). First, other body parts were suggested for assessment, and the hip and pelvis were the primary areas of the skeleton used for analysis; whereas, previously the hand and wrist had been used almost exclusively. Second, a new rating format was introduced using a numbering approach. Each easily recognized maturity indicator of the hip and pelvis were given a number, and the total of the numbers became the skeletal maturity index. This method is advantageous in that the very young child has more maturity indicators in this area than in any other, but its use is undesireable because the anatomical

area of study is larger and more apt to expose the gonads to unnecessary doses of radiation.

In 1959 and again in 1962, further refinements of this assessment technique were proposed (Tanner and Whitehouse, 1959; Tanner, Whitehouse and Healy, 1962). The way this research group proposed to rate skeletal development was quite similar to Acheson's Oxford method (1957), except they expressed the necessity for weighting each bone stage so the ". . . relative importance of each stage of each bone would be assessed statistically. . ." (Tanner et al., 1962). Their work culminated with the publication of Assessment of Skeletal Maturity and Prediction of Adult Height (TW2 Method) in 1975 (Tanner, Whitehouse, Marshall, Healy and Goldstein).

Criticism of the Methods of Skeletal Age Assessment

Investigations have shown the standards initially established by Todd (1937) and revised by Greulich and Pyle (1950, 1959) to be unsatisfactory in certain cases. Mainland's work (1953, 1954, 1957) led him to report that the novice reader tended to give lower assessments than expert readers, and the systematic error caused by this tendency was significant. Mainland suggested that the method may be suitable for assessing the skeletal maturity of communities but not individuals. After testing the validity of the Greulich-Pyle method, Schoen, Solomon and Milkovich (1970) concluded that the standards were adequate for the evaluation of tall girls, above the 97th percentile, but not for short boys, below the 3rd percentile.

Other investigations have reported positive findings with regard to the reliability of assessing skeletal age using the Greulich-Pyle

approach. Koski, Haataja and Lappalainen (1961) stated that the magnitude of the error in their readings was not great enough to disregard them for use on individuals. Differences in levels of assessment by judges prior to being trained were found to border on statistical significance; however, after being trained, the judges became reliable, and each of their assessments were considered to be no better or worse than any of the other judges' assessments (Acheson, Fowler, Fry, Janes, Koski, Urbano and van der Werff ten Bosch, 1963).

It was also found that by interpolating between the standard plates, when an x-ray did not match a plate exactly, the 95% confidence intervals were reduced for a single reading. This method decreased the number of times an x-ray was reassessed exactly as it had been before (Acheson et al., 1963). Another study involved five judges reading 33 hand-wrist x-rays twice each. No statistical differences between levels of assessment by the readers was found and the within judge reliability correlations ranged between .95 and .99 (Moed, Wight and Vandegrift, 1962). It has also been reported that the confidence limits could be reduced by approximately 30% by using the mean of two assessments of a roentgenogram, instead of using one or the other. This study agreed with previous reports that showed no significant differences between repeated observations by a single observer nor differences between observations by paired observers (Roche, Davila, Pasternack and Walton, 1970).

The bone-specific approach of Tanner, et al. (1959, 1962) has been investigated. It was reported in 1964 that eight raters could assess and repeat their own assessments with precision using the bone-specific approach. However, the assessments statistically

differed between raters. There was more difficulty in evaluating the round bones, especially the carpals, than with the short or long bones (Acheson, Vicinus and Fowler, 1964).

Contrasting the Methods of Skeletal Age Assessment

Three methods, two applied to the Greulich-Pyle Atlas and one developed by Tanner *et al*., are presently available for use. There is a distinct variation between two of the methods. The original Greulich-Pyle technique was meant to be an overall inspectional matching of a hand-wrist roentgenogram with an atlas plate in order to determine a subject's skeletal age. The Tanner-Whitehouse method is one of specificity in that each bone of the hand and wrist is evaluated and assigned a number which accumulate to provide a skeletal index. The third approach is similar to the Tanner-Whitehouse, except the Greulich-Pyle Atlas is used to assign each bone a developmental level from which the mean age is derived and considered to be the appropriate one.

Not only do the techniques vary, but the standards from which the assessments are made also differ. The atlas of Greulich-Pyle is based on a 1931-1932 population of Cleveland, Ohio children who were reported to be above average in economic and educational status. In contrast the Tanner-Whitehouse standards were obtained from data collected between 1945 and 1958 on a group of British children who were said to be representative of the average socio-economic level. These variations in approach to assessment and basis of standards have been studied and discussed extensively in recent years.

Skeletal ages of identical children, when determined by the

Tanner-Whitehouse method, are consistently in advance of skeletal ages determined by the Greulich-Pyle method. Acheson et al. (1966) reported that the mean skeletal age of a group of children, as assessed by the Tanner-Whitehouse method, was approximately a year higher than the age derived through the use of the Greulich-Pyle Atlas. A study by Fry (1968) showed statistically significant differences between Tanner-Whitehouse and Greulich-Pyle ratings at all ages for boys. The Tanner-Whitehouse ratings had higher values for every age group, except the two youngest groups (12 and 15 months of age). With girls the Tanner-Whitehouse ratings were higher in every age group, but the differences were not statistically significant in three of the twenty groups. Roche, Davila and Eyman (1971) also reported consistently advanced skeletal ages produced by the Tanner-Whitehouse bone-specific approach as compared to the Greulich-Pyle method. One might conclude, however, that the bone-specific approach is not the cause of the Tanner-Whitehouse technique providing older ages consistently, because it has also been reported that the bone-specific approach using the Greulich-Pyle atlas gave skeletal ages approximately two months younger than the overall inspectional method using the same atlas as the standard (Johnston, Dorst, Kuhn, Roche and Davila, 1973).

No unqualified recommendation to use any one method over the others was found in a search of the literature. Roche (1965) stated that the Tanner-Whitehouse method does not make use of all the information available and that proof of its clinical reliability has not been secured. Andersen (1968) has stated that the Greulich-Pyle method can be learned far more quickly and was proven to be equally

as accurate as the Tanner-Whitehouse technique. On the other hand, Malina (1971) has written that when a more finely calibrated scale for each bone is the goal, the Tanner-Whitehouse procedure is preferred. Fry (1968) stated that neither method can be considered correct or incorrect.

Symmetry of the Body

Even though for years it was perceived that the two sides of the anatomy are asymmetrical, it is now believed that while there are certain variations in bony structure, they are not large enough to cause discrepancies in skeletal age assessment (Flecker, 1942; Watson and Lowrey, 1954). As early as 1921, Baldwin was convinced of the uniformity of the carpal areas of the right and left hands in both sexes (Baldwin, 1921; Baldwin, Busby and Garside, 1928). Torgersen (1951) studied 404 children finding no differences in the right and left wrists of 249 cases and only slight differences in the others. His data confirm that if there is a difference, the left side is most likely to be advanced. He also stated that ". . . the differences are too small to be a source of error in the determination of developmental status." Two other studies also reported that differences between the two sides of the body do occur, but the divergencies are not great enough to be a hindrance in the assessment of skeletal age (Baer and Durkatz, 1957; Dreizen, Snodgrasse, Webb-Peploe, Parker and Spies, 1957).

Correlations of Skeletal Age with Student Characteristics

Cognitive Growth

Children who are advanced physiologically tend to score higher on mental ability tests than children of the same chronological age who are physiologically delayed (Abernethy, 1936; Freeman and Flory, 1937; Shuttleworth, 1939; Boas, 1941; Tanner, 1961). However, the disparity in mental ability vanishes as the early and late maturers complete their growth (Tanner, 1961). In a longitudinal study of 38 girls Freeman and Flory (1937) found that the group which matured last were lower in mental ability than the others until chronological age 17 years. The exception to this was at chronological age 13 years when the scores of the late maturing group were the same as those of the average group but both were below the early maturers. With data taken from the Harvard Growth Study, Shuttleworth (1939) established some relationship between intelligence and early maturation, although only a minority of the comparisons were statistically significant. Abernethy (1936) found a low positive correlation between mental ability and physical stature while studying 357 children in the Laboratory Schools of the University of Chicago. Finding no significant correlation between the mental test scores of adults and their precocity of maturity, he concluded that the existing positive correlation during adolescence was due solely to the degree of physical maturation.

During the late 1800's and the early part of this century, a number of papers were written concerning the relationship of physical maturation to academic scholarship or mental growth. There were those

who supported the idea that late maturation favors poor scholarship (Porter, 1893; Crampton, 1908; Foster, 1910; Stewart, 1916; Baldwin, 1922). While working with 2500 children in the Iowa Child Welfare Research Study, Baldwin (1922) stated that a scale cannot accurately measure mental growth unless the physiological differences between the individuals are taken into consideration. Stewart (1916) observed that taller and heavier boys of the same chronological age were advanced in school standing. On the other hand, Gates (1924) found little association between physical and mental growth while searching the possibilities of grouping children for more purposeful education. Franzblau (1935) found no relationship between intelligence ratio and age of first menstruation, suggesting that there was no relationship between mental and physical precocity or retardation.

Others have looked at combinations of physiological growth parameters in relation to academic achievement. Organismic age, the average of various physiological and structural ages, was studied by Klausmeier (1958), Blommers, Knief and Stroud (1955) and Klausmeier, Beeman and Lehmann (1958). These researchers found little or no association between the physical growth parameters and intelligence. In contrast, Millard (1958) and Olson (1959) reported that by making use of seven different types of assessment of age one can be more successful in appraising children's performance levels in such areas as arithmetic and language.

Motor Domain

Generally speaking, motor performance is enhanced by increases in body size, muscular strength and muscular power. Each of these

components increase at puberty and rapidly develop through the pubescent years. Boys, especially, gain fundamental characteristics for enhancing their motor skills and almost always do so during this period. With the trend toward becoming motorically efficient, girls in increasing numbers may take advantage of the benefits that accompany maturity to augment their motor capabilities.

For various reasons early maturing males have had much success in team athletics and other events that require motor skill prowess. Hale (1956) studied 112 boys who participated in the 1955 Little League World Series and found that 17 percent were pubescent, 37.5 percent were prepubescent and 45.5 were postpubescent. All who batted fourth and most of the starting pitchers were postpubescent. Krogman (1954) stated that skeletal assessment is fundamental to the grouping of children for teaching motor skills due to the readiness necessary for learning. Then, after analyzing 55 boys who played in the 1957 Little League World Series and finding 71 percent advanced in skeletal development, he made the following statement, "Advanced biological maturation is a favorable factor in Little League Baseball. It should be one of the screening mechanisms for eligibility and for evaluation of potential." (1959, p. 56) Clarke and Petersen (1961) found the highest skeletal age means belonged to members of athletic groups when compared to students who either did not try out for teams or did not complete the full season. Outstanding elementary and junior high athletes were found to have significantly higher mean skeletal ages than did the regular players, substitutes and nonparticipants (Clarke, 1971; Physical Fitness Research Digest, 1973).

A portion of the superiority of early maturers in motor abilities

can be attributed to the physiological development which accompanies maturation. Muscular strength and power are markedly increased during the adolescent growth spurt (Dimock, 1935; Jones, 1949; Espenschade, 1940; Tanner, 1955). Clarke and Harrison (1962), Bailey (1968) and Sekers (1969) supported this in a study of 273 boys who were placed into one of three groups classified as retarded maturity, normal maturity or advanced maturity. They found consistent significant differences on muscular strength tests, with the most mature having the highest means. Weight, hip width and lung capacity were found to be greater for boys with advanced maturity when compared to those with retarded maturity (Day, 1967; Santa Maria, 1968; Clarke, 1971). Espenschade (1940) credited a stronger framework and maximum length and breadth of structure as the facilitators of motor performance in males with advanced skeletal maturity.

The findings of Jordan (1966; Clarke, 1971) indicated that the skeletal development of children prior to puberty was not a crucial factor with regard to many motor tests. Children with advanced skeletal maturity did perform better than their counterparts with retarded maturity on a battery of strength tests. However, there was generally no difference between the advanced and retarded maturity groups on the motor ability tests, which included the 60-yard shuttle run and the standing broad jump. For this investigation the children were categorized into maturity groups at age 9 years chronologically and followed longitudinally throughout a four year span within their respective groups.

Skeletal maturity was not determined to be a factor of major importance with regard to the motor abilities of early primary

school children in other studies as well (Seils, 1951; Rarick and Oyster, 1964). However, Seils (1951) stated that because the contributing elements of efficient motor performance capabilities are so abundant and varied, skeletal maturity should be given more priority in the study of movement.

The literature does not include a great deal of information concerning the relationship of the skeletal maturity of girls to motor prowess. One study reported that the motor performance of 13- to 16-year-old girls was negatively correlated with the advancement of skeletal maturity (Espenschade, 1940). This fact is somewhat understandable for this age group, since it may be hypothesized that additional fat as well as changes in interests and attitudes caused a decline in vigorous physical activity which in turn resulted in lower motor performance scores.

Affective Domain

Early maturing individuals are known to differ behaviorally from late maturers (Judd, 1967). Boys and girls are elated at being the tallest and strongest children in their grade school classrooms, and when the late maturing girls grow taller than their early maturing peers in adolescence, it generally does not make the latter unhappy. On the other hand, when the late maturing boys equal or exceed the early maturers in size and strength and become competitive in sport and social functions, often there is a reversal in personality characteristics. This suggestion of how size may affect the personalities of growing males and females is but one example of the impact physical maturation has on youth.

