This is to certify that the

thesis entitled

THE RELATIONSHIP BETWEEN
MOTOR PERFORMANCE AND SKELETAL MATURITY IN
FEMALES SIX THROUGH TEN YEARS OF AGE

presented by

Sharon Elizabeth Culliton

has been accepted towards fulfillment
of the requirements for

Master of Arts degree in HPE

[signature]
Major professor

Date February 24, 1984

O-7639

THE RELATIONSHIP BETWEEN
MOTOR PERFORMANCE AND SKELETAL MATURITY IN
FEMALES SIX THROUGH TEN YEARS OF AGE

By

Sharon Elizabeth Culliton

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Health and Physical Education

1984

ABSTRACT

THE RELATIONSHIP BETWEEN
MOTOR PERFORMANCE AND SKELETAL MATURITY IN
FEMALES SIX TROUGH TEN YEARS OF AGE

By

Sharon Elizabeth Culliton

This investigation examined the relationship between skeletal maturity and motor performance. Data were obtained from females enrolled in the longitudinal Motor Performance Study at Michigan State University. This study was to determine if females when classified into three levels of skeletal maturity; early, average and late at six years of age, differ from each other on seven measures of motor performance over a four year span from six to ten years of age. With skeletal maturity as the independent variable motor performance scores were analyzed using multivariate and univariate techniques. Although maturity status was not significant, a visual trend was apparent for the early maturity group and the late maturity group to perform better than the average maturity group in the flexed arm hang, jump and reach and standing long jump at six and ten years of age. A significant multivariate main effect was found for time, indicating an improvement in motor performance ability from six to eight to ten years of age. This was evident for the agility shuttle run, standing long jump, 30-yard dash and 400-foot endurance run.

This work is dedicated to my parents
for their ever present love and support.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Dr. Crystal Branta for being instrumental in fostering my interest to undertake this investigation. Her inspiration, guidance and support throughout my Master's program are greatly appreciated. For providing me with invaluable "hands on" experience, I thank her.

My appreciation is also extended to Dr. Luke Kelly for acting as chairman during the completion of this thesis. His expertise and the extra time he devoted on the final phase of this document are most appreciated.

I also wish to thank Professor Vern Seefeldt for his advice and the time he found to read the x-rays for the skeletal age assessments. His wealth of knowledge and stimulating discussions were of great assistance in the completion of this study.

To Jan Vredevoogd, I give my thanks. Her consultation for the data programming and interpretation were invaluable.

Finally, I wish to thank Professor John Haubenstricker who is presently the Director of the Longitudinal Motor Performance Study and the many individuals who have helped to obtain the data which were part of this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

THE PROBLEM

Although the rate of growth varies among individuals, it is well established that every child follows the same growth pattern. The skeletal age range is narrowest in early childhood and becomes widest at adolescence (Hansman and Maresh, 1961). The result is a large variation in physical maturity among children of the same chronological age. Yet, chronological age and grade level remain the most often used criteria for categorizing children into subgroups for optimal motor learning and physical activity. Is a single set of performance standards for children of the same chronological age or grade level realistic? A measure of physiological development may provide a more valid indicator of readiness than chronological age and grade (Haywood, 1981).

A method should be devised to classify children for optimal learning and competition where motor skills are the foundation for success. In order to determine a more suitable criteria for homogeneous grouping during motor skill performance, more research is needed to understand which physical characteristics of children correlate highly with the ability to

perform motor skills. The study of the relationship between physiological age, of which skeletal age is an indicator, and motor performance may suggest a more useful criterion.

The concept of assessing physiological development of children is not new. At the beginning of this century, Crampton (1908) and Rotch (1908) began investigating the need for measuring physiological development. Yet standards for estimating skeletal age were not published until 1937 (Todd). From 1908 until 1937 several different scientists devised various methods to measure the bones of the hand and wrist for making the assessment of skeletal age a reliable and objective way to determine skeletal development. The significance of using skeletal age as an indicator of physiological development is well documented. The literature contains evidence that early maturers differ from late maturers in a variety of ways, including academic achievement, physical growth, personality development and motor ability (Olson, 1959; Malina, 1974, 1975; Krogman, 1962; Howell, 1979).

Need for the Study

Knowledge of the relationship between physical growth and maturity of children and their proficiency in performing gross motor activities might assist

teachers and physical educators in planning activities for children. To date the age group from three to ten years represents a neglected area of research in motor development. Understanding how the growth process affects performance may assist the teacher in planning activities for children. Based on growth patterns the teacher can assess individual readiness factors and can prescribe activities that lead to more successful experiences. Individualized, prescribed activity may enhance development of a positive (or more positive) body concept, as well as more positive attitudes toward engaging in physical activity (Haywood, 1981).

There are numerous variables that may inhibit or assist children while performing. For example, some children are genetically endowed with physical capabilities that others may never attain. Likewise, teaching methods, parental motivation and the learning environment play a vital role (Howell, 1979). The focus in this investigation is on one potential variable, physiological readiness for motor performance.

This study will attempt to determine if skeletal age is a valid indicator of the ability of females, age six through ten, to perform motor skills. If valid, skeletal age would be a better criterion for grouping children for motor skill learning than chronological age. Future research then would have to be directed towards making the assessment of skeletal age a more

practical measure.

Purpose of the Study

The aim of this study was to determine if females, when classified according to levels of skeletal maturity at six years of age, differ from each other on selected measures of motor performance over the four year span of six to ten years. The independent variable, skeletal maturity, was subdivided into three levels: early, average and late. The selected motor performance tasks 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 (Appendix A).

Research Hypotheses

The purpose of this study was to examine the relationship between skeletal maturity at age six, and performance on seven selected motor performance tests for females over the four year span of six to ten years. Based on former motor development research the expectation was that the early maturing females, would perform significantly better at each chronological age, than the average maturing females who would perform significantly better than the late maturing females on the vertical jump, the agility shuttle run, the standing long jump, and the thirty yard dash. 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. Significant age differences were expected in the vertical jump, agility shuttle run, standing long jump, and thirty-yard dash. Data provided in the literature lend support to these predictions (Seils, 1951; Glassow, 1960; Rarick and Oyster, 1964; Malina and Rarick, 1973; Hensley and East, 1982).

Research Plan

Females in the Motor Performance Study at Michigan State University over a four year span of six to years of age served as subjects for this investigation. The Motor Performance Study (MPS) is a longitudinal study which began in January, 1968 in the Department of Health and Physical Education at Michigan State University and has enrolled about 1200 children through June, 1983. The aim of this study was to determine if females when classified into three levels of skeletal maturity; early, average and late, at six years of age, differ from each other on seven selected measures of motor performance over a four year period of six to ten years of age. The research plan is explained in detail in Chapter III of this study.

Delimitations

The population for this study was delimited to females who were enrolled in the Motor Performance Study at Michigan State University while they were from six to ten years of age chronologically. All of the females for whom skeletal maturity assessments at age six and data on seven selected motor performance tests over a four year span from six to ten years were included in the sample. The literature concerning longitudinal information on the relationship between biological maturation and motor performance measures for this age group is lacking.

The study was further delimited by the test battery of the Motor Performance Study from which the data were taken. Seven motor performance measures were included as the dependent variables in this study. 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 maturity.

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 throughout the

measurement period was not evaluated; however, all subjects were urged to perform with maximum effort on all of the tests.

2. The effect of the facilities used for the testing sessions on the motor performance of the subjects is unknown.

3. The average chronological age for each level of skeletal age within the six year age group could not be controlled. For example, one level of skeletal age could have an average chronological age of 6.8 years, while another could have an average chronological age of 6.1 years.

4. Human error in the measurement of motor performance and skeletal age was operating to an unknown degree.

Significance of the Study

It is important to understand more about the effect of physiological development on elementary school age females. It has been well established that children do not mature at the same rate, yet it is not known how this variation in maturation affects them in regard to motor skills. If skeletal development is indicative of a child's ability to perform certain motor skills, then a more practical method should be considered to provide physical educators with this information.

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 be aware of this and give consideration to grouping by physiological development rather than by grade level or chronological age.

Definitions

Chronological age - The amount of time one has existed since birth.

Skeletal age - An assessment of the degree to which maturation has occurred in skeletal ossification centers, as seen on an x-ray of the hand-wrist area using the Greulich-Pyle bone specific approach.

Early maturer - One whose difference score, obtained by subtracting chronological age from skeletal age, is within the lowest twenty percent for this sample at six years of age.

Average maturer - One whose difference score, obtained by subtracting chronological age from skeletal age is within the middle twenty percent for this sample at six years of age.

Late maturer - One whose difference score, obtained by subtracting chronological age from skeletal age is within the highest twenty percent for this sample at six years of age.

CHAPTER II

RELATED LITERATURE

During the early years of this century, a method of rating the development of children was being sought. Chronological age no longer appeared to be satisfactory since many children function at a level above or below what is expected from their chronological age. Two investigators, Crampton (1908) and Rotch (1908) working independently explored methods of assessing growth of children at any age. Using the then new technique of x-ray photography, Carter (1926), Cattell (1934), and Flory (1936) made their contributions to formalizing this objective measurement of the human skeleton. They were followed by Todd (1937), Greulich and Pyle (1950, 1959), Acheson (1954, 1957) and Tanner, Whitehouse and Healy (1959, 1962) who popularized its use by establishing standards from which the x-rays could be compared and evaluated. Two other well known investigators who have made significant contributions to the literature concerning skeletal maturity include Krogman (1980) and Roche (1975). Krogman's work focused on identifying the factors of physical growth of children and how they may apply to physical education. Roche's research in the 1960's and 1970's focused on the comparisons and assessments of the methods of predicting skeletal age.

The purpose of this chapter is to establish skeletal age as an objective and valid form of developmental assessment in human beings. A need for its use will be established prior to a discussion of the overall concept of skeletal age. Then a historical look at the variety of methods for assessment and criticisms of these methods will be presented. The subsequent section deals with the differences in rate of skeletal development between the sexes. Finally, the inter-relationship that skeletal development has with a child's cognitive, motor, affective and somatic domains are discussed.

Physiological Age as a Developmental Criterion

Although every child follows the same growth pattern, the rate of development may vary. Children do not proceed from one stage of development to the next at precisely the same pace. Nor do they progress systematically with the calendar. This presents problems in settings where an index of physiological development is desirable. For instance, parents, physicians and educators, the people most intimately concerned with the child's growth, need to know developmental age far more than age in years. Parents care about the comparative growth of their children as they pass from infancy to childhood to adolescence. Likewise, physicians concern themselves with the normal physical growth of children in order to diagnose and treat abnormal growth, if necessary. Finally many educators agree that students should be grouped homogeneously if an optimum learning environment is to be established. Devoid of a comparative criterion, these concerns can never be addressed.

These and other situations imply that some form of developmental measure be available. Although it is commonly used, the number of days that a child has lived (chronological age) cannot accurately measure a child's developmental progress. 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 now properly be inferred from its height, weight and age alone." (1959, p. 1). However, presently there is no real practical method for its assessment.

The concept of skeletal age as an indicator of development is well established. By using this developmental criterion, one can delete some of the inherent problems of chronological age. Numerous investigators have published standards by which clinicians are able to assess, using x-rays, the maturational status of a child (Todd, 1937; Greulich and Pyle 1950, 1959; Acheson, 1954, 1957; Tanner and Whitehouse, 1959; Tanner, Whitehouse and Healy, 1962). The assessment of skeletal age, together with an accurate measurement of standing height can also be utilized for predicting the child's adult height (Bayley and Pinneau, 1952). A more detailed description of the physiological development criterion of skeletal age and an explanation of how it can be assessed follows.

Concept of Skeletal Age

Throughout this century many methods for assessing development have been proposed. The concept of developmental age was initially put forth by Crampton (1908) using the term physiological age and Rotch (1908) referring to anatomical age as a yardstick for development. Other developmental standards which have been published include dental age, maturational age, organismic age and skeletal age. Although the assessments of these measures vary, their one purpose was to establish the physiological developmental level of children. Yet, chronological age is most commonly used because it is readily obtained. However, this does not necessarily validate its use in many situations.

