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Grouped According to Age at Peak Height Velocity

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PHYSICAL GROWTH CHARACTERISTICS OF
EARLY, AVERAGE, AND LATE MATURING FEMALES
GROUPED ACCORDING TO AGE AT
PEAK HEIGHT VELOCITY

By

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ABSTRACT

PHYSICAL GROWTH CHARACTERISTICS OF
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The specific purposes of this study were to (1) determine if combinations of physical growth measures taken during childhood could be useful in predicting age at peak height velocity and onset of menstruation; (2) investigate differences in the magnitude and duration of the adolescent peak height spurt for early, average, and late maturing females; and (3) examine the relationship between age at peak height velocity and age of menarche among the three maturity groups.

Longitudinal data on five parameters of growth (standing height, sitting height, biacromial diameter, biiliac width, weight) and recall data on menarche were used to evaluate developmental patterns and maturation rates of sixty-five female subjects. Level of maturity (early, average, late) was chosen as the independent variable in this study and was determined by the age at peak height velocity for each girl. Early maturers (n=21) had peak height velocity before 11.5 years of age, average maturers (n=28) experienced peak velocity between 11.5 and 12.5 years, inclusive, while late developers (n=16) attained their peak height velocity after 12.5 years.

The findings indicate that accurate predictions of age at peak height velocity (APHV) and age of menarche (MA) may be difficult to obtain from measures of physical growth taken at nine years of age. Low relationships existed among all the physical growth variables and APHV and MA. The highest coefficient obtained was -.37 between biacromial width and MA.

Predictive equations for APHV and MA were similar. Of the five growth parameters measured, the biacromial and biiliac widths provided the best predictors of APHV, accounting for 11.2% of the variance. The stepwise regression procedure yielded the following equation:

$$\text{APHV} = 18.822 - .389(\text{Biacromial}) + .216(\text{Biiliac}) \pm .969$$

The prediction of MA from the growth measures showed that a higher percentage of the variance (15.0%) was explained than in the prediction of APHV, but that a larger standard error of the estimate existed. The regression was:

$$\text{MA} = 19.837 - .510(\text{Biacromial}) + .624(\text{Standing Height}) \pm 1.092$$

A multivariate analysis of variance revealed that the maturity main effect was significant ($p < .0001$). Univariate F procedures, step-down F tests, and discriminant function analyses indicated that spurt height (SH), spurt duration (SD), peak height velocity (PHV), and interval had important roles in differentiating the three maturity groups. Significant differences occurred between early and late maturers for SD, PHV, and interval. Moreover, the early developing females also differed statistically from the average maturers on PHV and interval, with the early maturing females displaying a longer SD and interval and a higher PHV. These data indicated that early maturers entered their adolescent growth cycle at a younger age but grew for a longer time before maturity than average or late developers. It seems that the later developing female is nearer her complete biological maturation at the time of PHV than the early maturer and, therefore, has a shorter interval to MA.

DEDICATION

To all those teachers who have provided me with the background necessary for graduate study, the desire to learn more, and the incentive to strive for higher goals.

Special dedication to the following physical educators who had a profound influence in directing my life and chosen profession:

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CHAPTER I

THE PROBLEM

Physical growth of human beings is highly predictable. Measures of length and breadth follow a definitive pattern of development, encompassing four phases. However, children proceed through their growth cycles at different rates, and individual variations in physical growth and motor abilities occur throughout the childhood and adolescent years. During the circumpuberal period, subjects can readily be divided into early, average, or late maturers according to their age at the onset of adolescent growth. It seemed appropriate, then, to determine whether the attainment of specific physical and biological events associated with puberty can be predicted from anthropometric data obtained in childhood.

Statement of the Problem

The purpose of this research effort was three-fold. First, this study was designed to decide if childhood measures of height, weight, body size, and/or body shape could be used to predict age at peak height velocity and the onset of menstruation in females. Second, the study investigated differences in the magnitude and duration of the adolescent peak height spurt for early, average, and late maturing females. A third area of investigation was to determine the relationship between age of menarche and age at peak height velocity among the three maturity groups.

Significance of the Study

It is common knowledge that children often are compared to a standard in some area of performance or development; for example, the fiftieth percentile of the fifty yard dash or the average height and weight for a specific chronological age. Too often, all children are judged by the mean values obtained from cross sectional data. It would be more appropriate to evaluate individuals according to standards from a longitudinal study of subjects selected from similar environmental circumstances. Therefore, one objective of this study was to develop criteria to assess a girl's progress toward physical maturation according to the appropriate growth pattern of an early, average, or late developing female and not necessarily according to the "normal" cycle.

Physical growth and body size have an effect on an individual's ability to perform motor skills. Physical educators and athletic coaches are constantly aware of the need to match students in some sports on the basis of size in order to provide healthy and enjoyable activity for them. The results from this investigation could help classify females by maturation criteria. These groupings then could be used to investigate whether classification of females by maturity level accounts for differences in athletic ability or motor performance. If such differences were reported, then the maturation criteria would be useful in equalizing competition on youth athletic teams or in physical education and recreational activity settings. This study also would provide the format whereby data relating maturity level to motor performance of males could be analyzed.