Studies from the 1950's and 1960's serve to further detail the differences in personalities of early and late maturing individuals. Jones and Bayley (1950) described the early maturing adolescent boys of their study as being physically more attractive, more matter-of-fact and more relaxed than their late maturing counterparts, while the latter were more eager, animated, active and tense. In a follow-up of these males at age 33 years it was found that: (a) the physical differences between the early and late maturers had disappeared, (b) where differences between the two groups were found in personality characteristics, they tended to support the stability of personality traits over time, and (c) a few of the early maturers had moved quickly into their careers, while some of the late maturers were still wandering vocationally (Jones, 1957).

Fourteen premenarcheal girls, with an average chronological age of 12 years and 3 months, and twelve postmenarcheal girls, with an average chronological age of 12 years and 6 months, were given the Rorschach Test. The means of all the scores were in the direction of greater emotional maturity for the postmenarcheal group (Davidson and Gottlieb, 1955). Mussen and Jones (1957, 1958) concluded that the socio-psychological environment of our culture may adversely affect late maturing boys, thereby creating feelings of personal inadequacy, prolonged dependency needs and rebellious attitudes toward their parents. This may be manifested by a drive for social acceptance through aggressive attention seeking; whereas the early maturers tended to have higher self concepts and maintained more independence. A study of seventeen year-old girls showed early maturers to have more favorable self concepts than their peers who were delayed in physical

growth (Jones and Mussen, 1958). Faust (1960) found that sixth grade girls who were "in phase" in physical maturation and that seventh, eighth, and ninth grade girls who were physically accelerated were thought to be "prestigious" by their classmates.

Somatic Growth

Size and bodily growth have been mentioned as obvious differing characteristics between late and early maturing individuals (Bayer and Bayley, 1959; Krogman, 1972). Characteristically mesomorphic in build, the early maturers are taller and heavier and have more total fat and muscle, though less relative muscle, than their late maturing counterparts. They also have relatively broader shoulders and narrower hips, are taller in sitting height, larger in neck circumference and upper arm girth and have greater lung capacity than their ectomorphic peers whose chronological age is the same but whose physical growth is somewhat retarded. The late maturing individuals grow to relatively taller heights than early maturers and have less weight per inch as adults.

These and other ideas concerning physical growth are supported in the scientific literature. Tanner (1962) noted that skeletal age is positively correlated with growth changes in fat, muscle and bone tissue, causing early maturers to have more weight per unit of height than do late maturers during adolescence (Malina, 1974, 1975). Speaking of the relationship between age and sexual maturation, Marshall (1974) stated that skeletal age varied just as much as chronological age in the prediction of initial genital or breast development. However, it was less variable than chronological age for pubic hair

stage three for males which occurs at the peak of the adolescent growth spurt and breast stages two and five for females.[1]

Differences in Skeletal Age Between the Sexes

Females at all ages have achieved a greater proportion of their maturity than males because of the sex-linked characteristics of the human female to mature at an earlier age. The tendency of females to surge ahead of the males in the attainment of physical growth explains why fifth and sixth grade girls are often taller and heavier than their male counterparts of an identical chronological age. A study of chronological age 6- to 11-year-old noninstitutionalized children in the United States illustrated this difference (Public Health Bulletin, 1974). The findings indicated that in terms of skeletal age boys were in delay of their chronological ages by a significant mean difference of 2.5 months at chronological age six years and by 14 months at chronological age eleven years. In comparison, the mean skeletal age of the girls at chronological age six years was 7.5 years and at chronological age eleven was 13.1 years. Other articles and monographs which demonstrate male and female skeletal age differences are available (Flory, 1936; Simmons, 1944; Fry, 1966; Maresh, 1970).

Another interesting topic that is derived from data such as these concerns the range of skeletal ages for children with the same chronological age. Hansman and Maresh (1961) studied a group of 36 girls and 27 boys longitudinally and found that skeletal variability is narrowest during the early childhood years and becomes greatest at

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[1]Stages defined by Tanner (1962).

adolescence. Their assessment describes a variation of six years in skeletal age between the most rapidly maturing girl and the least rapidly maturing girl in the same chronological age group. The early maturer had a skeletal age of 13 years and 9 months at chronological age 11 years, while the late maturer had a skeletal age of 7 years and 9 months at chronological age 11 years. For the boys the greatest variation occurred at chronological age 10.5 years when the most skeletally advanced boy had a skeletal age of 12 years and 3 months and the least developed boy had a skeletal age of 7 years and 6 months. For both males and females, the difference between skeletal age and chronological age was slight during early life. The chronological age of the girls was equal to the median skeletal age for the group during the first three years.

Summary

The first portion of this chapter was devoted to the rationale for the assessment of physiological age as an indicator of maturity. The concept of skeletal age has been suggested as a viable method of determining developmental levels of physical growth. The early work of Crampton and Rotch was primarily responsible for the conception of the need for such a criterion, and Todd, Greulich, Pyle, Acheson, Tanner and Whitehouse were given credit for refining the standards from which the assessment of skeletal age has become a reality.

Criticisms and contrasts of the various methods of evaluating skeletal age were presented. Surely each method has its own drawbacks, but just as certainly each was shown to have advantages. The author recommends that matching the advantages of a method to the

specific goals of a task is the key to the proper selection of a technique for skeletal age assessment.

Correlations of skeletal age with cognitive growth, the motor domain, the affective domain and somatic growth were discussed. The relationship of skeletal age with cognitive growth is controversial. Some authors have reported conclusions indicating that early maturity favors good scholarship and vice versa, while others have seen little association between the two variables. The positive relationship between advanced maturation and the motor domain is well established for boys during and after puberty. With the exception of two studies that focused primarily on prepubertal children, it was shown that late maturing boys are not as motorically skillful as early maturing peers of similar chronological ages, nor are they as successful on athletic teams. It was reported that children who are maturationally advanced may have an advantage in gaining a favorable self concept in our society, even though at some ages the early maturation may be a disadvantage. Concerning physical growth, the differences between the early maturer and the late maturer are many. Disparities were mentioned in body composition, body size, somatotype and sexual development.

The skeletal development of children varies from one to the other and especially between the sexes. Females are generally advanced in skeletal development over males of a similar chronological age. Furthermore, the variability between skeletal age and chronological age is narrowest at the early ages of life and has its greatest disparity during adolescence.

CHAPTER III

RESEARCH METHODS

The purpose of this study was to investigate the differences in motor performance between boys who are normal in skeletal development as compared to those who are either advanced or delayed in skeletal development. The study included data taken on seven motor performance tests for boys while they were 9 through 12 years of age chronologically. A subproblem was included to examine the differences in physical size between the comparison groups.

Subjects

Data from boys enrolled in the Motor Performance Study at Michigan State University, East Lansing, Michigan within the past ten years were analyzed. For this project, males for whom skeletal ages and motor performance data were available for the period during which they were 9 through 12 years of age served as subjects. The children were primarily from White families whose socio-economic status may be described as average to above average.

Experimental Design

A design comprised of one independent variable and its relationship with seven dependent variables was used. The same design was utilized for four age divisions: (a) Nine-year-old Subjects,

(b) Ten-year-old Subjects, (c) Eleven-year-old Subjects, and (d) Twelve-year-old Subjects. The independent variable, skeletal maturity, was subdivided into three levels: (a) Advanced, (b) Normal and (c) Delayed. The seven dependent variables were motor performance test scores, all of which yielded continuous data as they were either measured in time or distance. The dependent variables were: (a) Flexed Arm Hang, (b) Jump and Reach, (c) Agility Shuttle Run, (d) Standing Long Jump, (e) 30-yard Dash, (f) Sit and Reach, and (g) 400-foot Endurance Shuttle Run.

Independent Variable

The independent variable for this study was skeletal maturity (as assessed from an x-ray of the hand-wrist area using the Greulich-Pyle bone-specific approach). Each of the skeletal age assessments on the children involved in this investigation was made by Vernal D. Seefeldt, Ph.D., Director of the Motor Performance Study at Michigan State University.

For each chronological age 9 through 12 years, there were three levels of skeletal maturity. The levels were specified as advanced, normal, and delayed. Each subject was classified into one of the levels depending on the relationship between his chronological age and his skeletal age. A difference score was calculated for each of the subjects by subtracting his chronological age in months from his skeletal age in months. These difference scores were then used to categorize the subjects into skeletal maturity groups within each of their respective chronological age divisions.

The use of difference score distributions instead of skeletal

age distributions was necessary to classify the subjects into the levels of skeletal maturity. If only the skeletal age of the subjects was used for this classification, their chronological age may have had an unwarranted effect on the results. Logically, the oldest subjects chronologically would have a greater probability than their peers within the age division of having the oldest skeletal ages and vice versa.

To further illustrate this point, let's consider a hypothetical situation within one age division, say the nine-year-olds. Boys who were chronologically 103-114 months of age were categorized into this division. The probability of the 114 month-old boys having higher skeletal ages than the 103 month-old boys is clear. However, just because the skeletal ages of the 114 month-old boys were greater than those of the 103 month-old boys, it does not mean that the older boys were advanced in skeletal maturity. The difference score between the chronological age and skeletal age had to be considered to determine skeletal maturity. If only skeletal age had been used to classify the subjects, the 114 month-old boys would probably all have been included in the advanced maturity group, because their skeletal ages would probably have been greater than the younger boys. The same concept applies for the normal and delayed groups as well.

Descriptive statistics were used to ultimately set up the categories which separated the skeletal maturity groups. Difference score distributions were obtained for each chronological age division. If the difference score of a subject was within plus or minus one standard deviation of the mean, he was placed in the normal group for his age division. If his difference score was greater than

one standard deviation above the mean, he was placed in the advanced group for his age division. If his difference score was greater than one standard deviation below the mean, he was placed in the delayed group for his age division.

Rationale. The Greulich-Pyle bone-specific approach to assessing skeletal maturity was chosen for use in the Motor Performance Study at Michigan State University. The director of the study, Dr. Vernal D. Seefeldt, had prior experience with this particular technique and assumed the responsibility of ensuring that the assessments would be made. Hand-wrist roentgenograms were taken annually beginning in January 1968 with the inception of the study and continuing until the summer of 1975, when it became financially impractical to obtain the x-rays.

The technique chosen is a sound one in the view of many investigators. Though none of the assessment methods has received an unqualified recommendation over the others, the Greulich-Pyle bone-specific approach has received a good review. Koski et al. (1961) regarded the readings made in their study to be satisfactory for use on individuals. Roche et al. (1970) found that the differences between repeated observations by a single observer were not significant. Andersen (1968) has stated that the Greulich-Pyle method is equally as accurate as the Tanner-Whitehouse technique.

The hand-wrist area has received support as a suitable area of the anatomy for the study of skeletal age. Rotch (1908) made this observation many years ago. Todd (1937) indicated that fine discrimination is possible using the hand-wrist area, because there are many features that undergo change. In addition, the area is not one

that makes the gonads susceptible to unnecessary doses of radiation, which may not be the case for the hip and pelvic region.

The standards developed for use with the Greulich-Pyle and the Tanner-Whitehouse techniques differ substantially. Consistent findings show that skeletal age assessments for the same children by the Tanner-Whitehouse method are advanced when compared to Greulich-Pyle assessments (Acheson et al., 1966; Fry, 1968; Roche et al., 1971). For this investigation this is not important, because all of the subjects were assessed with the same procedure and are assigned to their respective levels of the independent variable on that basis. It would, however, become a significant factor if comparisons were being made with studies that used the Tanner-Whitehouse method.

Control of Extraneous Independent Variables

The potential of chronological age having a confounding effect on the results was evident. However, average chronological ages and skeletal ages were computed for each group to expose any obvious coincidences which may have occurred that would have caused an expected influence on the results. This was necessary, because everyone in the advanced group for nine years of age, for example, may have been born on June 30, 1968 and tested on December 31, 1977. In this case they would be considered nine years of age, however their skeletal age would be expected to be advanced for nine year-olds, because chronologically they were almost within the span considered to be ten years of age. Even if skeletal age had no effect, this group would have been expected to perform better on the motor performance tests due to an inflated chronological age over the other

groups.

When assessing motor performance, the testing conditions, facilities, subject motivation and technician treatment are always possible confounding variables. The Motor Performance Study has taken precautionary measures to reduce these potential problems as much as possible. Subject motivation or desire remained the most difficult factor to control. Technicians were instructed to verbally encourage each performer while testing, but certainly some performers responded to the positive reinforcement to a greater extent than others. The technicians were trained prior to, and possessed written instructions throughout, each testing period. One of two temperature controlled rooms with wooden, tongue and grooved flooring (gymnasium type) was used for each session, and the children performed without shoes while dressed in bathing suits.

Dependent Variables

The dependent variables for this study were the various motor performance measures which have been accumulated in the Motor Performance Study at Michigan State University. The following is a list of the specific motor performance tests, a description of how the technicians are instructed to administer the tests (Seefeldt and Haubenstricker, 1975) and a brief summary of their worth.

Motor Performance Tests. The performers were encouraged verbally during each of the tests. A copy of the form used to record the subjects' performance results is included as Appendix A.

1. Flexed Arm Hang. Adjust the bar so it is approximately six inches above the performer's height. Position the performer in a bent arm hang with the elbows flexed at greater than 90°. Hands should be in the reverse curl or pronated grip (palms away). The score is the time to the nearest whole second from the moment the performer hangs unaided until his chin rests on the bar or his elbows assume a position of less than 90° flexion. Record one trial unless the performer does not receive a fair chance, ie. if less than one or two seconds is recorded on the first trial, give an additional trial.