The term "skeletal age" is applied frequently to the maturational status of children (Hansman and Maresh, 1961). This is an assessment of the maturational level of children which is made by determining the amount of growth that has taken place in the bones. The procedure for these assessments requires that part of the skeleton be x-rayed. Then this x-ray film is compared to established standards. A developmental level is established that provides a vast amount of information about the growth of a child. It may be that the child is developing earlier or later than is suggested by chronological age. In many children this variability should not be overlooked and can be accounted for by using the skeletal age.

Though other measures may serve the purpose of estimating physiological maturity in some cases, Johnston gives reasons why the skeleton should be used to provide the best evidence of progressive maturation in the growing child:

1. The beginning and end points are established: only a few of the accessory centers for 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. The skeleton changes continuously throughout the growing period - its appearance records the maturation level at all times;
3. 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. The assessment of the maturation 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 (1962, p. 133).

The Evolution of Skeletal Age as an Estimate of Maturity

Inspired by the pioneer work of Charles Ward Crampton (1908) on the puberty of children, Rotch developed and proposed the concept of skeletal age. He believed, "that in the future we shall determine age, whether for gymnastics, athletic sports, kindergarten, school or child-labor, by means of anatomic conditions rather than by chronologic age." (1908, p. 1197) Roentgenograms of children's hands and wrists showed that their chronological ages meant little in regard to their biological development. Rotch concluded that:

1. A standard of development should be established and used in athletic and educational reform.
2. The wrist is the best part of the skeleton to use for assessment.
3. Divisions such as A, B, C, D should be thought of rather than months and years.

Later, a number of methods of assessing anatomical age were introduced. Freeman and Carter (1924) and Carter (1926) used planimeter measurements of areas of carpal bones as seen from roentgenograms. Cattell (1934) measured the diameters of carpal bones, meta-

carpals and epiphyses, while Flory (1936) studied the overall appearance of the carpals, metacarpals and epiphyses. Even these methods lacked standards for comparison, and it was not until 1937 that they were published.

By introducing standards of skeletal maturity of the hand, Todd (1937) improved the outlook for the use of skeletal age as a developmental indicator. In his atlas, he established the necessity of using skeletal development as a yardstick for assessing maturation and provided the rationale for using the hand for study and standardization.

The remainder of the atlas provides the standardized plates for comparison to skeletal age assessments. There are 40 plates of hand x-rays of males in the book. They range in age from three months through eighteen years, nine months. There are 35 plates of hand x-rays of females from age three months through sixteen years, three months. From three through fifteen months, the plates represent three-month intervals. Thereafter, the plates are standardized at six-month intervals. The plates are based on roentgenograms from over 3500 white males and 3400 white females.

Until this point in time, the hand and wrist was the only portion of the skeleton for which standards had been established. In 1955, Pyle and Hoerr published an atlas of the knee joint. They used children from the

Brush Foundation who were free from any gross physical and/or mental defects and who volunteered their continued participation in the study. Twenty-nine pictures from the 10,400 films studied were used as the plates of bone maturation from the neonatal period to 18 years of age. This research team also published an atlas of standard plates of the foot and ankle in 1962 (Hoerr, Pyle and Francis) and also revised their atlas of the knee in 1969 (Pyle and Hoerr).

The Todd Atlas of Skeletal Maturation was revised by Greulich and Pyle (1950). The second edition, a final report of Todd's work of 1937 was published in 1959. Additions included four new plates for the male series and one new plate for the female series, but the suggested techniques of assessment remained basically the same. These standards are used as a reference for skeletal maturation at the present time.

In 1954 an alternative method of assessing skeletal maturity was proposed (Acheson, 1954). This technique utilized selected bones rather than the entire film. Points are awarded to each bone, depending on the developmental stage of the child, and then the scores for all the bones are totaled. It was proposed that this technique could be utilized at any period throughout the developmental process, and details of its use were given for the first five years of life. A second 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 age to chronological age.

Acheson's (1957) Oxford method of evaluating skeletal maturity varied from the already established forms of assessment in two ways. First, other body parts were employed for assessment. The hip and the pelvis became 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 was awarded a number. These numbers were summed to establish the skeletal maturity index. The advantage to this method is that in the very young child more maturity indicators are available in this area than in any other, however, this anatomical area of study is undesirable as it: (1) requires a larger roentgenographic plate than any other region and therefore is more expensive, (2) exposes the gonads to unnecessary doses of radiation (while the risk of an occasional roentgenogram is negligible, it should not be forgotten), and (3) requires the removal of some clothing.

Further revisions of this assessment technique were suggested in 1959 (Tanner and Whitehouse) and in 1962 (Tanner, Whitehouse and Healy). This research team's method of rating skeletal development was not unlike Acheson's Oxford method (1957), however they proposed the necessity for statistically assessing the relative importance of each stage of each bone (Tanner et al., 1962).

Criticisms of the Methods of Skeletal Age Assessment

A number of studies have found fault with the standards initially developed by Todd (1937) and revised by Greulich and Pyle (1950, 1959). Mainland (1953, 1954, 1957) reported that the less experienced reader tended to give lower assessments than more experienced readers. He found this systematic error to be significant, yet suggested that the method may be suitable for assessing the skeletal maturity of communities but not individuals. However, Greulich and Pyle (1959) suggested that Mainland neglected to add that in the hands of those whose assessments have a smaller systematic error than those of the assessor in his study, the Greulich and Pyle skeletal method might be of some value in the assessment of a single hand-film or of a child's progress. Greulich and Pyle (1959) were aware that the assessment of a hand-film has a large subjective component. They felt that no method would likely ever be devised to assess a hand-film with pin-point precision. Hence, they intended the system devised in their atlas to provide merely useful estimates of skeletal states, and felt that it would do so, if it were properly

used. Scheon, Solomon and Milkovich (1970) tested the validity of the Greulich-Pyle approach for children with unusual height and concluded that the standards provided adequate evaluation for tall girls, but not for short boys.

Other investigators have shed a more positive light on the reliability of assessing skeletal age using the Greulich-Pyle method. Koski, Haataja and Lappalainen (1961) reported the magnitude of the error in their readings did not warrant that the method be disregarded for use on individuals. Differences in levels of assessment by judges before training bordered on statistical significance. These same judges after training became reliable, and each of their assessments were thought to be no better or worse than any of the other judges' assessments (Acheson, Fowler, Fry, Jones, Koski, Urbano and van der Werff ten Bosch, 1963).

Another study involved five judges making two readings on 33 hand-wrist roentgenograms. There was no significant difference between the levels of assessment by the judges and within judge reliability correlations ranged from .95 to .99 (Moed, Wight and Vandegrift, 1962). It has also been found that the confidence limits could be reduced by about 30 percent by using the average of two assessments of an x-ray, rather than deciding upon one or the other. The study by Roche, Davila, Pasternack and Walton (1970) supported the results of previous studies of no significant differences between repeated assessments by the same judge nor differences between observations by paired observers.

The bone-specific approach by Tanner, et al. (1959, 1962) has likewise been subjected to investigation. Eight judges repeated their assessments with precision using the bone-specific approach. But, the assessments were found to differ significantly between judges. In this same study it was noted that there was more difficulty in evaluating the round bones, particularly the carpals, than the short or long bones (Acheson, Vicinus and Fowler, 1964).

Contrasting the Methods of Skeletal Age Assessment

Presently there are three methods of assessing skeletal age that have stood the test of time, two applied to the Greulich-Pyle Atlas and one developed by Tanner et al. The original Greulich-Pyle technique utilizes an overall inspectional matching of a hand-wrist x-ray with an atlas plate in order to establish the subject's skeletal age. The Tanner-Whitehouse method is one of specificity in which every bone of the hand and wrist is evaluated, assigned a number, and totaled to provide a skeletal index. The third approach is similar to the Tanner-Whitehouse method. The Greulich-Pyle Atlas is used for assigning a developmental level to each bone from which the mean age is

calculated.

The techniques as well as the standards from which the assessments are made differ. The Greulich-Pyle Atlas is based on a sample of children born in 1931-1932 from Cleveland, Ohio who were reportedly from above average economic and educational status families. However, the Tanner-Whitehouse standards were obtained from data collected between 1945 and 1958 on a representative group of British children from the average socio-economic level. These divergent approaches to assessment and basis of standards have been extensively investigated and discussed in recent years (Krogman, 1970, 1975; Roche, 1970, 1971, 1975; Tanner, 1971, 1975).

The superiority of one method has yet to be established by investigators in the field. Skeletal ages of identical children, when assessed by the Tanner-Whitehouse method, are consistently in advance of skeletal ages assessed by the Greulich-Pyle method. Acheson et al. (1966) found the mean skeletal age of a group of children when assessed by the Tanner-Whitehouse method was about one year advanced to the age assessed through the Greulich-Pyle method. Fry (1968) reported statistically significant differences in comparing Tanner-Whitehouse and Greulich-Pyle ratings for all age groups of boys. Tanner-Whitehouse assessments were higher for every group, except the two youngest groups

(12 and 15 months). For girls the Tanner-Whitehouse assessments were higher in all the age groups but there was no statistically significant difference in three of the twenty groups. A study by Roche, Davila and Eyman (1971) likewise reported older skeletal age readings using the Tanner-Whitehouse method when compared to the Greulich-Pyle approach. One should be cautious however, before concluding that the bone-specific approach is the cause for the Tanner-Whitehouse method giving advanced ages, because Johnston, Dorst, Kuhn, Roche and Davila (1973) reported that the bone-specific technique using the Greulich-Pyle atlas assigned skeletal ages about two months younger than did the overall inspectional technique using the same atlas as the reference.

No one method is consistently recommended over the others. Roche (1965) has stated that the Tanner-Whitehouse approach does not use all the information available from the x-ray and its clinical reliability has yet to be established. Anderson (1968) stated that the Greulich-Pyle approach can be learned faster and is equally as accurate as the Tanner-Whitehouse method. However, Malina (1971) reported that the Tanner-Whitehouse approach is perferred if a more finely calibrated scale for each bone is necessary. In conclusion, Fry (1968) has written that neither of these methods is correct or incorrect.

Symmetry of the Body

Although for years it was perceived that the two sides of the human body are asymmetrical, the important practical question, is whether skeletal development in each of the two hands of a child is close enough that the same ratings can be derived from either of them (Greulich-Pyle, 1959). By 1921, Baldwin was convinced that in neither sex was there any significant difference between the carpal areas of the right and left hands (Baldwin, 1921; Baldwin, Busby and Garside, 1928). Likewise Flecker (1942) doubted whether there was any appreciable difference with respect to the left or right side. Torgersen (1951), Baer and Durkatz (1957) and Dreizen, Snodgrass, Webb, Peploe, Parker and Spies (1957) have all demonstrated that differences do occur between the sides. However, Torgersen's data of 404 children confirm that if there is a difference, the left is more likely to be advanced. Yet, the differences are too minimal to be a source of error when used to determine developmental status. In their own study, Dreizen, et al. (1957) found that the differences between the skeletal ages of the two hands exceeded three months in only 13 percent of the children and that it was more than six months in only 1.5 percent of them. They concluded that any divergencies in the overall skeletal maturation between hands are so minor as to be meaningless when evaluating the skeletal status from

roentgenograms.

Differences in Skeletal Age Between the Sexes

The human female reaches maturity at an earlier chronological age than the male and the acceleration can be demonstrated in the skeleton. Pryor (1925, 1933) was the first to recognize that ossification in females is advanced over that in males. The difference is relatively small at first, increases during childhood and puberty, then decreases again as maturity is reached. This tendency of females to surge ahead of males in the attainment of physical growth explains why junior high school girls are usually taller and heavier than their male peers. A study of chronological age 6 to 11 year old non-institutionalized children in the United States showed that in terms of skeletal age, boys were in delay of their chronological ages by 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 years was 13.1 years (Public Health Bulletin, 1974). Flory (1936), Simmons (1944), Fry (1966) and Maresh (1970) also illustrate male and female skeletal age differences.

The skeletal maturation of a group of children at

the same chronological age varies widely. Hansman and Maresh (1961) studied 36 girls and 27 boys longitudinally and found that the skeletal age range is narrowest in early childhood and becomes widest at adolescence. For girls they reported the greatest variation of six years skeletally was at chronological age 11 years. Skeletal ages assigned to the x-rays of the boys produced a similar picture. For the boys, the greatest variation of four year, nine months skeletally occurred at chronological age 10 1/2 years. For both males and females, the greatest difference between the average skeletal and chronological ages for the group occurred from seven to ten years of age. During the first three years of life, the median skeletal age for girls is equal to the chronological age.