Research Hypotheses

It was hypothesized that:

1. A selected number of childhood measures including height, weight, and breadths can account for a substantial percentage of the variance in age at peak height velocity and age at menarche.
2. The magnitude of the spurt will be greater and the duration of adolescent growth will be longer in the early maturing girls compared to the average and late maturers. The same relationship will exist between the average versus the late maturing groups.
3. The time interval between age at peak height velocity and age at menarche will be inversely related to the age at peak height velocity.

Research Plan

Data on five parameters of growth were collected semi-annually on the subjects (Table 1-1). In most cases the measurements on the

Table 1-1: Measures of Physical Growth
Obtained Semi-Annually

Weight
Standing Height
Sitting Height
Biacromial Diameter
Biiliac Diameter

girls were obtained first during early childhood and continued semi-annually for the next twelve years. All records containing continuous data from nine years of age through the completion of the adolescent growth spurt were included in the analyses.

In addition, menarche data were obtained on the subjects by the recall method. A letter explaining the study and requesting the age and/or date of first menstruation was sent to the girls and/or their mothers (Appendix A). Several guidelines were mentioned in the letter to facilitate the accurate recording of a specific date or time of menarche.

Scope of the Investigation

This investigation was delimited to the growth patterns and measurements of females during middle childhood and encompassing the adolescent growth spurt, but excluding the attainment of mature stature. Factors that could influence growth, such as diet, disease, or competitive activities, were not studied. Subject selection was limited to 65 females enrolled in the longitudinal Motor Performance Study at Michigan State University on whom data were available from middle childhood through adolescence.

The following assumptions were made:

1. The data are representative of other females in the Motor Performance Study and throughout the State of Michigan.
2. Measures of physical growth are stable over time.
3. The subjects were honest in their responses concerning age at menarche.

Potential weaknesses existed in the endeavor. One limitation of the study was that the anthropometric measurements were taken by four different investigators throughout the length of the study. Three of these, though, were all instructed and tested for reliability and accuracy by the fourth person, the primary investigator of the Motor Performance Study. A second limitation was that recall of menarche is not entirely accurate. Therefore, adjustment was made for the systematic underestimation of menarcheal age by adding six months to the age cited in the imprecise responses (see Chapter 3, page 30 for a detailed explanation). Finally, errors of recording or measurement could have been made. An attempt was made to minimize such errors by having the recorder compare each measurement to the one documented at the previous measurement period. Clarification or remeasurement was requested if a discrepancy, such as regression in the length of a long bone, was reported.

Definitions

The following definitions will aid the understanding of this study:

1. Acrom-radiale--upper arm length
2. Adolescent growth spurt--period of accelerated growth following childhood; also called "puberty" and the "circumpuberal period"
3. Biacromial width--shoulder width
4. Biiliac width--hip width
5. Chronological age--time since birth

6. Development--used interchangeably with growth and maturation; usually denotes a combination of the two
7. Girth--measure of circumference
8. Growth--changes in physical properties, such as gain in height and weight
9. Maturation--changes in functional capacity, such as sexual development
10. Menarche--first menstruation
11. Peak height velocity--maximum annual increment in height during the growth spurt
12. Radio-stylion--forearm length
13. Skeletal age--degree of development of the bones of the body
14. Skinfold--measure of subcutaneous fat

CHAPTER II

REVIEW OF LITERATURE

Normal human beings have highly predictable patterns of growth during their lives. From conception until maturity, marked changes in physical growth occur. For example, measures of height, weight, leg length, and arm girth all change with development. It was the purpose of this review to: (1) examine the pattern of growth in stature for females; (2) discuss individual growth parameters, especially those associated with the adolescent spurt; (3) inspect the relationship of menarche to other variables of physical growth; and (4) report the reliability of menarcheal data obtained via the recall method.

Pattern of Growth

When absolute measures of length and breadth are plotted, the resulting curve is S-shaped (Figure 2-1). This distance curve shows a cumulative gain in stature throughout the growing years, or actual height attained at successive chronological ages. The cumulative curve is a basic description of the additive outcome of stature or a record of the distance traveled toward final adult height. The oldest longitudinal record of stature was provided by de Montbeillard who measured and noted his son's height from birth to eighteen years of age during the years of 1759 to 1777 (Scammon, 1927). The normal pattern of standing height can be divided into four phases as shown in Figure 2-1 (Scammon, 1927; Deming, 1957; Malina, 1975, p. 8).