The flexed arm hang is used to measure strength and endurance of the arms and shoulder girdle (Johnson and Nelson, 1974; Barrow and McGee, 1971). The validity of the test is generally accepted at face value, and its reliability has been reported as high as .90 (Johnson and Nelson, 1974).

2. Jump and Reach. The performer stands with the right or left side to the wall and fully extends the elbow and shoulder vertically. Record the point where the distal-most part of the third digit contacts the tape. The performer then jumps (without an approaching step) and contacts the tape. The score is the difference between the height attained on the jump and touch and the score of the initial reach. Instructions to the performer: Be sure to bend the knees when getting ready to jump and swing your arms to help you get up higher. Record three trials.

The jump and reach, modified from the Sargent Jump (Sargent, 1921), is designed to measure power of the legs while jumping

vertically (Clarke, 1967; Johnson and Nelson, 1974). The test is best for use with performers who have been taught the proper technique to jump and has been found satisfactory for ages nine years through adulthood. Correlations of reliability have been found as high as .98 which was determined on high school girls (Cooper, 1945). Other investigations (Seils, 1951; Johnson, 1962) have reported test-retest reliability coefficients of between .75 and .96 when elementary children were evaluated. Validity coefficients, as measured by comparison with track and field events, have been reported at .65 and .81 for men and boys with slightly lower correlations for girls (Adams, 1934; Clarke, 1967).

3. Agility Shuttle Run. Two blocks are placed on a line 30 feet from the starting line. The performer takes a position with toes behind the starting line. Examiner's commands are: To your mark, Get set, Go. Performer runs to the 30-foot mark, picks up one block and places it on the starting line, then returns to the 30-foot mark for the second block, picks it up and runs past the starting line with it in his hand. The time is recorded to the nearest one-tenth second. Record two trials.

The purpose of the agility run is to measure speed and agility (Barrow and McGee, 1971). Keogh's report (1965) on the motor performance of elementary school children indicated test-retest reliability coefficients of .73 for first graders and .59 for third graders. Seils (1951), Latchaw (1954) and Johnson (1962) reported reliability correlations ranging from .79 to .95 when measuring speed and agility with their adapted agility runs.

4. Standing Long Jump. The performer begins with toes behind the restraining line. Take-off and landing must be on two feet. The score is the distance (to the nearest one-half inch) in inches from the take-off line to the point where the body touches nearest to the take-off line. Record three trials.

The standing long jump is designed to measure leg power for a horizontal jump (Clarke, 1967; Barrow and McGee, 1971; Johnson and Nelson, 1974). It is satisfactory for children of ages six years through college age. A validity coefficient of .607 has been reported when compared to a pure power test (Johnson and Nelson, 1974). Reliability coefficients ranging from .77 to .90 for within-day successive trials in the standing broad jump have been reported on college women, high school girls and elementary aged children (Scott and French, 1959; Glassow and Kruse, 1960; Hanson, 1965). Test-retest reliability correlations ranging from .77 to .91 have been reported when elementary aged children were tested (Seils, 1951; Kane and Meredith, 1952; Keogh, 1965).

5. 30-yard Dash. The performer begins the run with a five (5) yard running start. The starter's commands are: To your mark, Get set, Go. As the performer reaches the starting line, the starter gives a hand signal for the timer to start the watch. The performer reports his name to the timer, who records the time to the nearest one-tenth second. Instructions to the runner: "When I say Go, you are to run as fast as possible to . . . " The designated spot should be five (5) yards beyond the actual finish line, because young children will tend to stop on the finish line. Record two trials.

Dashes of various distances are frequently used to measure speed (Barrow and McGee, 1971; Johnson and Nelson, 1974). Face validity is generally accepted. Within-day reliability coefficients of .86 and .85 for the thirty-yard dash were reported by Keogh (1965) for first and third graders, respectively. In addition, Glassow and Kruse (1960) reported that 92 percent of the correlation coefficients of within-day reliability for girls age 6 to 14 years were above .85. Test-retest reliability coefficients for the thirty-yard dash have been reported ranging from .57 to .86 (Seils, 1951; Keogh, 1965).

6. Wells Sit and Reach. The performer sits on the floor with the soles of the feet in contact with the bench. Knees should be fully extended and remain in this position during the test. The performer moves both hands forward, one on top of the other, reaching as far beyond the toes as possible. The performer is asked to "bob and reach" three times and to hold on the fourth reach. The score is plus or minus the distance (to the nearest one-half inch) reached in relation to the vertical surface of the bench. Record three trials.

7. 400-foot Endurance Shuttle Run. Two objects (chairs, waste baskets, etc.) are placed so that their outer edges are 40 feet apart. Commands to the performer are: To your mark, Get set, Go. The performer runs five (5) laps, keeping the objects inside his path. Performers are asked to continue walking if they can not finish the race at a run. The time is recorded to the nearest one-tenth second. Instructions to the runner: Be sure to run so that you will

be able to finish the entire distance at a run. Record one trial unless the runner does not receive a fair chance, ie. slips or falls.

Measurement Equipment and Procedures. The motor performance tests required that two devices for measurement be available. One instrument was necessary for timed events, while the other was needed for linear measurement. For each of the timed events a stopwatch accurate to the nearest one-tenth second was used. The linear measurement was done using a steel tape for each event except the Jump and Reach and the Wells Sit and Reach. Homemade equipment accurate to the nearest one-eighth inch was available for measurement of these two events.

The reporting of scores was accomplished through training the personnel and providing a form for recording results. Each technician was verbally instructed and given written instructions indicating the methods to be used for measurement and recording. In addition, the technicians received on-the-job training from an experienced tester. A form was provided for each subject on which the scores were reported (see Appendix A) before being transferred onto permanent record forms (see Appendix C).

Data Collection. The data for the dependent variables for this study were collected at six month intervals over the past ten years. Beginning in January 1968 and still in existence, the Motor Performance Study enrollees are measured each summer and winter. The measurements are always performed under the leadership of a faculty member in the area of Motor Development within the Department of Health, Physical Education and Recreation at Michigan State University. In many instances the faculty member(s) obtain the measurements, but they may be procured by graduate students or other paid technicians.

Research Design

In essence, the study used an Ex Post Facto design. The subjects were previously assessed for skeletal age which pre-assigned them to comparison groups, and the motor performance scores were already in hand. Figure III-1 is a diagram of the design matrix for the multivariate analysis which was utilized for each of the four age divisions. These multivariate analyses treated the seven motor performance tests as dependent variables. Since there were subjects who appeared in more than one age division, statistical comparisons were not made across the age groups. Rather, the statistical results were discussed within chronological age divisions only.

A simple 1 X 3, fixed effects univariate analysis for each dependent variable was also included in this study. Statistical comparisons were made between the skeletal maturity groups for each dependent variable within each age group. No statistical comparisons were made across motor performance tests or age groups.

Treatment of Data

The Motor Performance Study was initiated at Michigan State University in the Department of Health, Physical Education and Recreation in January 1968. The initial enrollment included 110 children ranging in age from two to eight years chronologically. Currently, over 1200 boys and girls from the East Lansing, Michigan area have been involved.

Since the inception of the Motor Performance Study, semi-annual

		SKELETAL MATURITY		
		Advanced	Normal	Delayed
MOTOR PERFORMANCE TESTS	Flexed Arm Hang			
	Jump and Reach			
	Agility Shuttle Run			
	Standing Long Jump			
	30-yard Dash			
	Sit and Reach			
	400-foot End. Shuttle Run			

Figure III-1. A sample research design matrix for the multivariate analyses

assessments of physical growth and motor performance measures have been made on the subjects. In early December and June of each year the children's parents are contacted via telephone to set up an appointment for a time during a two week measurement period which takes place later in the respective months. The subjects are asked to report at a specific time and to bring their bathing suits to be worn when the measurements are taken. Qualified personnel perform the various physical growth assessments before the children are sent to an indoor facility to be measured on the motor performance tasks. With three trained technicians in the growth laboratory and two trained technicians in the motor performance laboratory, approximately 100 children can be measured during a five hour period.

There were always some subjects who were not available during the designated measurement period. Illnesses, vacation trips, work, injuries, or other scheduled events kept some children from their semi-annual appointments. An effort was made during the following month to contact and measure each of the subjects who were not available during the designated period. Despite these efforts, every measurement period there were a number of children for whom no data were collected.

Each subject's measurements were recorded as they were taken. Motor performance scores were initially recorded on a temporary form (Appendix A) and then later transferred to a permanent record form (Appendix C). Physical growth data were recorded directly onto a permanent record form (Appendix D). One person recorded the growth data for the individuals who procured the measurements, whereas the motor performance technicians recorded the data as the subjects were tested by them.

Data Analysis

Multivariate and univariate inferential statistics were utilized to analyze the data. For each age division, the initial analysis was performed using the MANOVA program of the SPSS (Nie, *et al*., 1975). The MANOVA procedure was chosen due to the correlation between the dependent variables (see Appendix E for the correlation matrix for each age division). If a significant multivariate F resulted ($p < .05$), Step-Down F tests and Standardized Discriminatn Function Coefficients were employed as follow-up techniques.

Additionally, univariate statistical results were generated. For each age division, univariate F tests (ANOVA) were run on all of the dependent variables. When warranted by a statistical relationship between skeletal maturity and particular dependent variabiles, Scheffe' *a posteriori* contrasts were examined to determine which of the levels were different from the others.

Significance Level

Alpha was set at the .05 level of significance for this study. In this investigation a Type I error was not of vital consequence, and the .05 level agrees with that which is frequently used in educational research.

CHAPTER IV

RESULTS

The results are reported under three main headings. The first two headings, classification of subjects and growth measurements, are provided to identify the subjects within the respective levels of the independent variable. The third heading, motor performance measurements, focuses on the purpose of the study which was to determine if motor performance ability was significantly related to skeletal maturity.

Classification of Subjects

The subjects available for this study were divided into twelve groups. Included were three groups for each of four chronological age divisions; namely, nine, ten, eleven and twelve years of age. The divisions by chronological age were defined as follows:

9 years	103-114 months
10 years	115-126 months
11 years	127-138 months
13 years	139-150 months

The three groups for each of these chronological ages were based on skeletal maturity.

The difference between the chronological age and skeletal age of each subject was the factor on which the three levels of skeletal maturity were formed. An advanced group, a normal group and a

delayed group made up the three levels for each chronological age division. A subject was considered to be in the normal group if his difference score, obtained by subtracting his chronological age from his skeletal age, was within plus or minus one standard deviation of the mean of the difference scores for his chronological age division.

The subjects of each advanced and delayed group had difference scores of greater than one standard deviation from the mean of their respective distributions. That is, the difference scores of the advanced group (skeletal age minus chronological age) were greater than one standard deviation above the mean of the difference scores for their chronological age division. The difference scores of the delayed group were more than one standard deviation below the mean of the difference scores for their chronological age division. For example, the difference scores for the nine-year-old age division ranged from -34 months to +26 months, the mean of the distribution of these scores was -4.47 months and the standard deviation was 11.53 months. So, for this age division a subject was considered to have advanced skeletal maturity if his difference score was +8 months or more. A subject was considered to have delayed skeletal maturity if his difference score was -17 months or less. Logically, a subject was considered to have normal skeletal maturity if his difference score was between (and not including) +8 and -17 months in the nine-year-old age division. See Tables IV-IA and IV-IB for the classification of the levels of the other age divisions.

Mean chronological age and mean skeletal age along with the sample size for each level of each age division are reported in Table IV-2. It can be noted that the mean chronological age in months of

Table IV-1A. Descriptive statistics of the difference scores (skeletal age minus chronological age in months) for each of the four age divisions

	Chronological Age			
	9 Years	10 Years	11 Years	12 Years
Mean	-4.47	-4.06	-5.44	-4.00
Std. Dev.	11.53	11.41	10.63	12.02

Table IV-1B. Difference scores (skeletal age minus chronological age in months) used to categorize subjects into levels of skeletal maturity for each of the four age divisions

	Chronological Age			
	9 Years	10 Years	11 Years	12 Years
Advanced	> +7	> +7	> +4	> +8
Normal	-16 thru +7	-15 thru +7	-16 thru +4	-16 thru +8
Delayed	< -16	< -15	< -16	< -16

Table IV-2. Descriptive statistics of chronological age and skeletal age for the levels of the independent variable

			Chronological Age		Skeletal Age	
	Level	N	$\bar{x}$ (months)	s	$\bar{x}$ (months)	s
Age Category 9	Adv	21	109	3.52	121	7.19
9	Norm	80	108	3.23	103	7.80
9	Delayed	21	109	3.67	88	5.72
10	Adv	11	122	3.59	136	8.78
10	Norm	60	120	3.35	117	6.71
10	Delayed	12	121	3.60	99	6.73
11	Adv	10	132	3.41	141	6.84
11	Norm	40	132	2.76	128	6.55
11	Delayed	11	132	3.67	110	4.78
12	Adv	7	145	3.85	159	5.68
12	Norm	32	144	3.59	141	8.15
12	Delayed	7	145	3.24	121	5.59

each group is quite similar to the others within its age division. The difference in skeletal age means between advanced and delayed groups within an age division ranges from 31 months in the eleven-year-old category to 38 months in the twelve-year-old category.

Growth Measurements

The subproblem of this investigation was to examine the differences in physical size between the comparison groups. The following data are presented to fulfill this objective, and in so doing they describe the physical characteristics of the subjects. The same inferential statistics that were described in Chapter III under the subheading Data Analysis were used to determine the relationship between physical growth and skeletal maturity. To examine this relationship, multivariate analysis of variance (MANOVA) was utilized, since the physical growth measurements were correlated. Correlation matrices for the physical growth measurements are included in Appendix E.