Secular Trend

Children today grow to be taller, weigh more, age for age, and reach maturity earlier than children of several generations ago (Malina, 1975). These observations are collectively known as the secular trend, a phenomenon postulated as resulting from better nutritional and environmental circumstances. This secular increase in height and weight begins early in life and increases with advancing age. The increased size differences between children of different generations reflects to a greater degree maturity differences.

Children today mature earlier than those of several generations ago. Early-maturing children tend to be taller and heavier, age for age than late-maturing children. The estimated rate that the age of menarche has been declining is approximately four months every ten years in Western Europe from 1830 to 1960 (Tanner, 1962). However, data from Norway by Brundtland and Walloe (1973) indicate that menarcheal age has not changed from 1952 to 1970.

This secular trend raises the question of whether or not the maturity of the Brush Foundation sample used by Greulich and Pyle (1950) may be significantly different from a sample studied today. However, within a sample the assessment of the x-rays is relative. Therefore the validity of using it to identify early, average and late maturers within a specific sample is justified.

Correlations of Skeletal Age With Student Characteristics

Cognitive Domain

The relationship between physical maturation and mental growth has been studied extensively. One's mental ability to perform in an academic situation may be referred to as scholarly ability. This differs from one's intelligence which is inherent learning potential. Intelligence is measured by Intelligence Quotient (IQ)

tests that are of questionable validity and reliability. Therefore literature dealing with some measure of mental ability should address this difference and publish the measurement instrument used to collect data. Among those who supported the belief that late maturation correlates with poor scholarship were Porter (1893), Crampton (1908), Foster (1910), Stewart (1916) and Baldwin (1922). Stewart (1916) observed that taller and heavier boys of identical chronological ages were higher in school standings. Baldwin (1922), while involved with the Iowa Child Welfare Research Study, stated that in order to measure mental growth accurately, the physiological differences among individuals must be considered. However, Bates (1924), in searching the possibilities of grouping children for more meaningful educational experiences, discovered little association between physical and mental growth. Franzblau (1935) found no relationship between mental and physical precocity or retardation.

Many investigators have found that children who are physiologically advanced tend to score better 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, Tanner (1961) found that this difference in mental ability dissipates as the advanced and delayed maturers complete their growth.

While studying 357 children in the Laboratory Schools of the University of Chicago, Abernethy (1936) found a positive but low correlation between mental ability and physical stature. She concluded that this existing positive correlation during adolescence was due solely to the level of physical maturation. In a longitudinal investigation of 38 female subjects, Freeman and Flory (1937) discovered that the group which matured last were lower in mental ability than any of the other subjects until chronological age 17 years. At chronological age 13 years the mental ability scores of the late maturers were the same as those of the average maturers and both these groups' scores were below the early maturers' scores. Shuttleworth (1930), using data from the Harvard Growth Study, established some relationship between intelligence and early maturation. However, only a few of his comparisons were statistically significant. His resulting growth curves of early versus late maturers of average mental age from chronological age 6.5 to 18.5 years illustrated a more intense growth of the early maturers except from 13.5 to 15.5 years. A study of the data collected by Boas (1941) shows an unexpectedly high relationship between intelligence quotient and stature. Children short for their age had an intelligence quotient markedly under the norm, those tall for their age, one above the norm. Their physical and mental development appeared

to be related. Boas interpreted this close correlation between anatomical and mental traits in childhood as being due to the influence of the tempo of physiological development over the body and its functions.

A number of physiological growth measurements have been studied in relation to academic achievement. Organismic age, the average of various physiological and structural ages, was investigated by Klausmeier (1958), Blommers, Knief and Stroud (1955) and Klausmeier, Beeman and Lehman (1958). Little or no association was discovered between various physical growth parameters and intelligence in these studies. To the contrary, Millard (1958) and Olson (1959) concluded that from making use of seven different kinds of assessment of age one can be more accurate in appraising children's performance in arithmetic and language.

Motor Domain

Does physical maturation affect children's proficiency in performing motor skills tests? Generally speaking, motor performance is augmented by increases in body size, muscular strength and muscular power. Each of these components increase at puberty and quickly develop through the adolescent years. This growth enables children to cope with a wider variety of skills; therefore motor performance improves. Boys,

especially, gain in characteristics such as strength, endurance, power, and agility that probably enhance their motor abilities. These increases almost always occur during the adolescent years. With the trend toward becoming motorically efficient, girls may likewise take advantage of the benefits that accompany maturity to enhance their motor skills involving balance, flexibility and agility.

Observations of motor performance of children in the early school years are limited (Seils, 1951; Glassow, 1960; Rarick and Oyster, 1964; Malina and Rarick, 1973; Hensley and East, 1982). Considerable information is available concerning the extent of the mean performance differences between young adult males and females. Less research, however, has focused on the variations in motor performances in children (Hensley and East, 1982). It is possible that the degree of coordination achieved throughout life depends upon that of preceding years. Therefore, a study of motor performance in early school and pre-school years is not only important for understanding children at these ages but for understanding motor development through the years of physical growth to maturity. The findings in Clark (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 delayed maturity on a battery of strength tests. However, there was generally no difference between the advanced and the delayed maturity groups on the motor ability tests, which consisted solely of the 60-yard run and the standing broad jump. For this investigation, the children were categorized into maturity groups at age nine years chronologically and then followed longitudinally over a four year period within their respective groups.

When comparing the motor abilities of maturity groups during childhood, the early maturing individuals generally achieve the greatest success. Their proportionately greater muscle tissue, longer bones, and ability to coordinate movements provide them with greater power and strength than late developing individuals. Yet, the late maturers may have an advantage in body projection as well as body support skills, since they have less body weight to raise and control (Branta, 1982).

Skeletal maturity was not a major factor in the motor performance of early elementary school children in other studies (Seils, 1951; Rarick and Oyster, 1964). Yet, Seils (1951) recognized that since the contributing elements for proficient motor skills are so numerous and diverse, skeletal maturity should be provided more priority in the study of movement.

In another investigation, data from motor performance tests were examined to decide whether or not they were significantly related to skeletal maturity in nine- through twelve-year-old boys (Howell, 1979). Although he found few significant differences, there was a visual trend for the performance of the late and average maturity groups to surpass the performance of the early maturity groups. Only the motor performance scores of the nine-year-old boys were significantly related to the skeletal maturity of the subjects ($p < .05$), indicating that the best performances were associated with the late and average maturity groups as compared to the early maturity group. The standardized discriminant function coefficients indicated the jump and reach, 400-foot endurance run, and flexed arm hang were the dependent variables contributing most to the overall multivariate group effect.

The literature to date includes very little information concerning the influence of skeletal maturity of girls on motor proficiency. One study reported that the motor performance of 13- to 16-year-old females was negatively correlated with increasing skeletal maturity (Espenschade, 1940). This is understandable to an extent for this age group, since additional fat deposition as well as changes in interests and attitudes during this time period may have caused a decrease in vigorous physical activity which therefore 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 to be taller than their earlier maturing peers during adolescence, the latter group is usually not unhappy. Similarly Krogman (1962) points out that the "stamp of approval" is frequently upon earliness, bigness, maturity, and sex trait achievement, sometimes the opposite is true with girls. Femininity may be valued so highly that a tall athletic girl may see herself as an inferior human being. This suggestion of how size may potentially affect the personalities of growing males and females is only a small example of the impact physical maturation has on children. An understanding of the relationship and relative independence of chronological and skeletal ages will be a distinct advantage for anyone dealing with growing children.

Together with the associated emotional, social, sexual and personality changes, level of maturity does contribute significantly to the reputation which a female has in her social group. Faust (1960) found that girls in the sixth grade who were "in phase" in physical

maturation and girls in the seventh, eighth and ninth grade who were physically accelerated were thought to be "prestigious" by their classmates.

Personality traits of early maturing individuals contrast those of late maturing individuals. Jones and Bayley (1950) reported that the early maturing adolescent boys in their investigation were more physically attractive, matter-of-fact, and relaxed than their later maturing peers; while the latter were described as more eager, animated, active, and tense. Davidson and Gottlieb (1955) administered the Rorschach Test to 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. The means of all the scores were in the direction of greater emotional maturity for the post-menarcheal group. Mussen and Jones (1957, 1958) concluded that the socio-psychological environment of our culture may negatively affect late maturing boys, thereby generating feelings of personal inadequacy, prolonged dependency needs and rebellious attitudes towards their parents. For seventeen year old girls, early maturers have more favorable self concepts compared with their peers who were delayed in physical growth (Mussen and Jones, 1958).

Even children in our society quickly realize the importance placed on physical appearance, size and

maturity. The feelings individuals have about themselves are partially a reflection of how they feel about their physical appearances (Haywood, 1981). Zion (1965) found a significant relationship between a person's body concept and self concept and felt that physical educators should be concerned with the development of the body concept in children.

Social stereotyping by body type has been found as early as kindergarten. Staffieri (1967) and Lerner (1969) both found that desirable personality traits such as, strong, quiet, polite and happy were associated with the mesomorph somatotype, whereas socially unfavorable personality traits such as sneaky, sloppy and mean were associated with endomorph and ectomorph somatotypes. In contrast to these findings, Caskey and Felker (1971) found that in grades one to five the ectomorphic body image received the socially favorable adjectives, while the mesomorphic body image received only favorable adjectives which were related to physical strength characterisitcs. These physical attributes appeared to have a more socially positive effect among boys than among girls. Girls favor the ectomorphic body type and dislike the endomorphic shape.

Somatotype is highly stable across time because it is a growth characteristic. Early maturing or fast-growing children are more apt to be tall and heavy individuals (i.e., mesomorphic, endomorphic

characteristics), while late maturing or slow-growing children generally are short and light (i.e., ectomorphic characteristics) (Krogman, 1980). Knowing these relationships, and understanding that if stereotypic behavior is a learned response, then nonstereotypic behavior can likewise be learned. Elementary physical educators can take advantage of opportunities to alleviate those situations which reinforce stereotyping (Caskey & Felker, 1971).

Somatic Domain

Size and anatomic growth differ between late and early maturing individuals (Bayer and Bayley, 1959; Krogman, 1972). During the childhood years there is a rather steady increase in weight (5-6 lbs. annually for both sexes ages 5-7; 7-8 lbs. for boys ages 8-11, and for girls ages 8-10). Boys are slightly heavier than girls, ranging from approximately one pound at age 5 to approximately two pounds by age 9.5. Females exceed males in weight for a period of approximately 18 months, age 12.0 through 13.5. Children grow an average of 2 to 2 1/2 inches annually from age 5 until they begin their growth spurt. This therefore represents a rather steady increase in height for a time period. Boys are consistently taller than girls during the childhood years by about 1/2 to 3/4 of an inch. The mean height of the females equaled that of the

males at 12.5 years of age. However, at no age did it exceed the mean height of the males. This is in contrast to findings of other studies reported in the literature (Haubenstricker and Sapp, 1980). Individuals grow at a relatively constant rate. Typical gains in height and weight per year are 2-2 1/2 inches and 5-10 pounds respectively.

However, the earlier maturing child may grow more and the later maturing child less than these averages. This explains the increase in different body sizes and weights among youngsters of the same chronological age as they enter adolescence (Branta, 1982). Rapidly maturing children, on the average, tend ultimately to be shorter than those who mature at a slower rate. Their period of growth is shorter, and they cannot develop fast enough within this period to overcome the advantage that the later maturers have in the form of a relatively longer growth time (Johnston, 1962).

The early maturers' precocious physical growth is repeatedly supported throughout the scientific literature. Malina (1974) noted that skeletal age is positively correlated with growth changes in fat, muscle and bone tissue, resulting in early maturers having more weight per unit of height than do late maturers during adolescence. Referring to the relationship between age and sexual maturation, Marshall (1974) stated that skeletal age varied comparably to chronological age in

the prediction of initial genital or breast development. However, it was not as variable as 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 (stages defined by Tanner, 1962). Howell (1979) found that early maturing boys from 9 through 12 years of age, were consistently larger in physical size than was the average maturity group, which was likewise larger than the late maturity group. Many of these differences were statistically significant at the .05 level.