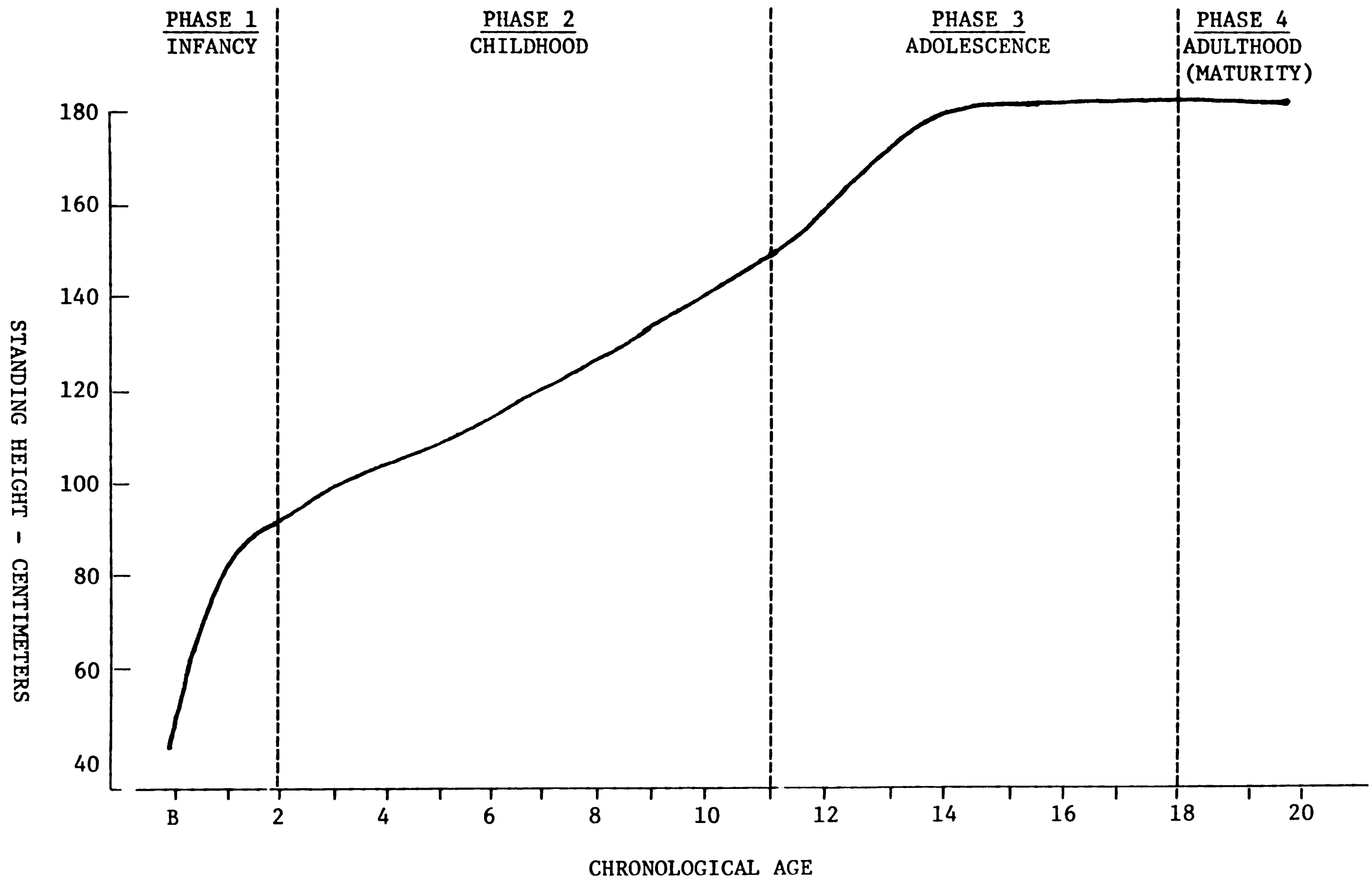

Figure 2-1: The Four Phases of Growth in Standing Height for Human Beings. (Adapted and redrawn from Malina, 1975.)

Phases of the Distance Graph

Infancy, phase one, usually extends from birth until approximately two years of age. This phase is a time of rapid growth of a child, as can be detected by the steepness of the curve. The body uses this period as a time for "catch-up growth," as described by Prader, et al. (1963), to compensate for any deprivation that may have occurred during interuterine life. Because the physical dimensions of the child are changing rapidly in infancy, prediction of future growth would meet with little success during these years.

Phase two, childhood, follows infancy and extends until the onset of the adolescent growth spurt. This period is characterized by steady, uniform development, shown in Figure 2-1 as the low sloping part of the line that rises at a fairly constant rate. This consistency or stability of growth during childhood has been documented by several investigators (Meredith, 1935; Simmons and Todd, 1938; Shuttleworth, 1949 a, b). The average gain per child during this period is approximately 6 cm per year. Since rate of growth is relatively stable during this phase, predictions of measures such as final adult height would be more accurate than those made during infancy.

The third portion of the human growth curve is represented by the sharp increase depicted in Figure 2-1. Known as adolescence or puberty, this period varies greatly in both its onset and termination as well as in its intensity and duration. In girls the spurt can occur from 8-19 years of age with an average gain of 8 cm per year. The normal duration is approximately 2-2½ years, with the average peak gain occurring from twelve to thirteen years of age (Tanner, 1962, p. 1; Malina, 1975, p. 21). Largo, et al. (1978) reported an average duration of 3.8 years in girls with peak height velocity equaling 7.1 cm, mean onset of spurt being 9.6 years of age, and age at peak height velocity equaling 12.2 years. The period surrounding the adolescent growth spurt is one of great change in young people and is a time of considerable variability in physical characteristics and abilities among individuals.