Fourteen growth measurements were analyzed to determine if the body size of 9-12 year-old boys with advanced skeletal age was different from those whose skeletal ages were normal or delayed. The measurements included were: (a) Weight, (b) Standing height, (c) Sitting height, (d) Bi-acromial breadth, (e) Bi-cristal breadth, (f) Acrom-radiale length, (g) Radio-stylion length, (h) Biceps girth, (i) Thigh girth, (j) Calf girth, (k) Triceps skinfold, (l) Subscapular skinfold, (m) Umbilical skinfold and (n) Ponderal index. A definition of each of these measurements can be found in Appendix B (Seefeldt and Haubenstricker, 1967).

The statistical results are reported under four subheadings:

(a) Nine-year-old Subjects, (b) Ten-year-old Subjects, (c) Eleven-year-old Subjects and (d) Twelve-year-old Subjects.

Nine-Year-Old Subjects

A significant multivariate group effect was found for the nine-year-old age division ($F_{2,107}$ = 2.78, $p < .001$). To further examine the group effect, univariate F, Roy-Bargman step-down F and standardized discriminant function coefficients for each of the fourteen dependent variables were calculated (see Table IV-3).

As can be seen, the univariate F values were significant for each dependent variable. In contrast only two of the step-down F values, those for weight and acrom-radiale length, were statistically significant. However, it is important to note that the step-down F values are dependent on the *a priori* ordering of the dependent variables. More importantly, the discriminant function coefficients indicated that standing height, sitting height, weight and ponderal index (in that order) were the four dependent variables which contributed most to the overall group effect.

Scheffe' post hoc examinations were performed on all of the dependent variables, because each had a univariate F value which was statistically significant. Table IV-4 illustrates these results using the common underlining method to indicate which of the group means are different from one another ($p < .05$).

It is obvious that the measurements of those with advanced maturity were consistently larger than those with normal and delayed maturation. In almost every case there was a significant difference between the advanced and the normal maturing groups. On seven of the

Table IV-3. Univariate F, Step-Down F and Discriminant Analysis results for the growth measurements of the nine-year-old subjects

Dependent Variable	df	Univariate F	Step-Down F	Standardized Discriminant Function Coefficients
Weight	2,107	28.19***	28.19***	1.30
Standing Height	2,107	11.68***	.04	5.20
Sitting Height	2,107	14.47***	1.11	-2.41
Bi-Acromial Breadth	2,107	10.54***	.74	-.10
Bi-Cristal Breadth	2,107	16.42***	2.14	.34
Acrom-Radiale Length	2,107	11.87***	3.25*	.30
Radio-Stylion Length	2,107	14.24***	1.20	.47
Arm Girth	2,107	16.79***	.30	.06
Thigh Girth	2,107	22.05***	.73	-.07
Calf Girth	2,107	26.60***	.81	.38
Triceps Skinfold	2,107	11.87***	.23	.02
Subscapular Skinfold	2,107	11.92***	.83	.38
Umbilical Skinfold	2,107	7.88***	.37	-.28
Ponderal Index	2,107	5.59**	4.38	1.00

* $p < .05$

** $p < .01$

*** $p < .001$

Table IV-4. Results of the Scheffe' post-hoc tests for the growth measurements that were significantly affected by skeletal maturity: nine-year-old subjects

Dependent Variable	Skeletal Maturity		
	Advanced	Normal	Delayed
Weight	75.43	64.35	57.38
Standing Height	139.23	134.22	131.30
Sitting Height	74.18	71.72	70.55
Bi-Acromial Breadth	30.13	29.21	28.34
Bi-Cristal Breadth	21.47	20.28	19.82
Acrom-Radial Length	27.02	25.62	25.22
Radio-Stylion Length	23.10	21.87	21.23
Arm Girth	21.31	19.61	18.35
Thigh Girth	40.62	37.23	34.56
Calf Girth	29.23	26.92	25.32
Triceps Skinfold	12.24	9.49	7.75
Subscapular Skinfold	6.62	5.30	4.02
Umbilical Skinfold	9.55	6.93	4.08
Ponderal Index	13.00	13.21	13.42

dependent variables there was a significant difference between the normal and the delayed maturing groups. For six of the remaining seven dependent variables, the trend for the measurements of those with normal maturation to be larger than those with delayed maturation was the same, even though they were not significant at the .05 level.

Ponderal index, the remaining dependent variable, is unlike the other thirteen measurements. It is not a measurement per se, but rather a calculated index which is equal to weight divided by the cube root of standing height. For this reason it is more difficult to interpret. Those with advanced maturation were heavier than the other two groups, but an increased standing height more than compensated for it; thus resulting in the lowest ponderal index. Those with delayed maturation had the highest ponderal index, while those with normal maturation were in the middle. Only the advanced and delayed groups differed significantly.

Ten-Year-Old Subjects

The multivariate group effect was not found to be significant for the ten-year-old division ($p < .05$). For this reason the follow-up multivariate statistics are not presented. However, 11 of the 14 dependent variables proved to be significantly affected by skeletal maturity when analyzed with the univariate procedure (see Table IV-5). It is interesting to note the consistency of the pattern for the cell means of the advanced group to be larger than those of the other two groups. These results are reported in Tables IV-6A and IV-6B. For every dependent variable, except ponderal index, the measurements increased as skeletal maturity increased.

Table IV-5. Univariate F results for the growth measurements of ten-year-old subjects

Dependent Variable	df	Univariate F
Weight	2,80	11.47***
Standing Height	2,80	12.14***
Sitting Height	2,80	10.33***
Bi-Acromial Diameter	2,80	9.00***
Bi-Christal Diameter	2,80	13.88***
Acrom-Radial Length	2,80	9.75***
Radio-Stylion Length	2,80	10.04***
Arm Girth	2,80	2.36
Thigh Girth	2,80	5.24**
Calf Girth	2,80	6.55**
Triceps Skinfold	2,80	2.25
Subscapular Skinfold	2,80	3.50*
Umbilical Skinfold	2,80	1.29
Ponderal Index	2,80	.27

* $p < .05$

** $p < .01$

*** $p < .001$

Table IV-6A. Results of the Scheffe' post-hoc tests for the growth measurements that were significantly affected by skeletal maturity: Ten-year-old subjects

Dependent Variable	Skeletal Maturity		
	Advanced	Normal	Delayed
Weight	83.09	71.00	64.50
Standing Height	146.26	139.56	135.72
Sitting Height	76.32	73.83	72.22
Bi-Acromial Breadth	31.76	30.29	29.72
Bi-Cristal Breadth	22.56	21.11	20.20
Acrom-Radiale Length	28.39	26.68	25.94
Radio-Stylion Length	24.37	22.85	22.32
Thigh Girth	41.94	38.84	36.67
Calf Girth	29.94	28.01	26.85
Subscapular Skinfold	8.00	5.68	4.73

Table IV-6B. Cell means for the growth measurements that were not significantly affected by skeletal maturity: Ten-year old subjects

Dependent Variable	Skeletal Maturity		
	Advanced	Normal	Delayed
Arm Girth	21.47	20.29	19.49
Triceps Skinfold	12.20	10.07	8.23
Umbilical Skinfold	10.20	7.57	5.77
Ponderal Index	13.22	13.31	13.36

Eleven-Year-Old Subjects

A significant multivariate group effect was found for the eleven-year-old age division ($F_{2,52} = 2.32$, $p < .01$). As in the case of the nine-year-old age division, univariate F, Roy-Bargman step-down F and standardized discriminant function coefficients for the fourteen dependent variables were examined. Table IV-7 contains these results.

As was true for the nine-year-old age division, all of the univariate F values were significant. Concerning the step-down analysis, after the effect of weight was taken into account, none of the other values were significant. Weight was not the major contributing factor to the overall group effect, however. The standardized discriminant function coefficients indicated that the greatest contributors were standing height, weight, sitting height, ponderal index and subscapular skinfold in that order.

Scheffe' post hoc tests were performed on all of the dependent variables. The results of those analyses are reported in Table IV-8 utilizing the common underlining method to indicate which of the group means were different from one another ($p < .05$).

The group with advanced skeletal maturity differed significantly from the group with delayed skeletal maturity on every dependent variable, except ponderal index. Differences between the advanced vs. the normal and the normal vs. the delayed groups were not as distinct. Concerning these adjacent groups, three of the six skeletal measurements, standing height, sitting height and bi-cristal breadth, were shown to be significantly different between the advanced vs. normal as well as the normal vs. delayed, while the other three were only significant for the normal vs. delayed groups. All of the analyses

Table IV-7. Univariate F, Step-Down F and Discriminant Analysis results for the growth measurements of the eleven-year-old subjects

Dependent Variable	df	Univariate F	Step-Down F	Standardized Discriminant Function Coefficients
Weight	2,52	25.39***	25.39***	2.68
Standing Height	2,52	11.19***	1.78	4.43
Sitting Height	2,52	11.46***	.56	-2.01
Bi-Acromial Diameter	2,52	9.06***	2.61	-.67
Bi-Cristal Diameter	2,52	11.23***	.60	-.14
Acrom-Radiale Length	2,52	7.81**	.27	.31
Radio-Stylion Length	2,52	7.49**	.37	-.33
Arm Girth	2,52	12.17***	1.48	-.18
Thigh Girth	2,52	17.96***	.19	-.07
Calf Girth	2,52	20.10***	.25	.51
Triceps Skinfold	2,52	9.33***	.58	-.80
Subscapular Skinfold	2,52	7.83**	1.12	1.27
Umbilical Skinfold	2,52	4.14*	3.11	-1.04
Ponderal Index	2,52	3.26*	1.35	1.28

* $p < .05$

** $p < .01$

*** $p < .001$

Table IV-8. Results of the Scheffe' post-hoc tests for the growth measurements that were significantly affected by skeletal maturity: Eleven-year-old subjects

Dependent Variable	Skeletal Maturity		
	Advanced	Normal	Delayed
Weight	94.30	75.88	66.09
Standing Height	144.39	143.78	136.81
Sitting Height	77.53	75.35	72.64
Bi-Acromial Diameter	32.18	31.18	29.90
Bi-Cristal Diameter	22.77	21.78	20.55
Acrom-Radiale Length	28.81	27.74	26.21
Radio-Stylion Length	24.62	23.80	22.67
Arm Girth	23.42	20.81	19.48
Thigh Girth	46.05	40.08	37.24
Calf Girth	32.01	28.65	27.00
Triceps Skinfold	15.65	10.03	7.67
Subscapular Skinfold	9.80	5.59	5.00
Umbilical Skinfold	11.95	6.99	5.94
Ponderal Index	12.96	13.39	13.35

for the girth and skinfold measurements resulted in significant differences between the advanced vs. normal groups, while no significant differences were found between the normal vs. delayed groups.

Twelve-Year-Old Subjects

A significant multivariate group effect was found for the twelve-year-old age division ($F_{2,43} = 1.83$, $p < .05$). As reported before, at each age division for which the MANOVA analysis proved significant, the univariate F, Roy-Bargman step-down F and standardized discriminant function coefficients were applied for each of the fourteen dependent variables. The results of these analyses are presented in Table IV-9.

The pattern for these analyses is almost identical to those of the nine- and eleven-year-old age divisions. The univariate F values for all of the dependent variables, except arm girth, umbilical skinfold and ponderal index were statistically significant. Only the first and fourth dependent variables, weight and bi-acromial breadth, were statistically significant under the step-down F; however, this analysis is highly dependent on the a priori ordering of the variables. When the standardized discriminant function coefficients were examined, it was noted that standing height, sitting height, arm girth, ponderal index and subscapular skinfold (in that order) contributed most to the overall group effect.

Scheffe' a posteriori contrasts were generated and examined for each of the dependent variables which were statistically significant under the univariate F analyses ($p < .05$). The results are presented in Table IV-10A utilizing the common underlining method to indicate

Table IV-9. Univariate F, Step-Down F and Discriminant Analysis results for the growth measurements of the twelve-year-old subjects

Dependent Variable	df	Univariate F	Step-Down F	Standardized Discriminant Function Coefficients
Weight	2,43	11.33***	11.33***	.45
Standing Height	2,43	7.39**	.68	3.78
Sitting Height	2,43	7.10**	.01	-1.20
Bi-Acromial Diameter	2,43	5.11**	3.82*	-.83
Bi-Cristal Diameter	2,43	6.42**	.67	.20
Acrom-Radiale Length	2,43	9.92***	3.06	.82
Radio-Stylion Length	2,43	9.09***	.77	.05
Arm Girth	2,43	3.16	1.58	-1.20
Thigh Girth	2,43	7.05**	.29	-.70
Calf Girth	2,43	10.39***	.51	.53
Triceps Skinfold	2,43	3.89*	.15	-.12
Subscapular Skinfold	2,43	5.92**	2.38	1.10
Umbilical Skinfold	2,43	1.94	2.64	-.33
Ponderal Index	2,43	.65	.63	-1.12

* $p < .05$

** $p < .01$

*** $p < .001$

Table IV-10A. Results of the Sheffe' post-hoc tests for the growth measurements that were significantly affected by skeletal maturity: Twelve-year-old subjects

Dependent Variable	Skeletal Maturity		
	Advanced	Normal	Delayed
Weight	100.86	86.44	73.29
Standing Height	155.30	149.63	142.89
Sitting Height	80.06	77.53	74.90
Bi-Acromial Breadth	32.89	32.44	30.73
Bi-Cristal Breadth	23.31	22.73	21.41
Acrom-Radiale Length	30.41	28.98	27.21
Radio-Stylion Length	25.90	24.89	23.27
Thigh Girth	44.70	41.73	38.84
Calf Girth	32.54	29.88	27.74
Triceps Skinfold	14.14	11.11	7.86
Subscapular Skinfold	9.14	5.83	4.50

Table IV-10B. Cell means for the growth measurements that were not significantly affected by skeletal maturity: Twelve-year-old subjects

Dependent Variable	Skeletal Maturity		
	Advanced	Normal	Delayed
Arm Girth	23.19	21.82	20.57
Umbilical Skinfold	10.50	8.58	5.14
Ponderal Index	13.18	13.35	13.46

which of the group means were different from one another ($p < .05$). Cell means for each skeletal maturity group are reported in Table IV-10B for the growth measurements that were not significantly affected by the independent variable.