Summary

The rationale for the assessment of physiological age as a maturity indicator has been presented. The concept of skeletal age has been suggested as the most useful single procedure that is at present available for determining the developmental status of children. Crampton (1908) and Rotch (1908) were primarily responsible for recognizing a need for such a criterion and Todd (1937), Greulich and Pyle (1959), Acheson (1954, 1957), and Tanner and Whitehouse (1959) refined the standards making it possible to assess skeletal age.

Criticisms and contrasts of the various techniques for rating skeletal age were discussed. Each method has been shown to have both disadvantages and advantages. The ideal procedure for skeletal age

assessment would be to match the advantage of a particular method to the specific goals of the task at hand.

The range in skeletal development of children within the same chronological age and particularly between the sexes has been illustrated. Females are generally advanced in skeletal maturation over males at the same chronological age. Also the skeletal age range is smallest in the early period of life and increases to its greatest degree during the adolescent period.

Correlations between skeletal age and cognitive, motor, affective and somatic domains have been discovered. The relationship between skeletal age and cognitive growth appears to be controversial. Some investigators have concluded that earlier maturers are better scholars and vice versa, yet others have reported only a very slight association between the two variables. This could be due in part to the specific aspect of mental ability which was measured, such as academic achievement or intelligence, as well as the instrument used to collect the data. The positive relationship between advanced maturation and the motor domain of prepubertal children is indicated in the literature, but still awaits more concrete evidence. The findings have been that children who are maturationally advanced may have an advantage in

establishing a favorable self concept in our society, even at a very early age. In regard to physical growth, the differences between the advanced and delayed maturer are plentiful. Dissimilarities have been addressed for body composition, body size, somatotype and sexual development.

CHAPTER III

RESEARCH METHODS

The purpose of this investigation was to study the motor performance of females over a four year span of six to ten years of age who were early, average or late in skeletal development at age six. In this study longitudinal data was compared on females at six, eight and ten years of age on seven motor performance tests.

Sampling Procedures

Sample selection involved identifying those females from the Motor Performance Study (MPS) whose data were relevant to the present research. This section first describes the sample of the MPS and then the criteria by which the sub-sample was obtained.

Sample of Motor Performance Study

The MPS began in January, 1968, with an initial enrollment of 80 children in the instructional program, equally divided between males and females, ranging in age from five to eight years. Additionally, 30 children between the ages of two and four years were enrolled in a non-instructional program which provided for the semi-annual assessment of physical

growth and motor performance. In the summer of 1968 the age range was extended to include children nine and ten years of age. Concurrently, 40 children were added at the kindergarten level. Presently, children are enrolled in the skills instruction from kindergarten through seventh grade and measured starting at two years of age until their growth ceases. To date, over 1,200 children have been enrolled in the programs. The subjects are primarily white and have a socio-economic status of middle to upper class. Thus, the MPS sample consists of voluntary subjects whose parents request to enter the study, make a long-term commitment to the research program and pay to participate in the instruction program offered from kindergarten through seventh grade.

Sub-sample of the Motor Performance Study

This investigation focused on the motor performance and skeletal x-rays of females, the sub-sample was limited to those families participating in the longitudinal study from 1968 to 1975 and for whom necessary data were available. Criteria for inclusion in the sub-sample were (1) hand-wrist x-ray at age six (72-83 months) and (2) complete motor performance data at six, eight and ten years of age. The application of these criteria to the MPS data resulted in a total available sample of 95 females. From a total sample of MPS

females at chronological age six years a difference score distribution was calculated by subtracting each subject's chronological age in months from her skeletal age in months. If the difference score of a subject was within the lowest 20 percent, she was placed in the early group (n=19). If the difference score of a subject was within the middle 20 percent, she was placed in the average group (n=19). If the difference score of a subject was within the highest 20 percent, she was placed in the late group (n=19). Therefore the final sample size for data analysis was 57. The second and fourth quintiles of the original sample were not included in the final sample in an effort to maximize differences between groups.

Experimental Design

A design which consisted of one independent variable and its relationship with seven dependent variables at three successive ages was used (Table 3-1). The independent variable, skeletal maturity, was subdivided into three levels: (a) Early, (b) Average, (c) Late. The seven dependent variables were motor performance test scores, all of which yielded quantitative data as they were either measured in time or distance. These measures 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 (Appendix A).

TABLE 3-1 RESEARCH MODEL

	6 years	8 years	10 years
Early	S_1	. . . . .	. . . . .
	S_2	. . . . .	. . . . .
n=19	. . .		
	S_{19}	. . . . .	. . . . .
Average	S_{39}	. . . . .	. . . . .
	S_{40}	. . . . .	. . . . .
n=19	. . .		
	S_{57}	. . . . .	. . . . .
Late	S_{77}	. . . . .	. . . . .
	S_{78}	. . . . .	. . . . .
n=19	. . .		
	S_{95}	. . . . .	. . . . .

S = Each of the subjects in the final sample used for data analysis.

The following seven motor performance measures are recorded for each subject at each of the time periods; six, eight and ten years.

Flexed Arm Hang
Jump and Reach
Agility Shuttle Run
Standing Long Jump
30-Yard Dash
Sit and Reach
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 subjects of this study was made by Vern D. Seefeldt, Ph.D., Professor and Director of the Youth Sports Institute at Michigan State University.

Dr. Seefeldt's reliability had been established a number of times prior to this study. His assessment of the hand-wrist x-rays was established in several ways. As a graduate student at the University of Wisconsin, Professor Vern Seefeldt assisted Lawrence Rarick and Ionel Rapaport in a study of Down's Syndrome disease by assessing the hand-wrist x-rays from the Greulich and Pyle atlas (the only atlas available at the time). To determine Seefeldt's ability to assess hand-wrist x-rays his readings were compared to those of experts. He showed no systematic bias. Professor Seefeldt's test-retest correlations were .988 for 10 year old children and .997 for 14 year old children. In his doctoral dissertation, Professor Seefeldt's test-retest correlations were .978 for 9-10 year old children and .990 for 13-14 year old children. In another doctoral dissertation (Marshall, 1974) Dr. Seefeldt's test-retest correlation for 30 x-rays of adolescent males was .96.

Dr. Seefeldt uses the following method: (1) He

searches through the Greulich-Pyle atlas respective gender standards to locate the two standards between which the respective bone to be assessed fits; (2) He assesses each of the 28 sites individually and interpolates between the ages of two standards then assigns a month value to each site; (3) He averages the values assigned to the 28 sites for a skeletal age estimate.

From having established this methodology and from past experiences, Dr. Seefeldt has established himself as a skilled assessor of hand-wrist x-rays, therefore he was chosen to make the assessments on the subjects of this study.

At chronological age six years, each subject was assigned into a level of skeletal maturity (early, average, late) depending on the relationship between her chronological age and her skeletal age. The difference score was calculated for each of the subjects by subtracting her chronological age in months from her skeletal age in months. These difference scores then served to divide the subjects into skeletal maturity groups.

A difference score distribution was obtained at chronological age six years. If the difference score of a subject was within the lowest 20 percent of this sample, she was placed in the early group. If the difference score of a subject was within the middle 20 percent of this sample, she was placed in the average

group. If the difference score of a subject was within the highest 20 percent of this sample, she was placed in the late group.

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 original director of the study, Dr. Vern D. Seefeldt, had prior experience with this particular technique and assumed the responsibility of ensuring that the assessments would be made. At the time when Dr. Seefeldt was initially becoming involved with assessing hand-wrist x-rays, the Greulich-Pyle atlas was the only set of standards available to him. He has chosen to remain with this atlas which he finds relatively familiar to him and efficient to administer. Also, there is a lack of supportive evidence that other atlases are superior to the Greulich and Pyle atlas. Hand-wrist x-rays were taken annually beginning in January 1968 with the inception of the study and continued until the summer of 1975, when it became financially impractical to obtain the x-rays.

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 early group, for instance, may have been born on July 30, 1963 and x-rayed and tested on June 30, 1970. In this case they would be considered six years of age; however, their skeletal age would be expected to be advanced for six year olds, because chronologically they were almost within the span considered to be seven 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. However, it can be noted from Table 3-2 that the mean chronological age in months of each group is identical to the others (77.79 months).

When assessing motor performance, the testing conditions, facilities, subject motivation and technician treatment are considered as possible confounding variables. The Motor Performance Study has attempted to minimize these potential problems. Subject motivation or desire remained the most difficult factor to control. Technicians were instructed to encourage verbally each subject being tested but some subjects responded more favorably to the positive verbal reinforcement than others. The technicians were trained prior to, and utilized written instructions throughout each testing period.

TABLE 3-2 DESCRIPTIVE STATISTICS OF CHRONOLOGICAL AGE AND SKELETAL AGE FOR THE LEVELS (GROUPS) OF THE INDEPENDENT VARIABLE

		Chronological Age			Skeletal Age		
Group	N	$\bar{X}$ Months	s.d.	Range	X Months	s.d.	Range
Early	19	77.79	3.09	11.00	86.58	4.97	16.79
Average	19	77.79	2.97	8.00	75.08	2.78	9.10
Late	19	77.79	3.24	11.00	60.93	6.66	28.63

Dependent Variables

The dependent variables for this investigation were the seven motor performance measures which have been accumulated in the Motor Performance Study at Michigan State University (Appendix A).

Flexed Arm Hang: The flexed arm hang is a measure of arm and shoulder girdle strength and endurance (Johnson and Nelson, 1974; Barrow and McGee, 1971). The validity of the test is generally accepted, and the reliability of the test has been reported as high as .90 for college students (Johnson and Nelson, 1974). No validity or reliability coefficients have been reported for females six to ten years of age on the Flexed Arm Hang.

Jump and Reach: The jump and reach is a modification of the Sargent Jump (Sargent, 1921) designed to measure power of the legs while jumping vertically (Clarke, 1967; Johnson and Nelson, 1974). Correlations of reliability have been reported as high as .98 which was determined on high school girls (Cooper, 1945). When elementary school children were evaluated, the test-retest reliability coefficients ranged between .75 and .96 (Seils, 1951; Johnson, 1962). In comparison with track and field events, validity coefficients for males have ranged from .65 to .85 with slightly lower correlations for females (Adams, 1934; Clarke, 1967).

Agility Shuttle Run: The agility run measures

speed and agility (Barrow and McGee, 1971). When elementary school children were evaluated, the test-retest reliabilities ranged from .59 for third graders to .73 for first graders (Keogh, 1965). With modified agility runs, reliability coefficients have ranged from .79 to .95 (Seils, 1951; Latchaw, 1954; Johnson, 1962).

Standing Long Jump: The standing long jump is designed to measure leg power for a horizontal jump (Clarke, 1967; Barrow and McGee, 1971; Johnson and Nelson, 1974). In comparison to a pure power test, a validity coefficient of .607 has been reported (Johnson and Nelson, 1974). Reliability coefficients for within-day successive trials on college, high school and elementary school females have ranged from .77 to .90 (Scott and French, 1959; Glassow and Kruse, 1960; Hanson, 1965). When elementary school children were evaluated, the test-reliability correlations ranged from .77 to .91 (Seils, 1951; Kane and Meredith, 1952; Keogh, 1965).

30-Yard Dash: The dash is a measure of speed (Barrow and McGee, 1971; Johnson and Nelson, 1974). The validity of the test is generally accepted. When elementary school children were evaluated, the test-retest reliabilities ranged from .85 for third graders to .86 for first graders (Keogh, 1965). Glassow and Kruse (1960) reported within-day reliability correlation coefficient of .85 or greater for females 6 to 14 years. Test-retest coefficients for the 30-yard dash have been

reported ranging from .57 to .86 (Seils, 1951; Keogh, 1965).

Sit and Reach: No validity or reliability coefficients have been reported for the Wells Sit and Reach.

400-Foot Endurance Shuttle Run: No validity or reliability coefficients have been reported for the 400-foot Endurance Shuttle Run.

The investigator acknowledges the lack of validity and reliability coefficients for the seven motor performance tests particularly for females six to ten years of age. However, those values available in the literature for female samples whether they be elementary, high school or college age have been reported in this study.

Conduct of Treatments

Protocol for the semi-annual measurements involved several steps. In early December and June of each year the children's parents were contacted via telephone to set up an appointment for testing. The subjects were asked to report at a specific time and to bring their bathing suits to be worn when the measurements were taken. Qualified personnel perform the various physical growth assessments before the children were sent to a gymnasium to be measured on the motor performance tasks. With three trained technicians in the growth laboratory and three trained technicians in the motor performance laboratory, approximately 100 children were measured

during the five hour period.