Adulthood, the fourth and final phase of the human growth cycle, begins after the acceleration of growth during adolescence is completed. The flattened portion of the curve in Figure 2-1 depicts that adult stature has been reached and that no more gain in height will occur.

In brief, then, the cumulative curve is descriptive of the data and depicts the total distance traveled toward maturity. It has limited applicability, though, as a diagnostic tool when analyzing the adolescent growth spurt. Exact onset, intensity, and duration of the spurt are extremely difficult to ascertain via the distance graph. Therefore, for quantitative analyses, the velocity curve displaying incremental changes should be used.

Characteristics of the Velocity Graph

Children proceed through the growth cycle at different rates. A velocity graph, then, can be used to characterize how individuals grow, as such a plot would show incremental change from year to year. Shuttleworth (1937) and Tanner (1952) suggested that the study of physical growth was clarified through the use of velocity rather than distance curves. Boas (1932) discussed the close relationship of the entire growth curve to the moment of maximum rate of growth.

The typical velocity curve for gain in height of females is shown in Figure 2-2. During infancy the velocity of growth decreases tremendously until the early childhood years. The rate of growth during childhood is fairly constant until just prior to the adolescent growth spurt. At this point, several investigators show a pre-spurt dip in growth velocity (Scammon, 1927; Shuttleworth, 1937; Israelshon, 1960; Lindgren, 1978) (shown in Figure 2-4). This dip is followed by the sharp rise in growth ranging from 7 to 12 cm per year. After the adolescent gain, there is a steady decrease in velocity until the zero point, signifying that adult height has been attained.

Specific parameters of growth such as peak height velocity and onset of the spurt are easily identified on the velocity plot (Figure 2-3). For the present purposes, these characteristics of the growth cycle were adapted from Largo, et al (1978) and defined as follows:

1. MPSV - minimal pre-spurt velocity; onset of growth spurt
2. AMPSV - age at minimal pre-spurt velocity; age at which spurt begins
3. PHV - peak height velocity; maximum height velocity during the growth spurt
4. APHV - age at peak height velocity
5. SH - spurt height or increase in height velocity during the growth spurt; calculated as PHV - MPSV
6. ST - spurt termination; return to MPSV
7. AST - age at spurt termination
8. SD - spurt duration or length of growth spurt; calculated as AST - AMPSV