As was true for the nine-year-old and eleven-year-old age divisions, the boys whose skeletal maturity was advanced had growth measurements that were significantly larger than those of boys whose skeletal maturity was delayed. Again, the differences between the adjacent groups were not as distinct. For most of the dependent variables the delayed group was the isolated one, while there were no differences between the advanced and normal groups. This was in contrast to the nine-year-old age division where the advanced group was isolated, and the normal and delayed groups were not different.

Motor Performance Measurements

The purpose of this study was to examine the relationship, if any, between skeletal maturity and the ability to perform motor tasks. The levels of the independent variable, skeletal maturity, were explained in detail at the beginning of this chapter under the heading "Classification of Subjects." The dependent variables, of which there were seven, included: (a) Flexed arm hang, (b) Jump and reach, (c) 30-foot shuttle run, (d) Standing long jump, (e) 30-yard dash, (f) Sit and reach and (g) 400-foot endurance shuttle run. A description of these motor performance tests was given in detail in Chapter III of this report.

Due to the correlation between the dependent variables, a multivariate analysis of variance (MANOVA) was considered to be the

appropriate initial form of analysis. Follow-up analyses were performed by using univariate F with Scheffe' *a posteriori* contrasts, Roy-Bargman step-down F and standardized discriminant function coefficients. The following is a report of these findings.

Nine-Year-Old Subjects

A statistically significant multivariate group effect was found for the nine-year-old age division ($F_{2,95} = 2.38$, $p < .01$). Table IV-11 reveals the results obtained for this age division from the various inferential statistics utilized.

Table IV-11. Univariate F, Step-Down F and Discriminant Analysis results for the motor performance measurements of the nine-year-old subjects

Dependent Variable	df	Univariate F	Step-Down F	Standardized Discriminant Function Coefficients
Flexed Arm Hang	2,95	4.40*	4.40*	-.55
Jump and Reach	2,95	.43	1.78	.83
30-foot Shuttle Run	2,95	1.21	1.34	-.31
Standing Long Jump	2,95	1.76	1.73	-.11
30-yard Dash	2,95	.30	1.07	.16
Sit and Reach	2,95	4.14*	2.70	-.39
400-foot Endurance Run	2,95	3.93*	3.28*	.74

* $p < .05$

Three of the seven dependent variables had univariate F values which were statistically significant at the .05 level. Two of those

three, the flexed arm hang and 400-foot endurance run, also has step-down F values which were statistically significant at the .05 level. The third dependent variable was sit and reach. It must be remembered that the step-down F analysis is highly dependent on the a priori ordering of the dependent variables; however, in this case the two variables which proved to be significant were also two of the three that played an important role in producing the overall multivariate group effect. That is, the standardized discriminant function coefficients indicated that jump and reach, 400-foot endurance run and flexed arm hang (in that order) were the three dependent variables that contributed most to the overall multivariate group effect.

Scheffe' a posteriori comparisons were examined for the three dependent variables whose univariate F values were statistically significant. Those contrasts are illustrated in Figure IV-1. The common underlining method was used to denote which of the three groups differed from one another ($p < .05$). The means for the four additional dependent variables are depicted for informational purposes.

When plotted, the means for all three dependent variables whose univariate F values were statistically significant indicated that the best performances were associated with the delayed and normal skeletal maturity groups as compared to the advanced skeletal maturity group. Graphs for two of the remaining four dependent variables denoted a trend in the same direction. It should be pointed out, however, that only the flexed arm hang and the 400-foot endurance run showed a statistically significant group effect under the Scheffe' analyses ($p < .05$). For the flexed arm hang, the advanced maturity group was different from the normal and delayed groups, and for the

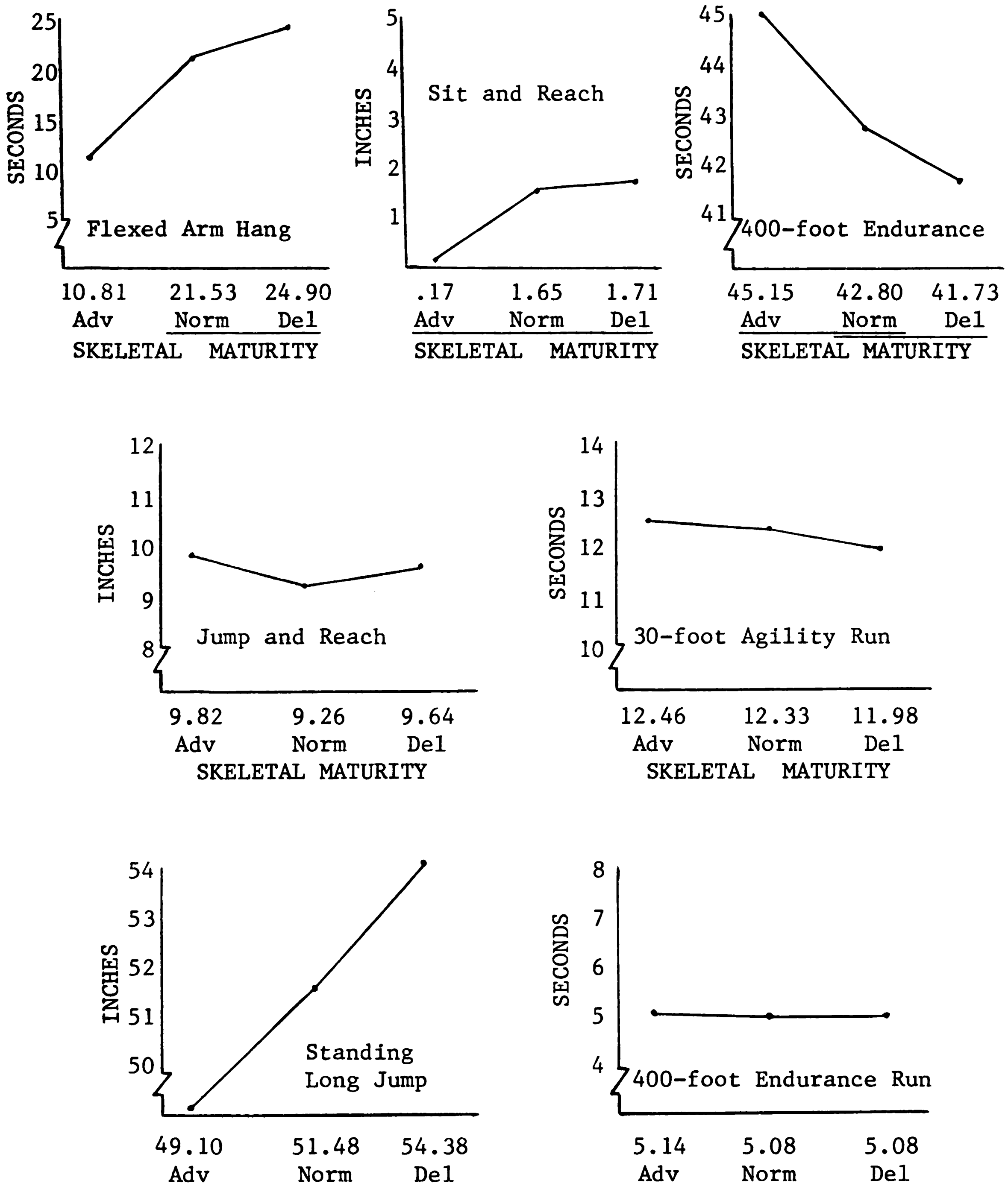

Figure IV-1. Results of the Scheffe' post-hoc tests for the motor performance measurements that were significantly affected by skeletal maturity and cell means for the remaining motor performance measurements: Nine-year-old subjects

400-foot endurance run, the advanced group was different from the delayed group.

Ten-Year-Old, Eleven-Year-Old and Twelve-Year-Old Subjects

There were no statistically significant multivariate group effects for the ten-year-old, eleven-year-old or twelve-year-old age divisions ($p < .05$). Therefore, no multivariate follow-up statistics were appropriate. Of the twenty-one univariate *F* tests (seven for each age division), only one revealed a significant group effect (see Table IV-12). For that dependent variable, flexed arm hang in the eleven-year-old age division, Scheffe' post hoc results are reported using the common underlining method (Figure IV-3).

Table IV-12. Univariate *F* value for the flexed arm hang for the eleven-year-old subjects

Dependent Variable	df	Univariate F
Flexed Arm Hang	2,52	3.56*

*$p < .05$

Means for the other twenty analyses will be presented for informational purposes. The results for the ten-year-old age division are contained in Figure IV-2, those for the eleven-year-old age division in Figure IV-3 and those for the twelve-year-old age division in Figure IV-4.

Not much can be said with authority about the motor performance measurements for the ten-year-old, eleven-year-old and twelve-year-old

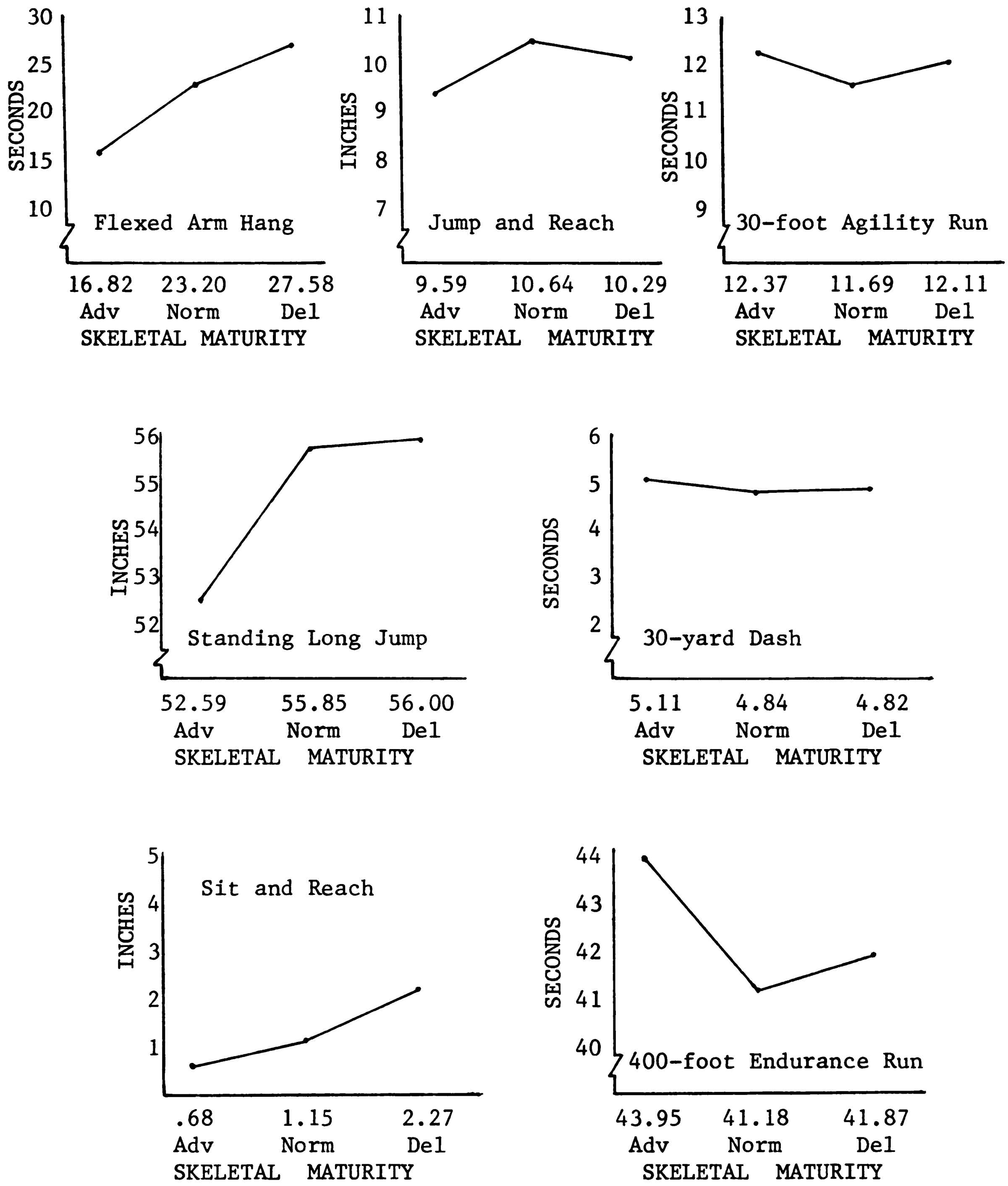

Figure IV-2. Cell means for the motor performance measurements for the ten-year-old subjects