There were always a number of subjects who were not available during the designated measurement period. Illnesses, vacation trips, work, injuries or other scheduled events kept these children from their semi-annual appointments. There was always an effort put forth in the following month to contact and measure each of the subjects who, for one reason or another, were unavailable during the designated measurement period. Despite these efforts, there were a number of children for whom no data were collected at any one measurement period. These incomplete data sets resulted in eliminating ten potential subjects from this study.

Measurement Equipment and Procedures. The motor performance tests required that two devices for measurements be available, one for timed events, the other for linear measurements. 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 by trained personnel using a recording form. Each technician was provided verbal and written instructions indicating the methods to be used for

measurement and recording. In addition, the technicians were given on-the-job training from an experienced tester. Tester reliability was not obtained. A form was provided for each subject on which the scores were reported (Appendix B) before being transferred to permanent data records (Appendix C).

Procurement of Motor Performance Data. The data for the dependent variables for this study were collected at six month intervals in the summer and winter from 1968 to 1975. The measurements were always performed under the leadership of a faculty member in the area of Motor Development within the Department of Health and Physical Education at Michigan State University. Data were collected by faculty members, graduate students and/or paid technicians.

Research Design

The study used an Ex Post Facto design. The skeletal age of subjects were used to assign them to maturity groups, after their motor performance scores had been recorded. Table 3-1 is a diagram of the design matrix for the multivariate analysis which was used. This multivariate analysis treated the seven motor performance tests as dependent variables.

Processing the Data

After obtaining all the data, additional steps were followed to ensure accurate analyses. This section will

outline the preparation of the maturity data, the techniques of preparing the motor performance data, and finally, the statistical analysis procedures.

Preparation of Data on Maturity Status

Fifty-seven subjects were selected from the 95 subjects available for this study, nineteen each of early, average and late. These groups were based on skeletal maturity at chronological age six (72-83 months).

Skeletal ages (in months) at chronological age six years were obtained from the original x-ray assessment sheet, attached to the x-ray and stored in each subject's folder. Chronological ages (in months) were calculated from the subject's birthdate on file. The difference between a subject's chronological age (in months) and her skeletal age (in months) at six years determined her maturity status. Once identified as an early, average and late maturer this status was held constant for each of the comparisons between the groups on motor performance at ages six, eight and ten years.

After recording the skeletal ages a t-test was used to evaluate whether or not they were significantly different from the skeletal ages of girls in the Brush Foundation Study (Greulich and Pyle, 1950). The results are presented in Table 3-3. This test for a difference between samples indicated a significant difference did exist (t value 3.66, $p > .05$). Therefore an alternate

method was found for assigning individuals to maturity levels to that suggested in the Greulich-Pyle atlas (± 1 standard deviation from the mean).

A subject was considered to be in the average group if her difference score, obtained by subtracting her chronological age from her skeletal age, was within the middle 20 percent (-5.50 to -0.75) of the difference scores distribution at chronological age six. The subjects of the early group had difference scores in the upper (positive) 20 percent (3.48 to 19.29) of the distribution and the late group had difference scores in the lower (negative) 20 percent (-30.88 to -11.82) of the distribution.

TABLE 3-3 COMPARISON OF SKELETAL AGE FOR FEMALE SUBJECTS AT CHRONOLOGICAL AGE SIX YEARS (72 MONTHS) OF THE BRUSH FOUNDATION STUDY AND THE MOTOR PERFORMANCE STUDY

	Chronological Age	No. of Hand-Films	Skeletal Age (in months) Mean	s.d.
Brush Foundation Sample	72 mos.	67	70.4	9.0
Motor Performance Sample	72 mos.	95	74.1	9.8

t = 3.66* Critical t = 1.99

*Significant at the .05 level.

<u>Preparation of Data on Motor Performance</u>

Following each measurement period, all data were placed on Hollerith cards, verified, and stored on a

permanent file on the Michigan State University Control Data Corporation 6500 (CDC 6500). The appropriate subset of the data for this study was selected using routines from the Statistical Package for the Social Sciences (SPSS). Seven steps were employed in preparing the data for analysis using the program MULTIVARIANCE (Finn, 1980).

1. Data was cataloged into a permanent file. Sample size equaled 95.
2. Permanent file printout was checked for missing values and/or errors.
3. Subjects' difference ages were computed and descriptive statistics were computed.
4. A t-test was run to test the null hypothesis that the Motor Performance Study sample was not significantly different from the Brush Foundation Study sample. The null hypothesis was rejected.
5. The highest, middle and lowest 20 percent of the difference score distribution was determined to represent the early, average and late maturity groups respectively.
6. Early, average and late maturity groups, were computed and stored in a permanent file. Sample size equaled 57.
7. Permanent file printout was checked for missing values and/or errors.

Procedures for Statistical Analyses

A multivariate analysis (MANOVA) with repeated measures was conducted to determine whether there were significant differences between the three maturity levels at six, eight and ten years on the dependent variables. When the multivariate F test was significant, univariate F tests were obtained to determine which dependent variable contributed most to differentiating among the groups. The criterion level for this and for all other statistical tests performed was $p \leq .05$. In this investigation a Type I error was not of vital consequence, and the .05 level agrees with that which is commonly used in educational research. Upon evidence of significant univariate F's, Scheffe post hoc tests were used to evaluate differences between means.

Summary

A longitudinal design was employed to study skeletal maturity and motor performance of fifty-seven females. The subjects were a sub-sample chosen from individuals in the MPS. Measurements were taken at three successive two year intervals on seven indices of motor performance. Subjects were categorized by skeletal age at age six into early, average, or late maturers. Skeletal data were obtained via hand-wrist x-rays assessed by the Greulich-Pyle atlas (1959). After

the subject data were obtained, processed and checked, they were subjected to multivariate analysis to determine differences among maturity levels.

CHAPTER IV

RESULTS AND DISCUSSION

This study was undertaken to determine whether females when classified as early, average and late maturers by their skeletal age at six years, would differ from each other on selected measures of motor performance at six, eight and ten years of age. Additionally this research effort analyzed age differences in motor performance ability. In this chapter, the results from the multivariate analysis will be presented and examined in relationship to the three maturity groups.

Mean chronological ages and mean skeletal ages along with the sample size for each group were reported in Table 3-2. It can be noted that the mean chronological age in months of each of the groups was identical.

Multivariate Analysis

The aim of this investigation was to examine the relationship, if any, between skeletal maturity and motor performance ability. The divisions of the independent variable, skeletal maturity, were explained at the beginning of Chapter III under the heading "Experimental Design." The seven dependent variables

included: (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. A description of these motor performance tests is provided in Appendix A.

Due to the correlation between these dependent variables and the longitudinal nature of this study, a multivariate analysis of variance (MANOVA) with repeated measures was considered to be the appropriate initial form of analysis. The following is a report of the findings.

Descriptive statistics on the samples' motor performance data are presented in Table 4-1a and Table 4-1b. In Table 4-1a are the mean, standard deviation and range for the Flexed Arm Hang, Jump and Reach, and Agility Shuttle Run for each maturity group at six, eight, and ten years of age. Similarly in Table 4-1b are the mean, standard deviation and range for the Standing Long Jump, 30-Yard Dash, Sit and Reach, and 400-Foot Endurance Shuttle Run for each maturity group at six, eight, and ten years of age. These values are plotted in Figure 4-1.

TABLE 4-1a DESCRIPTIVE STATISTICS OF THE DEPENDENT VARIABLES FOR EACH MATURITY GROUP FOR SIX, EIGHT AND TEN YER OLD FEMALES

Age	Maturity	N	Flexed Arm Hang (Seconds)			Jump and Reach (Seconds)			Agility Shuttle Run (Seconds)		
			Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range
6	Early	19	12.95	8.40	29.00	7.16	1.83	7.50	14.55	1.78	5.90
	Average	19	10.42	5.78	20.00	6.71	1.69	6.00	14.46	2.32	10.20
	Late	19	10.84	8.57	36.00	6.92	1.61	6.00	14.42	1.92	6.70
Total		57	11.40	7.63		6.93	1.69		14.48	1.98	
8	Early	19	13.95	9.74	34.00	9.37	2.05	7.00	12.93	1.07	4.30
	Average	19	13.74	14.26	63.00	8.61	1.36	6.00	12.63	1.14	4.30
	Late	19	15.37	10.20	35.00	9.74	1.90	6.50	12.43	.92	3.90
Total		57	14.35	11.39		9.24	1.83		12.66	1.05	
10	Early	19	18.21	12.02	36.00	11.66	2.41	9.00	11.66	1.00	4.10
	Average	19	14.05	11.80	47.00	10.37	1.78	7.50	11.64	.87	3.40
	Late	19	16.68	14.27	59.00	10.92	1.95	8.00	11.70	.85	3.50
Total		57	16.32	12.64		10.98	2.09		11.67	.89	

TABLE 4-1b DESCRIPTIVE STATISTICS OF THE DEPENDENT VARIABLES FOR EACH MATURITY GROUP FOR SIX, EIGHT AND TEN YEAR OLD FEMALES

Age	Maturity	N	Standing Long Jump (Seconds)			30-Yard Dash (Seconds)			Sit and Reach (inches)			400-foot Endurance Shuttle Run (inches)		
			Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range
6	Early	19	42.71	8.26	33.50	5.66	1.55	8.00	8.77	2.24	9.00	49.53	6.19	24.50
	Average	19	40.45	6.20	24.50	6.11	.64	2.20	8.16	2.75	11.50	49.40	6.90	26.10
	Late	19	41.63	8.87	33.00	5.84	1.60	7.70	7.68	2.84	12.50	49.61	7.59	31.30
Total		57	41.60	7.78		5.87	1.33		8.20	2.61		49.51	6.48	
8	Early	19	52.16	8.21	29.00	5.25	.49	1.80	9.16	1.97	8.50	44.64	3.45	14.20
	Average	19	51.03	6.72	22.00	5.41	.41	1.80	9.31	1.84	7.00	44.44	3.72	12.30
	Late	19	50.61	7.63	33.00	5.33	.45	1.60	9.05	2.13	8.00	44.78	4.30	17.60
Total		57	51.26	7.44		5.33	.45		9.18	1.95		44.62	3.77	
10	Early	19	61.87	6.50	25.00	4.89	.45	1.60	9.74	2.52	11.00	40.66	2.96	12.00
	Average	19	58.00	6.22	25.00	5.00	.31	1.10	8.87	2.79	10.00	41.62	2.94	11.20
	Late	19	58.84	7.73	29.00	4.99	.51	2.20	9.29	2.29	7.50	41.75	3.25	14.60
Total		57	59.57	6.93		4.96	.43		9.30	2.52		41.31	3.04	