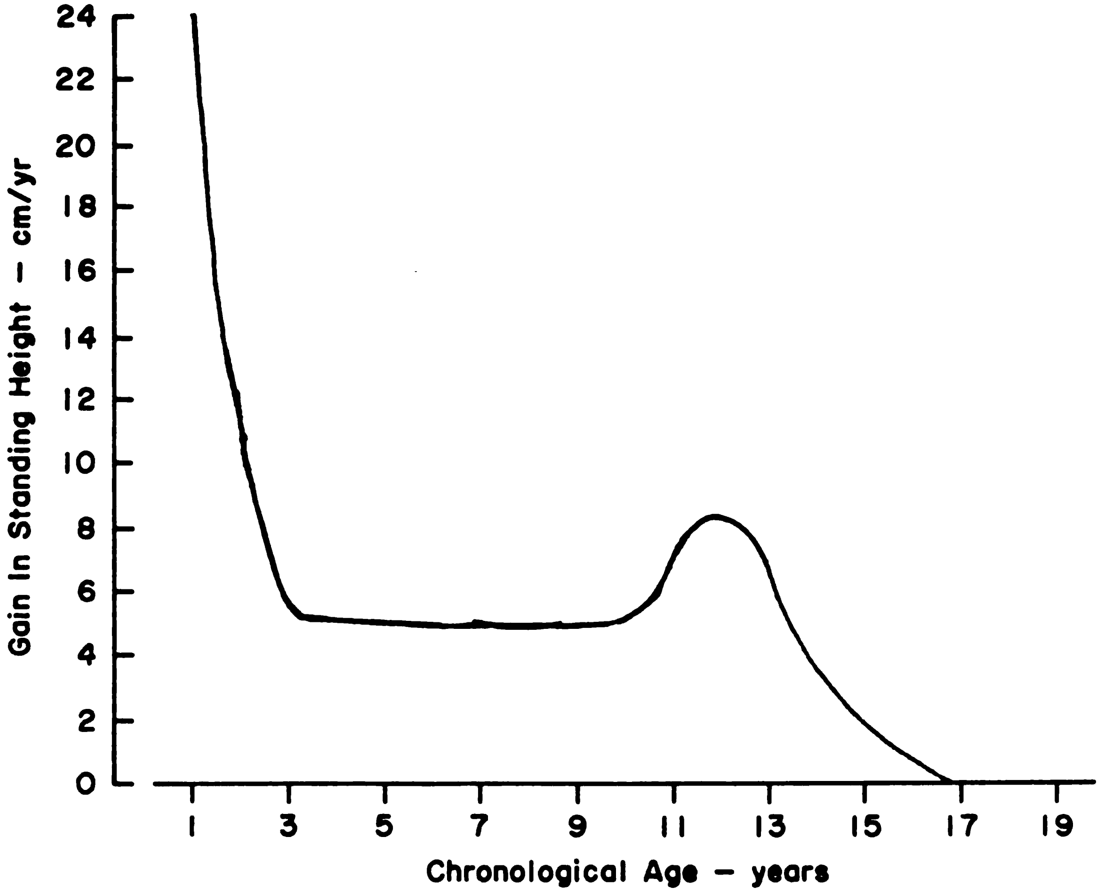

Figure 2-2: Typical Velocity Curve for Gain in Standing Height for Females.

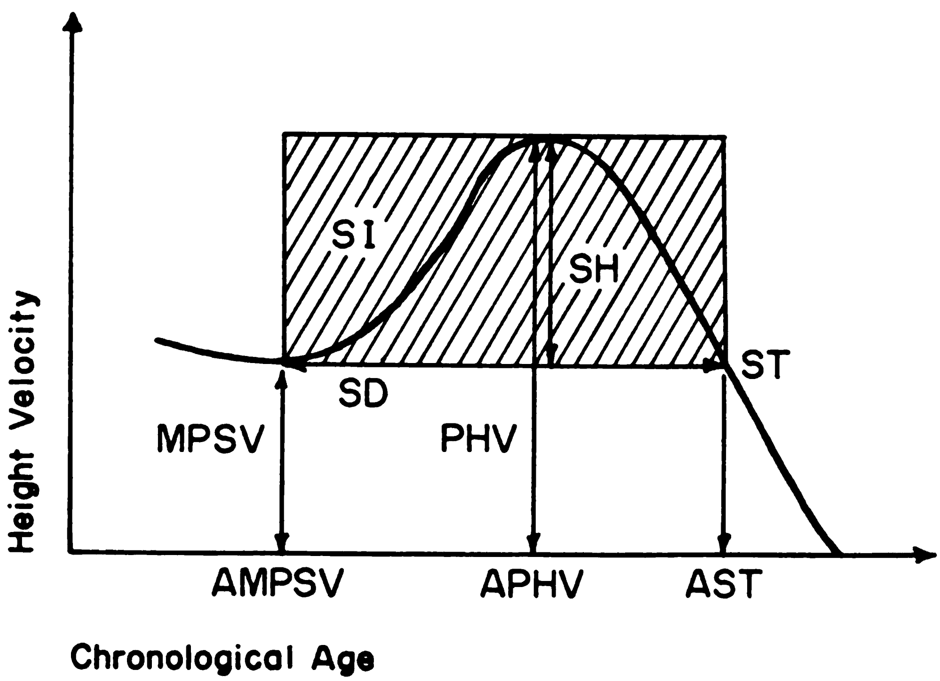

Figure 2-3: Definitions of the Parameters of the Growth Cycle of Human Beings. (See text for detailed explanation.)

9. SI - spurt intensity or area of the spurt; calculated as SD x SH

Techniques of Curve-fitting

Growth data have been smoothed with either graphical or computerized procedures in order to remove (1) measurement error, (2) seasonal variation, and (3) minor variations due to other causes (Tanner, et al., 1966a). Several techniques have been used to fit longitudinal growth data to a curve. The Gompertz function was first used by Deming (1957) to describe the data of the adolescent growth spurt. However, the lower asymptote of the spurt (onset of adolescent growth) was not always easily and objectively determined. Other investigators since have stated that the logistic function fits the growth data for height better than the Gompertz curve (Marubini, et al., 1972). These scientists reported that the logistic model showed slightly lower residuals than the Gompertz function. Bock, et al. (1973) described a double logistic function with two separate components--pre-pubertal and adolescent--summed to complete the model. Six parameters were used to establish the growth curve, five of which were estimated by non-linear least squares and the sixth being the actual measurement of mature stature. The predicted values of this function, though, were high from ages four to six years, low in early adolescence, and again low in late adolescence. The authors acknowledged that the model might need a slight change in composition. As stated earlier, these functions require a measure of final height in order to be used to estimate the growth curve.

If data on mature stature are not available, a graphical technique can be used to deal with the adolescent growth spurt (Figure 2-4). Four steps are necessary in this procedure, adpated from Tanner, et al. (1966a).

1. Plot the individual measurements.
2. Draw a distance curve through the points by linear interpolation.
3. Read off increments from this distance curve at three-month intervals, convert to cm/year, and plot.
4. Draw the velocity curve through these points.

This procedure is clearly an exacting method, but does allow one to avoid the constraints of a preselected curve to be fitted. Individual variations in growth (i.e., a pre-spurt dip) may be retained in the curve rather than smoothed out. The finalized velocity graph then can be labeled according to the parameters adapted from Largo, et al (1978), listed in the preceeding section.