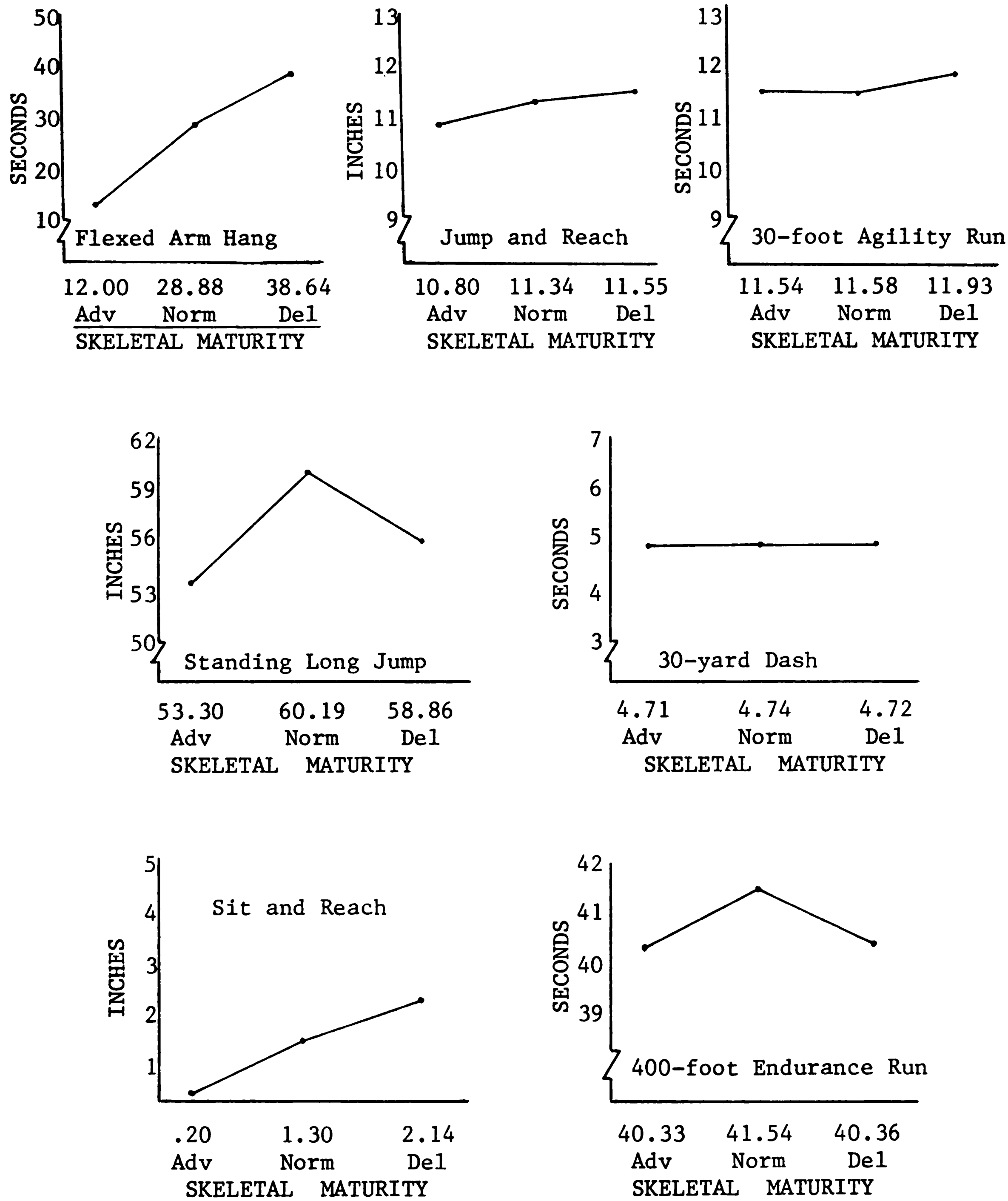

Figure IV-3. Results of the Scheffe' post-hoc test for the motor performance measurement that was significantly affected by skeletal maturity and cell means for the remaining motor performance measurements: Eleven-year-old subjects

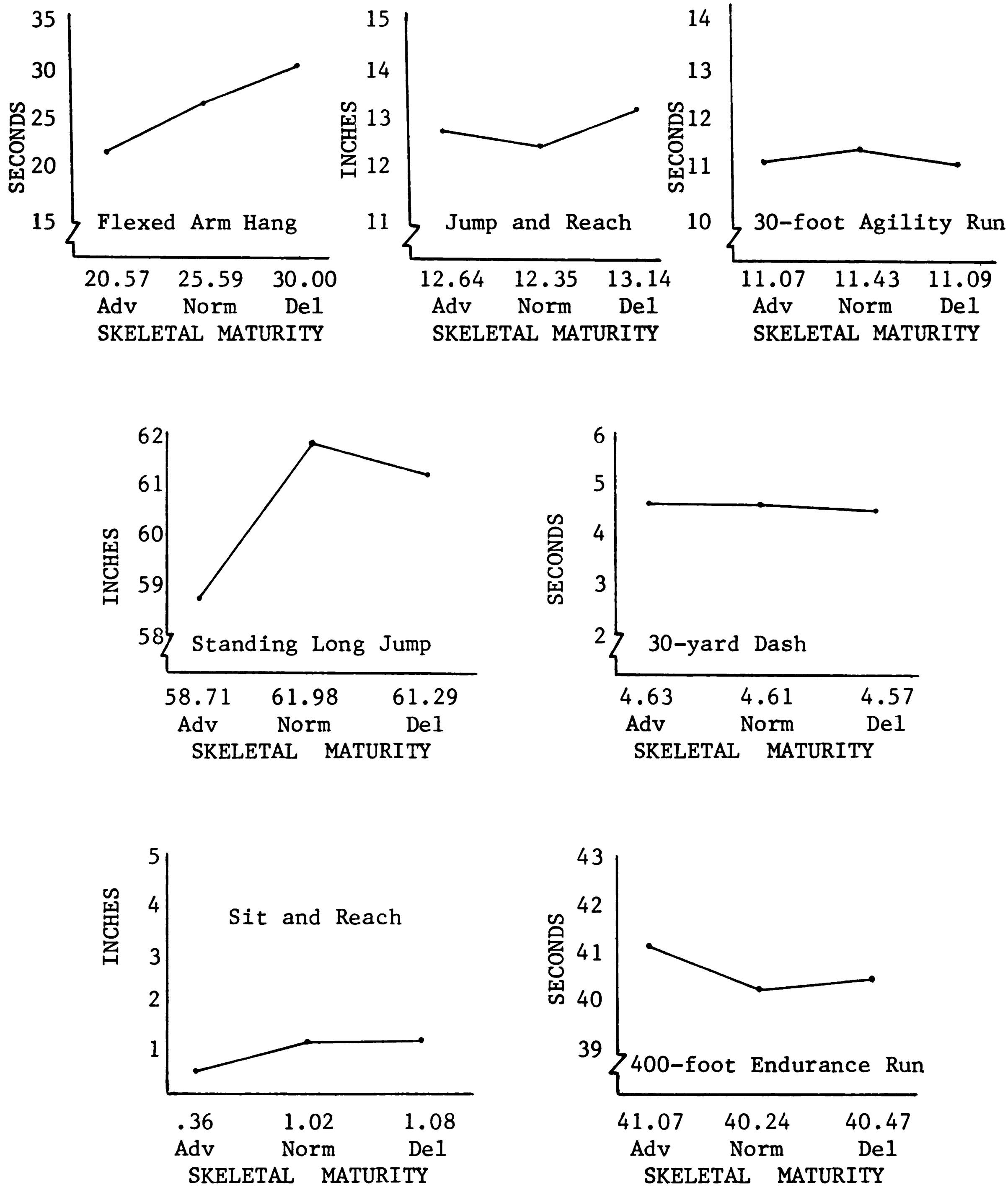

Figure IV-4. Cell means for the motor performance measurements for the twelve-year-old subjects

age divisions, because there was only one dependent variable which was significantly related to skeletal maturity. However, there were a few trends that deserve mention:

(1) The delayed group performed better than the normal group which performed better than the advanced group in the flexed arm hang for each of the three age divisions.

(2) The normal and delayed groups performed better than the advanced group in the standing long jump for each of the three age divisions.

(3) The delayed group performed better than the normal group which performed better than the advanced group in the sit and reach, especially for the ten-year-old and eleven-year-old age divisions.

Summary

In order to study the relationship of skeletal maturity with motor performance ability of nine-, ten-, eleven- and twelve-year-old boys, three groups of subjects for each age division were selected. The groups were designated as advanced, normal or delayed in skeletal maturity. The division of the groups was such that the chronological age in months for each group within their respective age divisions was nearly the same. The skeletal ages of the boys varied systematically with the most skeletally mature in the advanced groups, the least skeletally mature in the delayed groups and the others in the normal groups.

Physical growth data were presented to describe the characteristics of the subjects who participated in the study. Inferential

statistics including multivariate and univariate analyses were reported. Within their respective age divisions, the advanced maturity group was consistently larger in physical size than was the normal group which was larger than the delayed group. Many of these differences were statistically significant at the .05 level.

Data from motor performance tests were examined to determine if they were significantly related to skeletal maturity. Only the motor performance scores of the nine-year-old age division were significantly related to the skeletal maturity of the subjects ($p < .05$). All the cell means for each age division are presented for informational purposes, however. Though not much could be reported statistically, the visual trend was for the delayed maturity groups and the normal maturity groups to perform better than the advanced maturity groups.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

This investigation tested the common assumption that the most physically mature individuals within an age category are apt to possess the greatest prowess in selected motor tests. It was hypothesized that the advanced maturity groups would perform significantly better than the delayed maturity groups on the vertical jump, the agility shuttle run, the standing long jump and the thirty-yard dash ($p < .05$). It was further hypothesized that the three groups would not be statistically different in their performance on the sit and reach, the flexed arm hang and the 400-foot endurance run. However, within the age limit of nine- to twelve-year-old boys the research hypotheses were generally not supported in this study.

Statistically significant relationships between skeletal maturity and motor performance were not found for most of the analyses ($p < .05$). For the nine-year-old age division, univariate statistical differences were detected for the flexed arm hang, the sit and reach and the 400-foot endurance run. For the eleven-year-old age division, a univariate statistical difference was found for the flexed arm hang. Out of 28 univariate analyses (seven dependent variables for each of the four age divisions), only the four mentioned above proved to be statistically related to skeletal maturity.

The three motor performance tasks for which no differences were hypothesized proved to be statistically different for the nine-year-old age division. With regard to post hoc evaluations for this age group: (a) The advanced group differed from the normal and delayed groups in the flexed arm hang, with the latter groups performing better than the former, (b) The advanced group differed from the delayed group in the 400-foot endurance run, with the latter group performing better than the former. As mentioned previously, there were overall significant relationships between skeletal maturity and the sit and reach (nine-year-old boys) and the flexed arm hang (eleven-year-old boys); however, Scheffe' a posteriori contrasts did not indicate significant differences between the groups at the .05 level. Visual inspection indicated that the order of performance for the three groups in both cases, listing the most skilled group first was: delayed, normal and advanced.

These were the only dependent variables which revealed overall significant differences and therefore are the only ones for which follow-up inferential statistics were computed. However, the general trend of the raw scores over the four age divisions consistently revealed that the normal and delayed groups performed better than the advanced groups. This was not expected, especially for the speed, power and agility events; and, in fact, the trend was least evident for these motor performance tasks (except the standing long jump). The other three motor performance events which measured relative strength, endurance and flexibility showed this trend quite consistently, though.

A few thoughts concerning flexibility and strength may help to

explain why the subjects with delayed maturation performed comparatively better than the other groups on the tasks which measured these components. Flexibility tends to be reduced as chronological age increases, so children who are younger than their peers in terms of skeletal maturity possibly have an advantage in this regard. One might speculate that limb length could have been a factor in causing these results, since the advanced groups have consistently larger physical growth measurements. An analysis of the growth measurements refutes this, as the ratio of leg length to arm length for the advanced groups and delayed groups for all four age divisions is almost the same, approximately 1.31:1.

Strength, as measured by the flexed arm hang, is relative to the amount of body weight which must be lifted. A larger child may possess more absolute strength than a smaller child and yet not perform as well as the latter on this motor performance test because the ratio of strength to body weight may favor the smaller child. This might well be the underlying factor regarding the better performances of the delayed groups as compared to the advanced groups in this study on the flexed arm hang. For example, the nine-year-old advanced skeletal maturity group weighed an average of 75.43 pounds, while the delayed group weighed 57.38 pounds. This relationship between skeletally advanced and delayed groups existed for all four age divisions. The advanced groups were possibly stronger in terms of absolute strength, but they were not capable of coordinating their body weight as well as the normal and delayed groups.

Potential Factors of Bias

This report did not support the significant relationships between skeletal maturity and the movement components that were hypothesized, but a few factors which may have confounded the results deserve to be mentioned.

Cell Size. In order to keep the advanced and delayed maturity groups at the extremes of the distributions, only the subjects who were more than one standard deviation from the mean were chosen to be included in them. This limited the cell sizes to small numbers for these groups in most cases (see Table IV-2). With small cell sizes statistical significance is difficult to obtain.

Dropout. The Motor Performance Study at Michigan State University is an instructional program for children of ages 2-15 years. The subjects for this investigation were selected from this program. Motor performance classes are held on Saturday mornings during the school year and half-days from Monday through Thursday for four weeks during the summer. These times correspond closely with the favorite time of day for children's athletic teams to practice or play games.