FIGURE 4-1 TEST MEANS FOR THE MOTOR PERFORMANCE MEASUREMENTS OF THE MATURITY GROUPS AT SIX, EIGHT AND TEN YEARS OF AGE

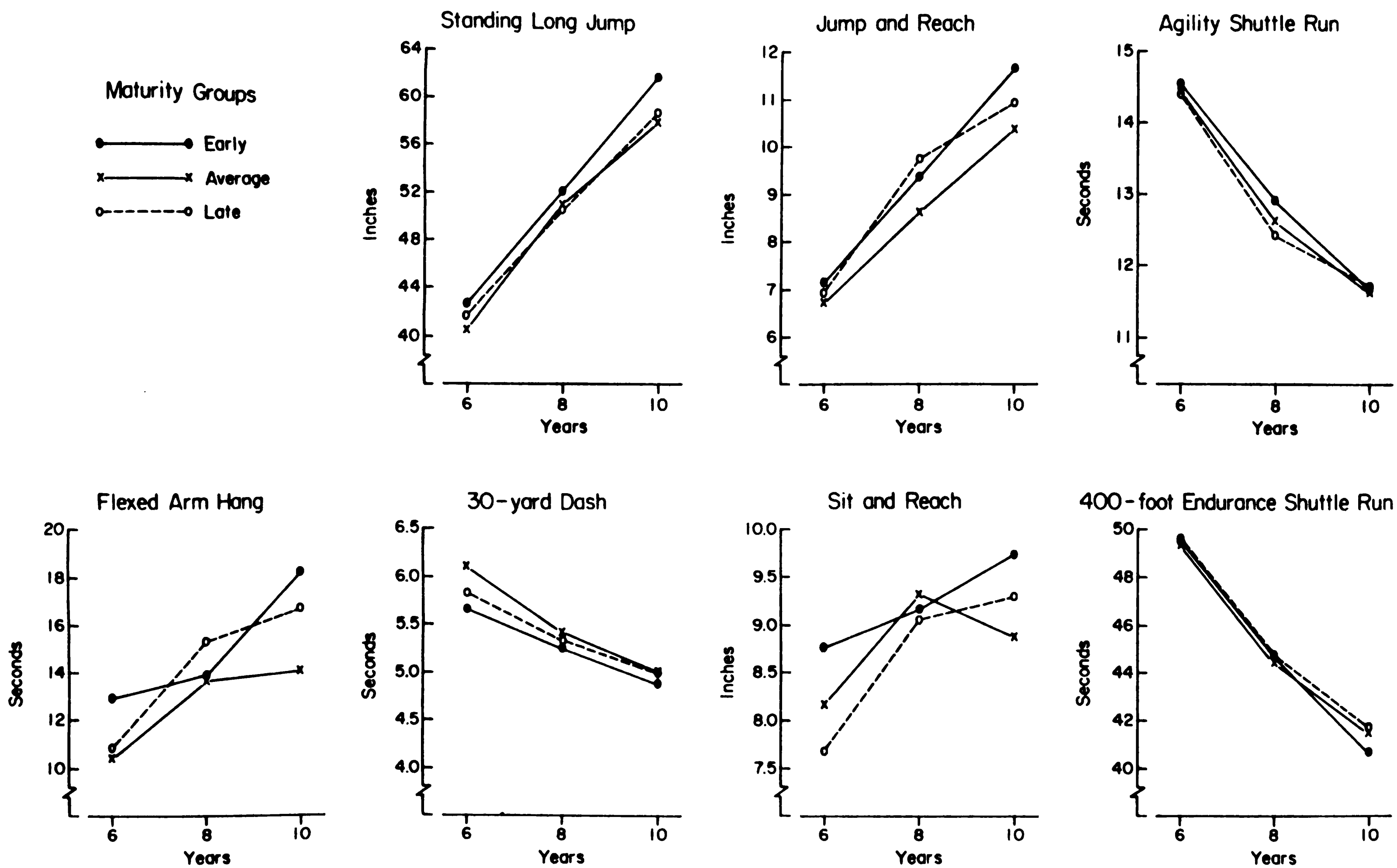

TABLE 4-2: MULTIVARIATE F AND UNIVARIATE F RESULTS FOR THE MOTOR PERFORMANCE MEASUREMENTS OF MATURITY GROUPS

	Mult F	Sig of F	Univ F	Sig of F
Groups				
Early vs. Else	1.43	.22		
Average vs. Late	.42	.89		
Time				
Linear	78.62	.00		
Jump and Reach			339.22	.00
Agility Shuttle Run			130.47	.00
Standing Long Jump			475.40	.00
30-yard Dash			25.05	.00
Flexed Arm Hang			14.41	.00
Sit and Reach			10.61	.00
400-foot Endurance Run			121.91	.00
Quadratic	2.67	.02		
Jump and Reach			2.63	.11
Agility Shuttle Run			11.66	.00
Standing Long Jump			1.28	.26
30-yard Dash			.94	.34
Flexed Arm Hang			.20	.65
Sit and Reach			4.13	.05
400-foot Endurance Run			1.69	.20
Group By Time Interaction				
Linear	.41	.97		
Quadratic	.84	.62		

The MANOVA results are presented in Table 4-2 and revealed that the Group main effect, $F(14, 96) = 0.90$, $p > 0.56$ was not significant. Overall the early group did not perform significantly different from the average and late groups combined. Likewise, the average group did not perform significantly different from the late group. The Time main effect, for the linear function, $F(7, 48) = 78.62$, $p < .0001$ and for the quadratic function, $F(7, 48) = 2.6702$, $p < .0204$ were both significant. This means that the females, ten years of age performed significantly better on the seven motor performance tests than the females, eight years of age who performed significantly better than the females, six years of age, but the trend included a curvilinear component. The Group by Time interaction for the linear function, $F(14, 96) = .4078$, $p > .9693$ and for the quadratic function, $F(14, 96) = .8437$, $p > .6208$ were both not significant. Therefore the early, average and late groups were not significantly different at six, eight or ten years, nor did this lack of difference change over the four year time span.

Group Main Effect

There was no statistically significant multivariate group effect for the maturity groupings ($p < .05$). Therefore, no univariate follow-up statistics were appropriate. As a result little inferences could

be made with authority about differences in motor performance measurements between maturity levels.

There were a few trends apparent in Figure 4-1 that deserve mention:

1. The early group performed better than the late group which performed better than the average group in the 30-yard dash for each of the three age divisions.
2. The early group performed better than the late group which performed better than the average group in the flexed arm hang, jump and reach and standing long jump at six and ten years of age.
3. The late group performed better than the average group which performed better than the early group in the agility shuttle run, especially for the six-year-old and eight-year-old age divisions.

Time Main Effect

A statistically significant multivariate time main effect was found for time. Table 4-2 reveals the results obtained for the linear and quadratic functions from the various inferential statistics utilized.

All seven dependent variables had univariate *F* values which were statistically significant at the .05 level. Three of the seven, the jump and reach, agility shuttle run and standing long jump, also had step-down *F* values which were statistically significant at the .05 level. It must be remembered that the step-down *F*

analysis is highly dependent on the *a priori* ordering of the dependent variables. In this case the three variables which proved to be significant were also the three that played an important role in producing the overall multivariate group effect.

When plotted (Figure 4-1), the means for all seven dependent variables illustrate this significant linear trend over time, indicating an improvement in motor performance ability from six to eight to ten years of age. This is especially noted for the agility shuttle run, standing long jump, 30-yard dash and 400-foot endurance run.

Summary

In order to study the relationship between skeletal maturity and motor performance ability of six-, eight-, and ten-year-old females, three groups of subjects were chosen from a non-random sample of 95 subjects. The groups were categorized as early, average or late with respect to their skeletal maturity at chronological age six. The division of the groups was such that the mean chronological age in months for each of the groups was identical. The skeletal ages of the subjects were distributed such that the most skeletally mature 20 percent of the sample were in the early group, the least skeletally mature 20 percent of the sample were in the late group and the middle 20 percent

of the sample were in the average group.

Data from seven motor performance tests were examined to determine if they were significantly related to skeletal maturity. Although the maturity status was not statistically significant, a visual trend was apparent for the early maturity group and the late maturity group to perform better than the average maturity group especially for the six- and ten-year-olds. The motor performance scores showed a statistically significant linear trend when analyzed over the time period from six to ten years of age ($p < .05$). However, the Group by Time interaction was not statistically significant.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

This study investigated the common assumption that the most physically mature individuals within a chronological age are likely to possess the greatest proficiency in selected motor tests. The hypothesis was that the early maturity group would perform significantly better than the late maturity group on the following tests: jump and reach; agility shuttle run; standing long jump and 30-yard dash ($p < .05$). Early maturers characteristically possess the physiological advantages to excel at items which test power, speed and agility. The second hypothesis was that the three groups would not be significantly different in their performance on the flexed arm hang, sit and reach and 400-foot endurance run. The literature does not provide substantial evidence to suggest which of the three maturity groups would have the advantage on these tests. Finally, significant age differences were expected in the jump and reach, agility shuttle run, standing long jump and 30-yard dash. As age increases there would be expected gains in power, speed and agility.

The findings revealed that within the age range of

six- to ten-year-old females the first hypothesis was generally not supported in this study. Statistically significant differences between skeletal maturity and motor performance were not found for the analysis ($p > .05$). The author was aware that the small group size (n=19) and other potential factors of bias could account for not finding statistical significance.

Although statistical significance between skeletal maturity and motor performance was not obtained, it is worthwhile analyzing the data from a practical standpoint. The following points may be inferred from Figure 4-1. The order of the first hypothesis i.e., the early maturers would perform better than the average maturers who would perform better than the late maturers was substantiated by; the six-year olds in the Sit and Reach, the eight-year-olds in the Standing Long Jump and the ten-year olds in the 400-foot Endurance Shuttle Run. The early maturers were the best performers of all three age groups in the Standing Long Jump and the 30-Yard Dash. With the exception of the Sit and Reach it appears that the early maturers achieve the most success in running and jumping tasks. This may be explained by the following advantages characteristic of early maturers: greater muscle mass, longer bones and the ability to coordinate movements. The early maturers can produce greater power and speed than their later developing peers.

When considering all seven of the motor performance tests at the three ages, there were 21 possible first place positions. Of these 21 positions the early maturers were the best performers in 13 and the average and late maturers were the best performers in four each. Although statistical significance was not found, visual inspection of the group's performances show that the early maturers appear to be the better performers.

On four motor performance tests: Jump and Reach, Agility Shuttle Run, Standing Long Jump and 30-Yard Dash, it was hypothesized that the early maturing group would perform best. At the three time periods, six, eight and ten years of age the early maturers were the best on eight of the twelve items i.e., four motor performance tests at three time periods. This, however, was not the case on the agility shuttle run, where the early maturing group was never the best performer.

Recommendations

This investigation did not statistically support a significant relationship between skeletal maturity and performance on the seven motor skills, however a few factors which may have confounded the results deserve mention.

Cell Size: In order to keep the early and late maturity groups at the extremes of the distribution, only the subjects who were in the upper, middle or

bottom 20 percent respectively were used in the study. This reduced the potential sample size from 95 to a non-random sample of 57 subjects. This limited the cell sizes to smaller numbers i.e., n=19 for each of the three groups (Table 4-1). With small cell sizes means can be more dramatically effected by extreme scores, making statistical significance more difficult to obtain. However this grouping procedure made the three groups more homogeneous and resulted in equal cell size, two factors that increase the power of the test. Therefore it is recommended for future research that a larger, randomized sample be chosen.

Skeletal Maturity: Can skeletal maturity be used as a sole predictor of differing motor abilities for early, average and late maturing females? Perhaps in combination with another measure such as somatic growth this could be true. Size and bodily growth had been mentioned in Chapter II as obvious differing characteristics between late and early maturing individuals. Hence certain advantages may be afforded to one group for specific motor skills.

This study categorized a female into the early maturing group if the difference between her skeletal age and chronological age was in the upper 20 percent of the distribution at chronological age six years for this group. It may be that the population of females 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. It may be that a female identified as an early maturer at chronological age six by a hand-wrist x-ray may not be classified as an early maturer at chronological ages eight and ten if hand-wrist x-rays were available for those ages. Thus establishing maturity at only one age may have contributed to not finding significance at the other ages. It is recommended that this study be replicated and x-rays be secured for each time period so maturity may be established at each time period.

Summary

The relationship between skeletal maturity and motor ability is still debatable. This study lends support to the notion that skeletal maturity by itself is not of major importance with regard to selected items of movement as examined through seven motor performance tests for these age groups. A definitive explanation of a positive relationship between skeletal maturity and skillful performance could not be made on the basis of these data. Further research is needed to more fully explain this relationship.

There is a strong relationship between skeletal maturity and physical growth. There is also a possibility that longer bones and greater muscle mass

enhance the probability of becoming a superior performer. These relationships deserve in-depth examination.

Specific criteria for grouping students for optimal learning has not been established. More research is needed to determine which characteristics of children correlate highly with the ability to learn and perform motor skills. With this in mind, it is recommended that a longitudinal study of elementary females be conducted in which a randomized sample can be chosen, with cell sizes greater than n=19 and finally, that hand-wrist x-rays be available at each age being studied. Therefore maturity status can be assigned separately at each age group and not be dependent on a single measure as used in this study. It might also be advisable to study children more representative of the general population.

BIBLIOGRAPHY

BIBLIOGRAPHY

Abernethy, E.M. Relationships between mental and physical growth. Monographs of the Society for Research in Child Development, 1936, 9 (7), 1-80.

Acheson, R.M. A method of assessing skeletal maturity from radiographs. Journal of Anatomy, 1954, 88, 498-508.

Acheson, R.M. The Oxford Method of assessing skeletal maturity. Clinical Orthopaedics and Related Research, 1957, 10, 19-39.