Variability in Growth

Various parts of the body develop at different rates during the growth cycle from conception to adulthood. After birth, a child's head will double in size, while the trunk triples, the arms quadruple, and the legs increase five-fold (Krogman, 1955). The head is the fastest-developing structure before birth. During infancy, the trunk grows the fastest, whereas, during childhood until adolescence, the arms and legs have the highest velocity. Finally, the trunk continues growing between puberty and adulthood (Whipple, 1966, p. 122). The proportions of the individual segments to each other change throughout the growth cycle. Therefore, anthropometric measures of these body parts and

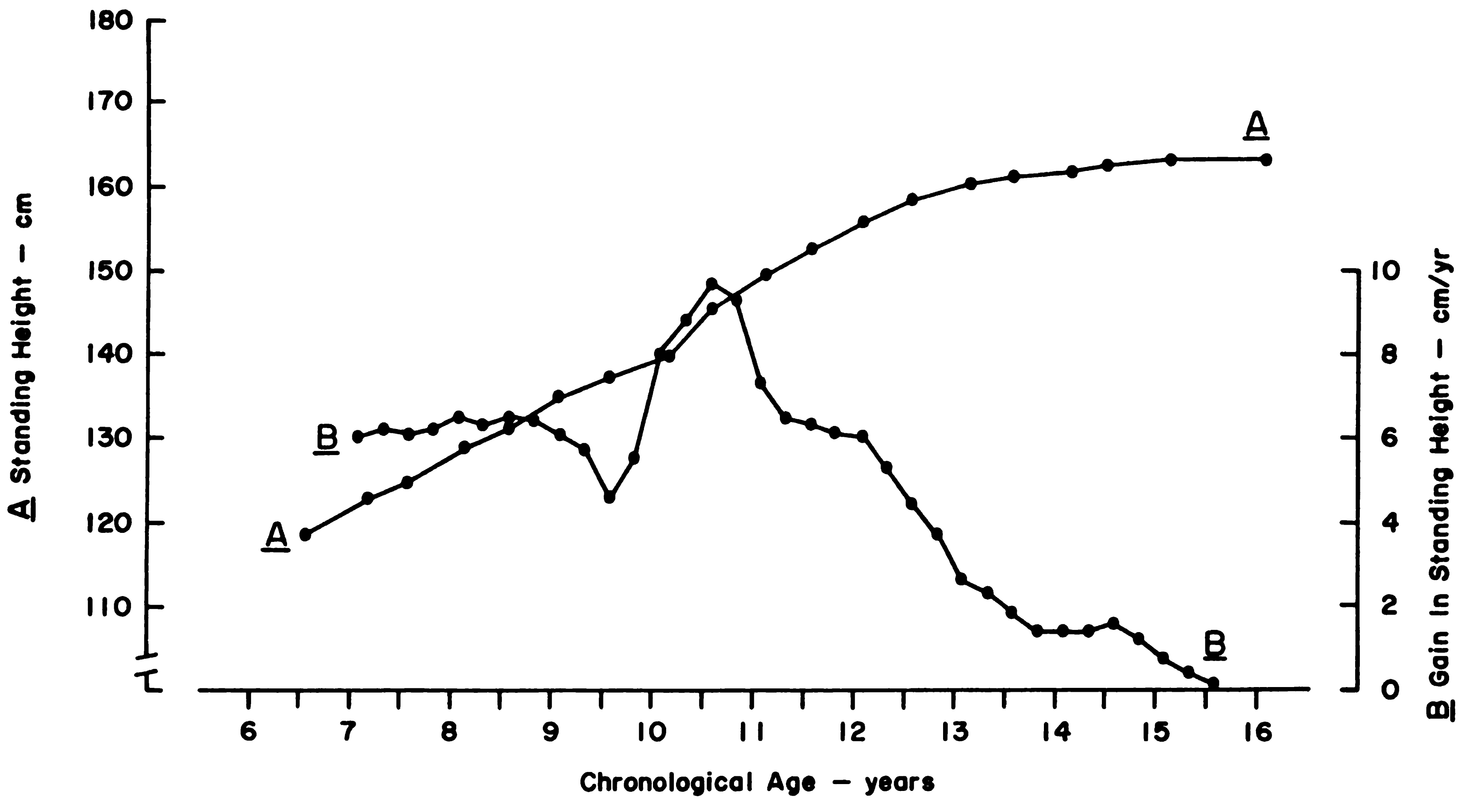

Figure 2-4: Example of the Graphical Technique Used to Interpolate the Growth Data. (See text for detailed explanation.)

their relationships to each other possibly could be used to predict the various characteristics of future physical growth.