The boys who are motorically proficient and likely to be successful on these athletic teams may have dropped out of the instructional classes given by the Motor Performance Study to participate in the agency-sponsored competition in the communities. These same boys may be the ones who are the most skeletally mature for their age groups. The skeletally advanced boys who remained in the instructional classes may be the ones who were not as motorically adept and found the individualized program more suited to their needs. If this was the case,

the sample for this study was biased in that regard.

Selected Early Maturers. This explanation is related very closely to the possibility of a "drop out" phenomenon discussed previously. The literature indicates that athletic teams are inordinately composed of early maturing boys. However, we have no evidence as to the proportion of superior athletes from which the population of early maturers is comprised. It is quite possible that of the entire population of early maturing boys at any given chronological age only a small percentage of them may be motorically superior to their peers. In other words, advanced skeletal maturity is possibly only a precursor to becoming a superior athlete in youth leagues, rather than a definite indicator of outstanding performance capabilities.

Advanced Skeletal Maturity. What is advanced skeletal maturity? Perhaps in order for the early maturers to have an advantage on motor performance tests they must be extremely advanced for their chronological age. This study categorized a boy into the advanced skeletal maturity group if the difference between his skeletal age and chronological age was greater than one standard deviation above the mean of the difference score distribution for his chronological age group. It may be that the population of boys who served as subjects for this study did not contain subjects whose skeletal maturity was sufficiently advanced to produce significant differences when compared to the other groups.

Athletics vs. Motor Ability Contradiction

Generally speaking, the literature indicates that boys with advanced skeletal maturity have more success on athletic teams than their counterparts who are delayed in skeletal maturity (Krogman, 1954, 1959; Clarke and Petersen, 1961). The literature also reveals that skeletal maturity is not a factor of importance with regard to motor skill ability (Seils, 1951; Rarick and Oyster, 1964; Jordan, 1966; Clarke, 1971). These two statements seem to be contradictory. Certainly speed, agility, strength, power and flexibility are thought to be positive attributes in the performance of sports skills. However, the relationship between specific tests of motor ability and athletic performance has yet to be explained satisfactorily.

Why, then, does skeletal maturity not seem to be important with regard to these factors? No answer to that question will be found in this report. However, a feasible suggestion may be that possession of only one or two of the movement components and/or certain physical characteristics are all that is necessary to provide success in specific sports at the younger ages. For instance, if a boy is extremely strong and powerful compared to his peers, he may be one of the better baseball players on his team, even though he does not excel in other motor abilities. Or, if a boy is 5 inches taller and 20 pounds heavier than his childhood peers, he may be one of the better football or ice hockey players on his team, although his other characteristics may not especially augment the performance of motor skills.

These examples could be quite pertinent to the explanation of why boys who are advanced in skeletal maturity seem to have more success athletically than their counterparts who are delayed in

skeletal maturity. Although this study did not show the advanced groups to have more strength than their peers (may have been due to the strength measure used), this relationship has been shown previously (Jordan, 1966; Clarke, 1971). This would fit the common assumption that advanced maturers are generally better athletes than their peers. Also, concerning the second example, it has been consistently shown that advanced maturers are taller and heavier than their age group counterparts.

Recommendations

The relationship between skeletal maturity and motor ability is still debatable. This study lends support to the notion that skeletal maturity is not of major importance with regard to selected components of movement as examined through motor performance tests. A definite explanation of the positive relationships between skeletal maturity and skillful performance in youth athletics which have been reported in the literature could not be made on the basis of these data. Further research is needed to fully explain this seemingly contradictory relationship.

Many of the problems concerning the relationship of skeletal age to success in age-group athletics have been alluded to in the discussion section of this chapter. The relationship of physical characteristics to superiority in youth athletics has probably not received sufficient emphasis. There is a strong relationship between skeletal maturity and physical growth. There is also a strong possibility that large body measurements, as compared to those of peers, enhance the probability of becoming a superior player in youth athletics. These relationships deserve in-depth examination.

Specific criteria for equating athletes for optimal learning and competitive environments have not been established. More research is needed to ascertain which characteristics of children correlate highly with the ability to learn and perform motor skills. With this in mind, a factor analytic study including psychological, physiological, motor skill, and growth parameters is suggested. Advanced skeletal maturity alone may not prove to be the most important component of a successful youth athlete, and if it does, it may be subsumed by other measures which are more easily obtained.

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APPENDICES

APPENDIX A

FORM FOR THE TEMPORARY RECORDING OF MOTOR PERFORMANCE SCORES DURING THE MEASUREMENT PERIOD

SCORE SHEETS: MOTOR PERFORMANCE TESTS
Motor Performance Study

NAME ________________________ DATE __________

NUMBER __________ AGE (MONTHS) ________ BIRTHDATE __________

TEST ITEM	Previous Performance	Trial 1	Trial 2	Trial 3
Flexed Arm Hang (nearest whole second)..	______	______	______	(if necessary)
Jump and Reach (nearest one-half inch).	______	______	______	______
Agility Shuttle Run (nearest 1/10 second)...	______	______	______	______
Standing Long Jump (nearest one-half inch).	______	______	______	______
30-yard Dash (nearest 1/10 second)...	______	______	______	(if necessary)
Sit and Reach (nearest one-half inch).	______	______	______	______
400-foot Shuttle Run (nearest 1/10 second)...	______	______	______	(if necessary)

APPENDIX B

DESCRIPTION OF THE GROWTH MEASUREMENTS OBTAINED IN THE MOTOR PERFORMANCE STUDY

Seefeldt
Haubenstricker
1-4-67

DESCRIPTION OF MEASUREMENTS[1]
Motor Performance Study
Michigan State University
East Lansing, Michigan

LINEAR MEASUREMENTS

Standing Height: Measurements are taken with the subject standing against the wall. Heels are placed together, in contact with the wall. Hands are allowed to hang freely at the sides. The head is positioned in the Frankfurt plane. A two-meter, metal anthropometer is placed parallel to the wall, at the midfrontal plane. The sliding bar of the anthropometer is brought down, without pressure, on the vertex.

Sitting Height: The subject is seated on a thirty centimeter bench, with the back against the wall. Subject assumes the sitting position by first leaning forward and then sliding as far back as possible before sitting upright. The feet are placed so the thighs are perpendicular to the trunk and parallel to the floor. Head, and anthropometer positions are identical to those for standing height.

Acrom-radiale (Upper arm length): With the upper arm hanging free, and the forearm flexed at 90 degrees across the chest, from the lateral margin of the acromion process to the groove between the lateral condyle of the humerus and the head of the radius.

Radio-stylion (Lower arm length): With the upper arm hanging free and the forearm flexed at 90 degrees across the chest with the palm facing toward the body, from the groove between the lateral condyle of the humerus and the radius to the tip of tne styloid process of the radius.

BREADTH MEASUREMENTS

Bi-acromial Breadth: The subjects stand with the back to the examiner. The acromion processes are first palpated with the index fingers. One end of the sliding calipers is placed just to the left of the left acromial process. The free end is moved until it is just to the right of the right acromial process. The caliper is held so that the ends point up slightly. No pressure is applied.

Bi-cristal Breadth: The subject stands with the back to the examiner. The iliac crests are located by palpation. The points of the caliper are placed on the lateral side of each crest and pressed firmly in order to depress the fat over the bone.

CIRCUMFERENCES (taken with a metal tape just fitting the skin and not compressing either the skin or fat.)

Biceps (upper arm): Taken at the maximum bulge of the biceps muscle with the arm hanging freely at the side.

Thigh: With the weight of the subject on the right foot, place the left extremity on a bench so that the thigh is parallel to the surface. Measure mid-way between the proximal and distal ends of the femur.

Calf: With the lower extermity in the position for measuring the thigh, measure at the maximum bulge of the calf.

SKINFOLD

Triceps: With the arm hanging freely at the side, measure from a position mid-way between the proximal and distal end of the humerus.

Sub-scapular: From a line one inch below the inferior angle of the scapula.

Umbilicus: Measure at approximately one inch to the left of the umbilicus.

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1 All measurements are taken on the left side of the subject. All values are read to the nearest millimeter

APPENDIX C

FORM USED FOR PERMANENTLY RECORDING THE MOTOR PERFORMANCE SCORES OBTAINED IN THE MOTOR PERFORMANCE STUDY

	Age Categ. 5 6	Card No. 7	Sex 8	Race 9	S-E No. 10	Grade 11 12	Chronol. Age (Months) 14–16	Skeletal Age (Months) 18–20	Flexed Arm Hang 22–24	Jump and Reach 26–28	Agility Shuttle Run 30–32	Standing Long Jump 34–36	30-yard Dash 38–9	Sit and Reach 41–43	400-foot Endurance Shut. Run 45–47		DATE
0–51	06																
52–57	07																
58–63	08																
64–69	09																
70–75	10																
76–81	11																
82–87	12																
88–93	13																
94–99	14																
100–105	15																
106–111	16																
112–117	17																
118–123	18																
124–129	19																
130–135	20																
136–141	21																
142–147	22																
148–153	23																
154–159	24																
160–165	25																
166–171	26																
172–177	27																
178–183	28																
184–189	29																
190–195	30																
196–201	31																
202–207	32																
208–213	33																

NAME NUMBER BIRTHDATE

APPENDIX D

FORM USED FOR PERMANENTLY RECORDING THE GROWTH MEASUREMENTS OBTAINED IN THE MOTOR PERFORMANCE STUDY

	Age Cat.	Card #	Sex	Race	S-E No.	Grade	Chronol. Age (Months)	Skeletal Age (Months)	Weight	Standing Height	Sitting Height	Bi-Acrom	Bi-Crist	Acrom-Radiale	Radio-Stylion	Arm Girth	Thigh Girth	Calf Girth	Triceps Skinfold	Subscap. Skinfold	Umbil. Skinfold	DATE
	5 6	7	8	9	10	11 12	14-16	18-20	22-24	26-29	31-33	35-37	39-41	43-45	47-49	51-53	55-57	59-61	63-65	67-69	71-73	
0-21	01																					
22-27	02																					
28-33	03																					
34-39	04																					
40-45	05																					
46-51	06																					
52-57	07																					
58-63	08																					
64-69	09																					
70-75	10																					
76-81	11																					
82-87	12																					
88-93	13																					
94-99	14																					
100-105	15																					
106-111	16																					
112-117	17																					
118-123	18																					
124-129	19																					
130-135	20																					
136-141	21																					
142-147	22																					
148-153	23																					
154-159	24																					
160-165	25																					
166-171	26																					
172-177	27																					
178-183	28																					

NAME NUMBER BIRTHDATE

APPENDIX E

CORRELATION MATRICES FOR THE MOTOR PERFORMANCE, PHYSICAL GROWTH AND AGE VARIABLES USED IN THIS STUDY

Appendix E-1. Correlation matrix for the motor performance, physical growth and age variables used in this study: Nine-year-old through twelve-year-old age divisions (all data included)

	Chronological Age	Skeletal Age	Flexed Arm Hang	Jump and Reach	30-foot Shuttle Run	Standing Long Jump	30-yard Dash	Sit and Reach	400-foot Endurance Run	Weight	Standing Height
Skeletal Age	.78										
Flexed Arm Hang	.07	-.05									
Jump and Reach	.47	.31	.39								
30-foot Shuttle Run	-.26	-.12	-.37	-.50							
Standing Long Jump	.37	.14	.44	.66	-.57						
30-yard Dash	-.35	-.19	-.37	-.61	.61	-.61					
Sit and Reach	-.11	-.23	.26	.07	-.16	.28	-.07				
400-foot Endur. Run	-.20	-.03	-.35	-.49	.64	-.56	.57	-.16			
Weight	.61	.78	-.19	.11	-.12	.07	-.07	-.24	.02		
Standing Height	.69	.79	-.10	.28	-.22	.20	-.24	-.30	-.13	.82	
Sitting Height	.65	.74	-.05	.29	-.24	.24	-.23	-.20	-.12	.80	.88
Bi-acromial Breadth	.67	.73	.02	.23	-.24	.21	-.21	-.15	-.13	.82	.82
Bi-cristal Breadth	.56	.70	-.14	.16	-.15	.14	-.13	-.30	-.03	.78	.74
Acrom-rad. Length	.64	.76	-.06	.25	-.18	.16	-.19	-.24	-.07	.75	.88
Radio-styl. Length	.67	.78	-.06	.29	-.22	.22	-.22	-.18	-.10	.82	.89
Arm Girth	.41	.58	-.23	-.03	-.01	-.04	.07	-.14	.08	.87	.52
Thigh Girth	.46	.66	-.21	-.03	-.04	-.03	.03	-.18	.08	.91	.60
Calf Girth	.48	.69	-.25	.04	-.06	.00	-.04	-.22	.03	.92	.68
Triceps Skinfold	.15	.37	-.39	-.29	.13	-.26	.31	-.17	.25	.67	.32
Subscapular Skin.	.14	.35	-.30	-.35	.20	-.30	.32	-.17	.30	.63	.24
Umbilical Skin.	.11	.32	-.33	-.32	.21	-.28	.34	-.16	.33	.59	.20
Ponderal Index	.08	-.06	.15	.25	-.15	.18	-.26	-.07	-.23	-.38	.21