Acheson, R.M., Fowler, G., Fry, E.I., Jones, M., Koski, K., Urbano, P., & vander Werfften Bosch, J.J. Studies in the reliability of assessing skeletal maturity from x-rays. Part 1: Greulich-Pyle Atlas. Human Biology, 1963, 35, 317-349.

Acheson, R.M., Vicinus, J.H., & Fowler, G.B. Studies in the reliability of assessing skeletal maturity from x-rays. Part II: The bone specific approach. Human Biology, 1964, 36, 211-228.

Acheson, R.M., Vicinus, J.H., & Fowler, G.B. Studies in the reliability of assessing skeletal maturity from x-rays. Part III: Greulich-Pyle Atlas & Tanner - Whitehouse Method contrasted. Human Biology, 1966, 38, 204-218.

Adams, E.C. The study of age, height, weight and power as classification factors for junior high school girls. Research Quarterly, 1934, 5(2), 95-100.

Anderson, E. Skeletal maturation of Danish school children in relation to height, sexual development and social conditions. Acta Paediatric Scandanavia Supplemental, 1968, 185, 1-133.

Baer, M.J. & Durkatz, J. Bilateral symmetry in skeletal maturation of the hand & wrist: A roentgenographic analysis. American Journal of Physical Anthropology, 1957, 15, 181-195.

Baldwin, B.T. The relation between mental and physical growth. Journal of Educational Psychology, 1922, 13, 193-203.

Barrow, H.M., & McGee, R. A Practical Approach to Measurements in Physical Education. Philadelphia: Lea and Febiger, 1971.

Bayer, L.M., & Bayley, N. Growth Diagnosis. Chicago: The University of Chicago Press, 1959.

Bayley, N., & Pinneau, S.R. Tables for predicting adult height from skeletal age: Revised for use with Greulich-Pyle hand standards. Journal of Pediatrics, 1952, 40, 423-441.

Boas, F. The relation between physical and mental development. Science, 1941, 93, 339-342.

Branta, C.F. Physical growth and motor performance. Journal of Physical Education, Recreation and Dance, 1982, 53(5), 38-40.

Bruning, J.L., & Kintz, B.L. Computational Handbook of Statistics (2nd ed.). Illinois: Scott, Foresman & Co., 1977.

Carter, T.M. Technique and devices used in radiographic study of the wrist bone of children. Journal of Educational Psychology, 1926, 17, 237-247.

Caskey, S.R. Effects of motivation on standing broad jump performance of children. Research Quarterly, 1968, 39, 54-59.

Caskey, S. and Felker, D. Social Stereotyping of Female Body Image by Elementary School Girls. Research Quarterly, 1971, 52: 251-255.

Cattell, P. Preliminary report on the measurement of ossification of hand and wrist. Human Biology, 1934, 6, 454-471.

Clarke, H.H. Application of Measurement to Health and Physical Education. Englewood Cliffs, NJ: Prentice - Hall Inc., 1967.

Clarke, H.H. Physical and Motor Tests in the Medford Boys' Growth Study. Englewood Cliffs, NJ: Prentice - Hall Inc., 1971.

Clarke, H.H., & Harrison, J.C.E. Differences in physical and motor traits between boys of advanced, normal and retarded maturity. Research Quarterly, 1962, 33, 13-25.

Clarke, H.H., & Petersen, K.H. Contrast of maturational, structural and strength characteristics of athletes and nonathletes 10 to 15 years of age. Research Quarterly, 1961, 32(2), 163-176.

Crampton, C.W. Influence of physical age on scholarship. Psychological Clinics, 1908, 1, 115-120.

Crampton, C.W. Physiological age - a fundamental principle. Child Development, 1944, 15, 1-52.

Davidson, H.H., & Gottlieb, L.S. The emotional maturity of pre-and post-menarcheal girls. Journal of Genetic Psychology, 1955, 86, 261-266.

Dreizen, S., Sperakes, C.N. & Stone, R. E. A comparison of skeletal growth and maturation in undernourished and well-nourished girls before and after menarche. The Journal of Pediatrics, 1967, 70, 256-263.

Eckert, H.M. Age Changes in Motor Skills. In G. Rarick. Physical Activity Human Growth and Development. New York: Academic Press, 1973, 154-175.

Espenschade, A. Motor performance in adolescence. Monographs of the Society for Research in Child Development, 1940, 5(24), 1-126.

Faust, M.S. Development maturity as a determinant in prestige of adolescent girls. Child Development, 1960, 31, 173-184.

Finn, J.D. Multivariance VI Univariate and Multivariate analysis of variance, covariance, regression and repeated measures. Chicago: National Educational Resources, 1980.

Flecker, H. Time of appearance and fusion of ossification centers as observed by roentgenographic methods. American Journal of Roentgenology, 1942, 47, 97-159.

Flory, C.D. Osseous development in the hand as an index of skeletal development. Monographs of the Society for Research in Child Development, 1936, 1, 1-141.

Freeman, F.N., & Carter, T.M. A new measure of the development of the carpal bones and its relation to physical mental development. Journal of Educational Psychology, 1924, 15(5), 257-270.

Freeman, F.N., & Flory, C.D. Growth in intellectual ability as measured by repeated tests. Monographs of the Society for Research in Child Development, 1937, 2(2), 1-75.

Frisancho, A.R., Garn, S.M, & Rohmann, C.G. Age at menarche: a new method of prediction and retrospective assessment based on hand x-rays. Human Biology, 1969, 41, 42-50.

Frisch, R.E. A method of prediction of age at Menarche from height and weight at ages 9 through 13 years. Pediatrics, 1974, 53,(3), 384-390.

Fry, E.I. Assessing skeletal maturity: comparison of the atlas and individual bone technics. Nature, 1968, 220, 496-497.

Fry, E.I. Skeletal age by guess and by Tanner II, large sample analysis. American Journal of Physical Anthropology, 1966, 25, 202-206.

Glassow, R.B., & Kruse, P. Motor performance of girls age 6 to 14 years. Research Quarterly, 1960, 31, 426-433.

Greulich, W.W. The rationale of assessing the developmental status of children from roentgenograms of the hand and wrist. Child Development, 1950, 21, 33-44.

Greulich, W.W., & Pyle, S.I. Radiographic Atlas of Skeletal Development of the Hand and Wrist. Stanford, CA: Stanford University Press, 1950.

Greulich, W.W., & Pyle, S.I. Radiographic Atlas of Skeletal Development of the Hand and Wrist (Ed. 2). Stanford, CA: Stanford University Press, 1959.

Hansman, C.F., & Maresh, M.M. A longitudinal study of skeletal maturation. American Journal of Diseases in Children, 1961, 101, 305-321.

Hanson, M.R. Motor performance testing of elementary school age children. Microcard. University of Washington: Seattle, 1965.

Harris, R.J. A Primer of Multivariate Statistics. New York: Academic Press, 1975.

Haubenstricker, J.L. Motor performance testing. Personal communication. 1975.

Haubenstricker, J.L. and Sapp, M.M. A Longitudinal Look at Physical Growth and Motor Performance: Implications for Elementary and Middle School Activity Programs. Paper presented at AAHPERD National Convention, Detroit, MI 1980.

Haywood, K.M., & Loughrey, T.J. Growth and development implications for teaching. Journal of Physical Education and Recreation, 1981, 52, 57-58.

Hellebrandt, F.A., Rarick, G.L., Glassow, R., & Carns, M.L. Physiological analysis of basic motor skills. American Journal of Physical Medicine, 1961, 40, 14-25.

Hensley, L.D., Whitfield, B.E., & Stillwell, J.L. Body fatness and motor performance during pre-adolescence. Research Quarterly, 1982, 53, 133-140.

Hewitt, D., & Acheson, R.M. Some aspects of skeletal development through adolescence. American Journal of Physical Anthropology, 1961, 19, 333-343.

Hoerr, N.L., Pyle, S.I., & Francis, C.C. Radiographic Atlas of Skeletal Development of the Foot and Ankle. Springfield: C.C. Thomas, 1962.

Howell, R.D. The relationship between motor performance, physical growth, and skeletal maturity in boys nine through twelve years of age. Microcard. University of Oregon, Eugene, 1979, 1-99.

Johnson, B.L., & Nelson, J.L. Practical Measurements for Evaluation in Physical Education. Minneapolis, MN: Burgess Publishing Co., 1974.

Johnson, R.D. Measurements of achievement in fundamental skills of elementary children. Research Quarterly, 1962, 33, 94-103.

Johnston, F.E. The concept of skeletal age. Clinical Pediatrics, 1962, 1(3), 133-144.

Johnston, F.E., Dorst, J.P., Kuhn, J.P., Roche, A.F., & Davila, G.H. Reliability of skeletal age assessments. American Journal Roentgenology, Radiological Therapy and Nuclear Medicine, 1973, 118, 320-327.

Jones, H.E. Motor Performance and Growth. Berkeley: University of California Press, 1949.

Jones, M.C. The later careers of boys who were early- or late-maturing. Child Development, 1957, 28, 113-128.

Jones, M.C., & Bayley, N. Physical maturing among boys as related to behavior. Journal of Educational Psychology, 1950, 41, 129,148.

Jones, M.C., & Mussen, P.H. Self conceptions, motivations and interpersonal attitudes of early - and late-maturing girls. Child Development, 1958, 29, 491-501.

Kane, R.J., & Meredith, H. Ability in the standing broad jump of elementary school children 7, 9 and 11 years of age. Research Quarterly, 1952, 23, 198-208.

Keogh, J. Motor performance of elementary school children. Microcard Monograph. Department of Physical Education. University of California, Los Angeles, 1965.

Klausmeier, H.J. Physical, behavioral and other characteristics of high - and lower - achieving children in favored environments. Journal of Educational Research, 1958, 51, 573-581.

Klausmeier, H.J., Beeman, A., & Lehman, I.J. Comparison of organismic age and regression equations in predicting achievements in elementary school. Journal of Educational Psychology, 1958, 49(4), 182-186.

Koski, K., Haataja, J., & Lappalainen, M. Skeletal development of the hand and wrist in Finnish children. American Journal of Physical Anthropology, 1961, 19, 379-382.

Krogman, W.M. Child Growth. Ann Arbor, Michigan: The University of Michigan Press, 1980.

Krogman, W.M. Factors of physical growth of children as they may apply to physical education. AAHPER Proceedings, 60, 1954.

Krogman, W.M. Growth of head, face, trunk and limbs in Philadelphia white and negro children of elementary and high school age. Monographs of the Society for Research in Child Development, 1970, 35,(3).

Krogman, W.M. The Human Skeleton in Forensic Medicine, Springfield, IL: Charles C. Thomas, 1973.

Larsen, R.L. Physical activity and the growth and development of bone & joint structures. In G.L. Rarick (Ed.). Physical Activity: Human Growth and Development. New York: Academic Press, 1973.

Latchow, M. Measuring selected motor skills in fourth, fifth and sixth grades. Research Quarterly, 1954, 25, 439-449.

Lindeman, R.H., Merenda, P.F., & Gold, R.Z. Introduction to Bivariate & Multivariate Analysis. Illinois: Scott, Foresman & Co., 1980.

Lowery, G.H. Growth & Development of Children. Chicago, IL: Year Book Medical Publishers, Inc., 1973.

Mainland, D. Evaluation of the skeletal age method of estimating children's development, Part I. Pediatrics, 1953, 12, 114-129.

Mainland, D. Evaluation of the skeletal age method of estimating children's development, Part II. Pediatrics, 1954, 13, 165-173.

Mainland, D. Evaluation of the skeletal age method of estimating children's development, Part III. Pediatrics, 1957, 20, 979-992.

Malina, R.M. Adolescent changes in size, build, composition and performance. Human Biology, 1974, 46, 117-131.

Malina, R.M. A consideration of factors underlying the selection of methods in the assessment of skeletal maturity. American Journal of Physical Anthropology, 1971, 35, 341-346.

Malina, R.M., Harper, A.B., Avent, H.H., & Campbell, D.E. Age at menarche in athletes and non-athletes. Medicine and Science in Sports, 1973, 5(1), 11-13.

Malina, R.M., & Rarick, G. "Growth, Physique and Motor Performance," Chap. 6, pp. 125-142. In G. Rarick, Physical Activity: Human Growth and Development, Academic Press, New York, 1973.

Malina, R. M., Spirduso, W.W., Tate, C., & Baylor, A.M. Age at menarche and selected menstrual characteristics in athletes at different competitive levels and in different sports. Medicine and Science in Sports, 1978, 10(3), 218-222.