The time of onset of different growth parameters is highly variable. Tanner, et al. (1966a) reported APHV for girls ranging from 10.5-13.5 years, with age at menarche occurring from 11.4-14.7 years. The data of Anderson, et al. (1965) indicated that skeletal age at menarche varied between 11.5 and 14.5 years while that of chronological age at menarche varied from 10.08-15.83 years. Numerous investigators have reported mean ages of menarche (MA) ranging from 12.3-14.0 years (Tanner, 1973; Richardson and Pietus, 1977; Neyzi and Alp, 1975; Zacharias, et al., 1970; Frisch and Revelle, 1970; Johnston, et al., 1971; Lindgren, 1976; Frisancho, et al., 1969; Livson and McNeill, 1962; Damon, et al., 1969; Ljung, et al., 1974; Kralj-Cercek, 1956; Boas, 1932; Deming, 1957; Bojlen, et al., 1954; Kantero and Widholm, 1971). Marshall (1974) published data showing ages at breast stage two (B2) ranging from 8-14 years, while that at breast stage five (B5) ranged between 12 and 16 years. Pubic hair stages (PH), APHV, and MA all showed variability in occurrence of four to five years. Onat and Ertem (1974) depicted wide ranges at onset for PHV (10.61-14.46 years), PH2 (10.41-12.21 years), B2 (10.41-12.14 years), and axillary hair (11.33-12.51 years).

To minimize the ranges in age of onset of characteristics, it appears necessary to group individuals according to some parameter. Height age, weight age, skeletal age, MA, and APHV have all been used to classify children for specific events. However, Shuttleworth (1939) cited four advantages in using age at maximum rate of growth for the classification of individuals. First, there is universal application;

i.e., both sexes can be grouped in this manner. Second, it is a highly reliable technique. Third, such classification provides an excellent basis for grouping individuals with a similar growth pattern. Finally, APHV is a good indicator of underlying endocrine events and sexual maturity. Many studies have used APHV to divide individuals into groups of early, average, and late maturers (Lindgren, 1978; Largo, et al, 1978; Tanner, et al., 1976; Onat and Ertem, 1974; Boas, 1932; Shuttleworth, 1937, 1939; Deming, 1957; Tanner, et al., 1966a, b; Marubini, et al., 1971; Tanner and Whitehouse, 1976).

Parameters of Growth

The growth cycle has several identifiable phases and variables that can be analyzed. Some of these parameters will be discussed here. Special attention will be paid to those characteristics defined in the typical velocity graph for standing height (Figure 2-3, p. 12).

Magnitude of Peak Height Velocity

Numerous investigators have reported that the earlier the APHV, the more intense will be the growth spurt (Boas, 1930, 1932; Shuttleworth, 1937, 1939; Deming, 1957; Tanner, et al., 1966a, b, 1976; Marubini, et al., 1971; Lindgren, 1978). Lindgren (1978) reported significant differences in spurt intensities (SI) of 8.7 cm, 8.2 cm, and 7.9 cm among three groups whose mean APHV was 10.7 years, 12.0 years, and 13.5 years, respectively. It would appear from these findings that the growth of the early maturer is more intense at adolescence than that of the average or late developing individual.

However, several studies fail to support this claim. Onat and Ertem (1974) found that the magnitude of the spurt did not correlate significantly with APHV. An inverse trend was depicted, though, with a mean drop of .22 cm in PHV per year of APHV. This value should be compared to Deming's (1957) report of a .93 cm and Tanner's (1966a) of a .47 cm drop in PHV per year of APHV. In another study, the magnitude of the spurt was almost identical for well-nourished (early) and malnourished (late) individuals (Dreizen, et al., 1967). Israelshon (1960) stated that peak height velocities for an ectomorph (late maturer) and a mesomorph (early maturer) were similar, although acceleration was greater in the late individual. Moreover, Richey (1937) reported that early maturing females showed lower PHV than average maturers.

A controversy exists, therefore, concerning magnitude of the growth spurt in relationship to time of maximum rate of growth. The greatest amount of evidence shows that early maturing females have a significantly more intense spurt than the average or late maturers. Other studies have shown no significant differences in magnitude of SI. A longitudinal study and analyses of appropriate growth parameters might clarify this situation.

Duration of Peak Height Spurt

Evidence concerning the duration of the adolescent growth spurt (SD) is inconclusive. Marshall and Tanner (1969) and Reynolds and Wines (1948) found no difference in the average rate of passage through puberty for early and late maturers. Moreover, in 1970, Marshall and Tanner reported that the duration of the spurt varies so greatly that one male could develop secondary sex characteristics two years later than another, but reach sexual maturity first. Reynolds and Wines (1948) used the appearance of the first secondary sex charactersitics (either breast bud or pubic hair) as the onset of the spurt, whereas time of menarche marked its termination. However, when their data were grouped by "duration of maturation" (3.6 years = long; 1.4 years = short), there was a difference of two years in the termination of growth (MA) but little difference in the appearance of the breasts or pubic hair (onset of growth). Boas (1932) reported that the earlier the APHV occurred, the shorter was the total period of growth. Frisch and Revelle (1971b) showed that the mean time interval between onset of PHV and MA was eight months longer for late maturers than for early maturers. In contrast, Marubini, et al. (1971) stated that late maturers evidenced a spurt of shorter duration when compared to early maturers; that is, they had a more rapid rate of growth in height.