	Sitting Height	Bi-acromial Breadth	Bi-cristal Breadth	Acrom-radiale Length	Radio-stylion Length	Arm Girth	Thigh Girth	Calf Girth	Triceps Skinfold	Subscapular Skinfold	Umbilical Skinfold
Bi-acromial Breadth	.80										
Bi-cristal Breadth	.74	.76									
Acrom-rad. Length	.73	.77	.66								
Radio-styl. Length	.74	.81	.68	.89							
Arm Girth	.56	.60	.57	.47	.58						
Thigh Girth	.62	.66	.64	.56	.65	.90					
Calf Girth	.70	.67	.69	.60	.70	.86	.90				
Triceps Skinfold	.33	.36	.42	.29	.36	.77	.77	.69			
Subscapular Skin.	.26	.33	.40	.21	.29	.74	.73	.62	.83		
Umbilical Skin.	.25	.30	.31	.19	.28	.73	.69	.59	.81	.81	
Ponderal Index	.04	-.09	-.13	.14	.03	-.65	-.58	-.47	-.60	-.64	-.66

Appendix E-2. Correlation matrix for the motor performance, physical growth and age variables used in this study: Nine-year-old age division

	Chronological Age	Skeletal Age	Flexed Arm Hang	Jump and Reach	30-foot Shuttle Run	Standing Long Jump	30-yard Dash	Sit and Reach	400-foot Endurance Run	Weight	Standing Height	Sitting Height	Bi-acromial Breadth	Bi-cristal Breadth	Acrom-radiale Length	Radio-stylion Length	Arm Girth	Thigh Girth	Calf Girth	Triceps Skinfold	Subscapular Skinfold	Umbilical Skinfold
Skeletal Age	.41																					
Flexed Arm Hang	-.09	-.16																				
Jump and Reach	.13	.09	.28																			
30-foot Shuttle Run	-.16	.09	-.33	-.63																		
Standing Long Jump	.10	-.16	.36	.58	-.63																	
30-yard Dash	-.17	-.02	-.26	-.49	.55	-.50																
Sit and Reach	-.19	-.28	.23	.16	-.28	.41	-.03															
400-foot Endur. Run	.10	.31	-.33	-.56	.58	-.64	.46	-.36														
Weight	.32	.68	-.21	.06	.05	-.03	-.05	-.25	.24													
Standing Height	.33	.56	-.19	.06	-.02	.00	-.17	-.28	.12	.76												
Sitting Height	.34	.53	-.10	.19	-.09	.16	-.19	-.09	.02	.71	.82											
Bi-acromial Breadth	.26	.50	-.01	.06	-.10	.08	-.18	-.05	.07	.68	.66	.65										
Bi-cristal Breadth	.13	.50	-.09	.04	-.05	.02	-.12	-.31	.15	.64	.59	.56	.54									
Acrom-rad. Length	.30	.57	-.12	.07	-.06	-.02	-.11	-.23	.20	.70	.80	.56	.59	.49								
Radio-styl. Length	.27	.59	-.16	.08	-.06	-.02	-.09	-.25	.22	.76	.78	.53	.62	.51	.83							
Arm Girth	.19	.57	-.21	.04	.07	-.05	.01	-.12	.16	.82	.41	.47	.42	.40	.37	.47						
Thigh Girth	.26	.62	-.24	-.01	.10	-.09	.03	-.24	.25	.90	.53	.51	.52	.50	.52	.62	.84					
Calf Girth	.26	.63	-.25	.04	.11	-.11	-.02	-.21	.22	.91	.59	.57	.56	.57	.54	.63	.80	.91				
Triceps Skinfold	.08	.46	-.40	-.24	.26	-.28	.33	-.23	.42	.65	.26	.28	.31	.37	.29	.39	.66	.74	.69			
Subscapular Skin.	.04	.44	-.29	-.31	.40	-.35	.28	-.27	.52	.66	.25	.24	.28	.36	.22	.36	.71	.74	.67	.79		
Umbilical Skinfold	.11	.45	-.31	-.19	.26	-.21	.21	-.26	.46	.66	.24	.24	.34	.32	.25	.38	.72	.74	.63	.82	.84	
Ponderal Index	-.04	-.28	.04	-.02	-.09	.04	-.14	-.02	-.17	-.49	.19	.01	-.15	-.16	.00	-.10	-.69	-.65	-.57	-.61	-.64	-.65

Appendix E-3. Correlation matrix for the motor performance, physical growth and age variables used in this study: Ten-year-old age division

	Chronological Age	Skeletal Age	Flexed Arm Hang	Jump and Reach	30-foot Shuttle Run	Standing Long Jump	30-yard Dash	Sit and Reach	400-foot Endurance Run	Weight	Standing Height	Sitting Height	Bi-acromial Breadth	Bi-cristal Breadth	Acrom-radiale Length	Radio-stylion Length	Arm Girth	Thigh Girth	Calf Girth	Triceps Skinfold	Subscapular Skinfold	Umbilical Skinfold
Skeletal Age	.37																					
Flexed Arm Hang	-.05	-.17																				
Jump and Reach	.08	-.20	.57																			
30-foot Shuttle Run	.18	.23	-.36	-.42																		
Standing Long Jump	-.01	-.25	.51	.75	-.58																	
30-Yard Dash	.08	.31	-.45	-.61	.66	-.69																
Sit and Reach	-.14	-.24	.32	.20	-.19	.22	-.14															
400-foot Endur. Run	.20	.29	-.37	-.47	.71	-.54	.65	-.15														
Weight	.24	.61	-.29	-.28	.12	-.25	.30	-.32	.28													
Standing Height	.21	.53	-.19	-.11	-.06	-.05	.06	-.36	.08	.69												
Sitting Height	.22	.44	-.06	-.03	-.10	.10	.05	-.21	.08	.62	.81											
Bi-acromial Breadth	.14	.44	-.04	-.17	-.06	-.03	.10	-.13	.09	.68	.66	.64										
Bi-cristal Breadth	.14	.57	-.31	-.25	.07	-.12	.18	-.38	.22	.70	.65	.60	.67									
Acrom-rad. Length	.25	.51	-.16	-.18	.03	-.07	.13	-.26	.16	.59	.81	.55	.63	.54								
Radio-styl. Length	.21	.53	-.15	-.08	-.04	-.06	.08	-.15	.06	.71	.80	.55	.68	.56	.82							
Arm Girth	.23	.45	-.26	-.24	.15	-.27	.34	-.16	.21	.85	.31	.34	.46	.43	.29	.46						
Thigh Girth	.22	.52	-.28	-.31	.16	-.27	.35	-.16	.30	.87	.36	.39	.48	.47	.33	.44	.88					
Calf Girth	.19	.56	-.34	-.29	.12	-.26	.28	-.24	.21	.86	.52	.49	.47	.55	.40	.57	.84	.86				
Triceps Skinfold	.15	.42	-.45	-.44	.20	-.38	.46	-.19	.31	.75	.25	.22	.34	.39	.24	.34	.83	.82	.71			
Subscapular Skinfold	.10	.49	-.32	-.47	.31	-.49	.50	-.18	.38	.73	.24	.22	.34	.48	.23	.33	.76	.74	.64	.83		
Umbilical Skinfold	.13	.42	-.36	-.38	.32	-.37	.53	-.15	.40	.68	.18	.19	.29	.33	.20	.31	.78	.72	.62	.84	.82	
Ponderal Index	-.08	-.17	.16	.23	-.23	.26	-.32	-.01	-.26	-.50	.27	.12	-.14	-.15	.17	-.01	-.76	-.73	-.54	-.67	-.64	-.66

Appendix E-4. Correlation matrix for the motor performance, physical growth and age variables used in this study: Eleven-year-old age division

	Chronological Age	Skeletal Age	Flexed Arm Hang	Jump and Reach	30-foot Shuttle Run	Standing Long Jump	30-yard Dash	Sit and Reach	400-foot Endurance Run	Weight	Standing Height	Sitting Height	Bi-acromial Breadth	Bi-cristal Breadth	Acrom-radiale Length	Radio-stylion Length	Arm Girth	Thigh Girth	Calf Girth	Triceps Skinfold	Subscapular Skinfold	Umbilical Skinfold
Skeletal Age	.27																					
Flexed Arm Hang	.06	-.19																				
Jump and Reach	.43	-.07	.37																			
30-foot Shuttle Run	-.22	-.05	-.38	-.34																		
Standing Long Jump	.05	-.24	.54	.49	-.47																	
30-yard Dash	-.29	.02	-.39	-.65	.64	-.50																
Sit and Reach	-.24	-.34	.36	.02	-.11	.42	-.13															
400-foot Endur. Run	-.28	-.07	-.28	-.38	.63	-.41	.63	.01														
Weight	-.03	.60	-.37	-.43	-.03	-.29	.25	-.20	.03													
Standing Height	.28	.70	-.26	-.06	-.12	-.16	.11	-.40	-.14	.65												
Sitting Height	.16	.62	-.22	-.12	-.15	-.10	.10	-.30	-.06	.66	.78											
Bi-acromial Breadth	.09	.54	-.05	-.16	-.17	-.10	.12	-.21	-.10	.73	.68	.70										
Bi-cristal Breadth	-.03	.50	-.19	-.15	-.11	.02	.14	-.23	-.05	.67	.60	.67	.67									
Acrom-rad. Length	.24	.65	-.15	.02	-.03	-.09	.08	-.30	-.10	.54	.84	.63	.68	.51								
Radio-styl. Length	.26	.61	-.12	-.02	-.15	.00	.01	-.14	-.14	.63	.84	.64	.71	.45	.83							
Arm Girth	-.12	.41	-.34	-.57	.08	-.32	.33	-.11	.13	.89	.37	.43	.56	.46	.23	.42						
Thigh Girth	-.09	.50	-.31	-.51	-.02	-.31	.26	-.13	.06	.94	.45	.52	.61	.56	.33	.45	.92					
Calf Girth	-.11	.53	-.40	-.42	-.01	-.25	.16	-.14	.02	.90	.53	.59	.56	.57	.37	.53	.86	.87				
Triceps Skinfold	-.18	.32	-.40	-.54	.10	-.35	.38	-.17	.11	.77	.31	.32	.33	.37	.20	.27	.82	.82	.74			
Subscapular Skin.	-.27	.21	-.36	-.63	.14	-.40	.45	-.17	.19	.69	.10	.18	.31	.30	.03	.08	.78	.78	.61	.88		
Umbilical Skin.	-.32	.18	-.37	-.67	.15	-.36	.46	-.09	.21	.68	.14	.20	.30	.26	.03	.13	.78	.75	.63	.82	.90	
Ponderal Index	.33	.01	.17	.48	-.10	.17	-.20	-.21	-.20	-.54	.28	.01	-.20	-.19	.24	.11	-.73	-.69	-.57	-.60	-.71	-.68

Appendix E-5. Correlation matrix for the motor performance, physical growth and age variables used in this study: Twelve-year-old age division

	Chronological Age	Skeletal Age	Flexed Arm Hang	Jump and Reach	30-foot Shuttle Run	Standing Long Jump	30-yard Dash	Sit and Reach	400-foot Endurance Run	Weight	Standing Height	Sitting Height	Bi-acromial Breadth	Bi-cristal Breadth	Acrom-radiale Length	Radio-stylion Length	Arm Girth	Thigh Girth	Calf Girth	Triceps Skinfold	Subscapular Skinfold	Umbilical Skinfold
Skeletal Age	.30																					
Flexed Arm Hang	.23	-.07																				
Jump and Reach	.32	.01	.41																			
30-foot Shuttle Run	-.32	.06	-.44	-.39																		
Standing Long Jump	.35	-.09	.38	.59	-.41																	
30-yard Dash	-.31	-.02	-.42	-.52	.41	-.63																
Sit and Reach	-.02	-.13	.12	.07	-.06	.27	-.18															
400-ft. Endur. Run	-.34	-.03	-.46	-.33	.62	-.45	.50	-.05														
Weight	.03	.61	-.29	-.25	-.04	-.17	.30	-.15	.09													
Standing Height	.40	.66	-.13	.07	-.19	.03	-.10	-.24	-.23	.69												
Sitting Height	.19	.60	-.13	-.02	-.16	-.08	.04	-.25	-.03	.74	.76											
Bi-acromial Breadth	.18	.44	-.04	-.13	-.12	-.08	.16	-.18	-.09	.76	.72	.67										
Bi-cristal Breadth	.02	.47	-.30	-.11	-.02	-.21	.21	-.26	.04	.72	.54	.61	.69									
Acrom-rad. Length	.32	.62	.01	.02	-.21	-.05	-.00	-.14	-.23	.58	.81	.52	.63	.40								
Radio-styl. Length	.32	.62	-.05	.06	-.13	.11	-.03	-.04	-.20	.73	.89	.62	.71	.50	.85							
Arm Girth	-.18	.33	-.34	-.37	.06	-.23	.50	-.05	.22	.87	.34	.46	.57	.57	.29	.44						
Thigh Girth	-.03	.50	-.27	-.36	.02	-.25	.38	-.02	.10	.92	.53	.53	.64	.64	.47	.62	.87					
Calf Girth	-.11	.54	-.33	-.30	-.01	-.18	.31	-.19	.09	.93	.56	.69	.63	.71	.40	.59	.83	.87				
Triceps Skinfold	-.22	.27	-.39	-.44	.13	-.38	.48	-.02	.32	.74	.32	.38	.42	.55	.27	.40	.82	.80	.72			
Subscapular Skin.	-.25	.32	-.32	-.49	.18	-.34	.48	-.03	.36	.69	.16	.26	.32	.39	.19	.24	.81	.77	.68	.80		
Umbilical Skin.	-.39	.20	-.33	-.54	.30	-.54	.58	-.02	.38	.55	-.00	.21	.17	.22	.03	.11	.72	.62	.56	.73	.72	
Ponderal Index	.42	-.04	.23	.43	-.17	.26	-.54	-.09	-.36	-.53	.24	-.11	-.19	-.33	.17	.04	-.77	-.61	-.60	-.60	-.70	-.75