Marshall, W.A. Interrelationships of skeletal marturation, sexual development and somatic growth in man. Annals of Human Biology, 1974, 1(1), 29-40.

Marshall, W.A., & DeLimonge, Y. Skeletal maturity and the prediction of age at menarche. Annals of Human Biology, 1976, 3(3), 235-243.

Maresch, M.M. Measurements from roentgenograms, heart size, long bone length, bone, muscle, fat widths, and skeletal maturation. In Human Growth and Development, R.W. McCammon, ed., Springfield, Illionis: Charles C. Thomas Co., 1970.

Martens, R. Perspectives on research in children's sports. Paper presented at Annual Conference on North American Society for Psychology of Sport and Physical Activity, Tallahassee, Florida, 1978.

Moed, G., Wight, B.W., & Vandegrift, H.M. Studies of physical disability: Reliability of measurement of skeletal age from hand films. Child Development, 1962, 33, 37-41.

Mussen, P.H., & Jones, M.C. Self-conceptions, motivations and interpersonal attitudes of late- and early-maturing boys. Child Development, 1957, 28, 243-256.

Olson, W.C. Child Development (2nd ed.). Boston: Heath, 1959.

Onat, T., & Ertem, B. Adolescent female height velocity: relationship to body measurements, sexual and skeletal maturity. Human Biology, 1974, 46, 199-217.

Pryor, J.W. Roentgenographic investigation of the time element in ossification. American Journal of Roentgenological and Radiographic Therapy, 1933, 29, 798-804.

Pryor, J.W. Time of ossification of the bones of the hand of the male and female, and union of epiphyses with the diaphyses. American Journal of Physical Anthropology, 1925, 8, 401-410.

Public Health Bulletin. Skeletal Maturity of Children 6-11 Years, United States. U.S. Department of Health, Education and Welfare - Public Health Service, Washington, D.C., Series 11, No. 140, 1974.

Pyle, S.I., & Hoerr, N.L. A Radiographic Standard of Reference for the Growing Knee (2nd) Edition). Springfield, IL: Chas. C. Thomas Publishing, 1969.

Pyle, S.I., & Hoerr, N.L. Radiographic Atlas of Skeletal Development of the Knee. Springfield, IL: Chas. C. Thomas Publishing, 1955.

Rarick, G. "Stability and Change in Motor Abilities," Chap. 9, pp. 201-224. In G. Rarick Physical Activity: Human Growth and Development, Academic Press, New York, 1973.

Rarick, G.L., & Oyster, N. Physical maturity, muscular strength, and motor performance in young school-age boys. Research Quarterly, 1964, 35(4), 523-531.

Roche, A.F. Assessment of skeletal maturation, summary. American Journal of Physical Anthropology, 1971, 35, 467-469.

Roche, A.F. Clinical applications of skeletal age assessments. Australian Paediatric Journal, 1965, 1, 6-11.

Roche, A.F. Sex associated differences in skeletal maturity. Acta Anatomica, 1969, 71, 321-340.

Roche, A.F., Davila, G.H., & Eyman, S.L. A comparison between Gruelich and Tanner-Whitehouse assessments of skeletal maturity. Radiology, 1971, 98, 273-280.

Roche, A.F., Davila, G.H., Pasternack, B.A., & Walton, M.J. Some factors influencing the replicability of assessments of skeletal maturity (Greulich-Pyle). American Journal of Roentology, Radiographic Therapy and Nuclear Medicine, 1970, 109, 299-306.

Roche, A.F., Eyman, S.L., & Davila, G.H. Skeletal age prediction. Journal of Pediatrics, 1971, 78, 997-1003.

Roche, A.F., & Johnson, J.M. A comparison between methods of calculating skeletal age (Greulich-Pyle). American Journal of Physical Anthropology, 1969, 30, 221-229.

Roche, A.F., Wainer, H., & Tnisson, D. Skeletal Maturity. New York: Plenum Medical Book Co., 1975.

Rotch, T.M. Chronologic and anatomic age in early life. The Journal of the American Medical Association, 1908, 51, 1197-1205.

Sargent, D.A. Physical test of a man. American Physical Education Review, 1921, 26(4), 188-194.

Schoen, E.J., Solomon, I.L., & Milkovich, L. Bone age in short boys and tall girls. American Journal of Diseases of Children, 1970, 119, 252-254.

Scott, M.G., & French, E. Measurement and Evaluation in Physical Education. Dubuque, Iowa: Wm. C. Brown, Co., 1959.

Seefeldt, V.D. Youth sports: Developmental considerations. Paper presented at AAHPER National Convention, Kansas City, MO, 1978.

Seils, L.G. The relationships between measures of physical growth and gross motor performance of primary grade school children. Research Quarterly, 1951, 22, 244-260.

Shuttleworth, F.K. The physical and mental growth of girls and boys age six to nineteen in relation to age at maximum growth. Monographs of Society for Research in Child Development, 1939, 4(3).

Simmons, K. The Brush Foundation study of child growth and development II, physical growth and development. Monographs of the Society for Research in Child Development, 1944, 37.

Simmons, K., & Greulich, W.W. Menarcheal age and the height, weight and skeletal age of girls age seven to seventeen years. Journal of Pediatrics, 1943, 22, 518-548.

Slaughter, M.H., Lohman, T.G., & Misner, J.E. Association of somatotype and body composition to physical performance in 7-12 year old girls. Journal of Sportsmedicine & Physical Fitness, 1980, 20(2), 189-198.

Staffieri, J.R. A Study of Social Stereotype of Body Image in Children. Journal of Personality and Social Psychology, 1967, 7: 101-104.

Stewart, S.F. A study of physical growth and school standing of boys. Journal of Educational Psychology, 1916, 7, 414-426.

Tanner, J.M. Growth at Adolescence (2nd ed.). Oxford: Blackwell Scientific Publications, 1962.

Tanner, J.M. Education and Physical Growth. New York: International Universities Press, 1961.

Tanner, J.M. The essential characteristics of a rating system. American Journal of Physical Anthropology, 1971, 35, 339-340.

Tanner, J.M., & Whitehouse, R.H. Standards for Skeletal Maturity (Part I). International Children's Center, Paris, 1959.

Tanner, J.M., Whitehouse, R.H., & Healy, M.J.R. A New System for Estimating Skeletal Maturity from the Hand and Wrist, with Standards Derived from a Study of 2600 Healthy British Children (Part II). The Scoring System. Paris: International Children's Centre, 1962.

Tanner, J.M., Whitehouse, R.M., Marshall, W.A., Healy, M.J.R.,& Goldstein, H. Assessment of Skeletal Maturity and Prediction of Adult Height (TW2 Method). London: Academic Press, 1975.

Tatsuoka, M.M. Selected Topics in Advanced Statistics an Elementary Approach, Number 4 Significance Tests Univariate and Multivariate. Illinois: Institute for Personality and Ability Testing, 1971.

Tatsuoka, M.M. Selected Topics in Advanced Statistics an Elementary Approach, Number 7 The General Linear Model, A "New" Trend in Analysis of Variance. Illinois: Institute for Personality and Ability Testing, 1975.

Teeple, J. "Physical growth & maturation." In M.V. Ridenour (Ed.). Motor Development, Princeton: Princeton Book Co., Publishers, 1978.

Todd, T.W. Atlas of Skeletal Maturation (Hand). St. Louis: C.V. Mosby Co., 1937.

Torgersen, J. Asymetry and skeletal maturation. Acta Radiologica, 1951, 36, 521-523.

Watson, E.H., & Lowrey, G.H. Growth and Development of Children (2nd ed.). Chicago: The Year Book Publisher, Inc., 1954.

Wenzel, A., & Melsen, B. Replicability of assessing radiographs by the Tanner & Whitehouse - 2 method. Human Biology, 1982, 54, 575-581.

APPENDICES

APPENDIX A

DIRECTIONS FOR ADMINISTRATION OF TESTS IN THE MOTOR PERFORMANCE STUDY

MOTOR PERFORMANCE TESTING[1]

Directions for Administration of Tests

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, i.e., if less than one or two seconds is recorded on the first trial, given an additional trial.

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 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.

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 other block, picks it up and runs past the starting line with it in his hand. The time is recorded to the nearest 1/10 second. Record two trials.

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 1/2 inch) in inches from the take-off line to the point where the body touches nearest to the take-off line. Record three trials.

---

[1]Performers are encouraged verbally during the tests.

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 1/10 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.

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 1/2 inch) reached in relation to the vertical surface of the bench. Record three trials.

400-FOOT ENDURANCE SHUTTLE RUN: Two objects (chairs, waste baskets) 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 cannot finish the race at a run. The time is recorded to the nearest 1/10 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, i.e., slips, falls.

APPENDIX B

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

SCORE SHEET: MOTOR PERFORMANCE TESTS
Motor Performance Study

NAME________________________________ DATE______________________

NUMBER______ AGE (Months)_________ BIRTH DATE_______________

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

APPENDIX C

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

	AGE CATEGORY 5 6	CARD NO. 7	SEX 8	RACE 9	S-E NO. 10	GRADE 11 12	CHRONOL. AGE (MO.) 14 - 16	SKELETAL AGE (MO.) 18 - 20	FLEXED ARM HANG 22 - 24	JUMP AND REACH 26 - 28	AGILITY SHUTTLE RUN 30 - 32	STANDING LONG JUMP 34 - 36	30-YD DASH 38-9	SIT AND REACH 41 - 43	ENDURANCE SHUTTLE 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

CORRELATION MATRICES FOR THE MOTOR PERFORMANCE AND AGE VARIABLES

APPENDIX D-1 CORRELATION MATRIX FOR THE MOTOR PERFORMANCE AND AGE VARIABLES USED IN THIS STUDY: SIX-YEAR-OLD AGE DIVISION

	Chronological Age	Skeletal Age	Flexed Arm Hang	Jump and Reach	Agility Shuttle Run	Standing Long Jump	30-Yard Dash	Sit and Reach
Skeletal Age	.32							
Flexed Arm Hang	.05	.08						
Jump and Reach	.24	.16	.17					
Agility Shuttle Run	-.17	.00	-.37	-.61				
Standing Long Jump	.17	.15	.40	.59	-.71			
30-yard Dash	-.17	-.13	.01	-.15	.01	-.02		
Sit and Reach	-.08	.05	.24	.19	-.26	.39	.08	
400-ft Endurance Run	-.15	-.02	-.34	-.55	.77	-.58	.01	-.24

APPENDIX D-2 CORRELATION MATRIX FOR THE MOTOR PERFORMANCE AND AGE VARIABLES, AT SIX YEARS OF AGE, USED IN THIS STUDY: EIGHT-YEAR-OLD AGE DIVISION

	Chronological Age	Skeletal Age	Flexed Arm Hang	Jump and Reach	Agility Shuttle Run	Standing Long Jump	30-yard Dash	Sit and Reach
Skeletal Age	.32							
Flexed Arm Hang	.13	.09						
Jump and Reach	.25	.06	.32					
Agility Shuttle Run	-.22	.04	-.29	-.51				
Standing Long Jump	.19	.13	.31	.55	-.62			
30-yard Dash	-.07	-.14	-.34	-.41	.63	-.47		
Sit and Reach	.10	.06	.31	.23	-.28	.41	-.18	
400-ft Endurance Run	-.16	-.11	-.13	-.28	.61	-.48	.55	-.17

APPENDIX D-3 CORRELATION MATRIX FOR THE MOTOR PERFORMANCE AND AGE VARIABLES, AT SIX YEARS OF AGE, USED IN THIS STUDY: TEN-YEAR-OLD AGE DIVISION

	Chronological Age	Skeletal Age	Flexed Arm Hang	Jump and Reach	Agility Shuttle Run	Standing Long Jump	30-yard Dash	Sit and Reach
Skeletal Age	.32							
Flexed Arm Hang	.13	.09						
Jump and Reach	.24	.19	.39					
Agility Shuttle Run	-.14	-.09	-.45	-.43				
Standing Long Jump	.15	.19	.40	.72	-.60			
30-yard Dash	-.11	-.14	-.40	-.56	.57	-.67		
Sit and Reach	.02	.04	.25	.25	-.21	.34	-.22	
400-ft Endurance Run	-.29	.62	-.67	.77	-.56	-.53	-.18	-.16