There is also controversial evidence concerning a sex difference in SD. Largo, et al. (1978), Tanner, et al. (1967), and Deming (1957) reported that the growth spurt of the male was longer. However, Bock, et al. (1973) found no difference in SD between males and females.

Evidence pertaining to growth rate after PHV might lend insight to the controversy concerning SD. Two studies revealed longer growth periods after PHV for early versus average versus late maturing females. Onat and Ertem (1974) reported that growth velocity after PHV was significantly and inversely related to APHV. Growth after PHV was more intense in girls who had an earlier growth spurt, with a difference of 7.38 cm favoring early maturers. They reported a significant mean decrease in velocity after PHV of 2.5 cm per year of APHV. It is possible that since females with an early growth spurt are relatively less mature in sexual development at PHV, they would grow a longer time after PHV to attain maturation. Marshall (1974) found that the individual with a late PHV grew less after PHV than the child who reached PHV at an earlier skeletal age. Anderson, *et al*. (1965) published differences between maturity groups in growth of the trunk following PHV and after menarche. The early maturing group grew 10.4 cm after PHV and 9.5 cm after menarche, the average maturer showed gains of 5.6 cm and 4.6 cm, while the late maturer gained 1.7 cm and 2.1 cm, respectively.

In contrast, Frisch and Revelle (1971b) showed that the mean time interval between AMPSV (age at onset of spurt) and MA equaled eight months longer for late maturers when compared to early developers. They also found that early and late maturing girls (divided by MA) gained the same mean amount of height, about 22 cm, from AMPSV to MA. Additional data are needed to clarify the contradictory results obtained concerning duration of the growth spurt as well as growth after PHV until maturity.

Relationship of Age at Menarche to Age at Peak Height Velocity

The menarche traditionally has been the visible means for identifying the completion of the physical changes at adolescence in females. Boros, *et al*. (1977) used hormone assays to verify that the important physiological changes occurred before menarche. Therefore, menarche marks the completion of events, not the beginning. Menarche and the point of maximum deceleration of height growth occur simultaneously (Israelshon, 1960; Marshall and Tanner, 1969). It might be beneficial to understand the relationships between menarche and the other growth characteristics.

The correlations between MA and APHV have been reported as .59 (Marubini, _et al._, 1971), .69 (Lindgren, 1976), .75 (Shuttleworth, 1939), .76 (Onat and Ertem, 1974), .91 (Marshall and Tanner, 1969), and .933 (Deming, 1957). Marubini's figure is significantly smaller than those of Deming and Marshall and Tanner. A conflict exists, then, about the relationship between MA and APHV. Deming reported a mean interval of 14-15 months between APHV and MA, while Hewitt and Acheson (1961) stated that the average interval between age at peak acceleration and MA was 17-19 months.

Other investigators have found variation in length of time between age at peak height velocity and age at menarche. The bulk of the evidence supports the contention that the younger APHV yields a longer interval until menarche (Lindgren, 1978; Tanner, _et al._, 1976; Onat and Ertem, 1974; Deming, 1957; Boas, 1932). Boas' data show constantly decreasing intervals per year of increase in APHV (Table 2-1).

Table 2-1: Time Interval Between Age at Peak Height Velocity and Menarcheal Age. Data of Boas (1932).

APHV (Years)	INTERVAL TO MENARCHE (Years)
9.5	2.28
10.5	1.56
11.5	1.10
12.5	1.05
13.5	.98

However, several studies have reported that late maturers display the longest interval between APHV and MA. Shuttleworth (1937) reported that for early maturers MA occurred close to APHV, while for later maturers menarche occurred approximately eighteen months after the end of the year of maximum growth. Simmons and Greulich (1943) indicated that there were progressively greater gaps between APHV and MA as maturity status moved from early to late.

In Sweden, Ljung, et al. (1974) have published data indicating that the average interval from APHV to MA has decreased in the past ninety years. The interval was 3.1 years in 1883, 2.0 years in 1938, and 1.7 years in 1974. These data, coupled with the knowledge of a secular trend toward earlier maturity, suggest that the early maturing female has a shorter interval between APHV and MA than later maturing individuals. More likely, the female is probably growing at a faster velocity in a shorter time and is, therefore, more mature at the time of PHV. This greater maturity would allow the succeeding interval to be shortened because not as much time would be needed to reach maturation. More study is needed to clarify the relationship of the APHV to MA. Such an investigation could also help in understanding the difference in spurt duration, or lack thereof, among early, average, and late maturing females.

Prediction of Menarche and Age at Peak Height Velocity

A useful tool in studying the development of females would be the ability to predict accurately the APHV or MA. Accuracy in either of these predictions would enable researchers, parents, teachers, or physicians to classify a girl as an early, average, or late developer during her childhood and then to assess her progress in growth accordingly. Likewise, as the events of maximum growth and first menstruation neared, the individual could be prepared emotionally for the rapid changes about to occur in her body. This section discusses the prediction of menarche and APHV based on skeletal age, secondary sex characteristics, and body size.

Predictions Based on Skeletal Age

Predictions of MA and APHV based on skeletal age (SA) have been widely used in growth studies. Several investigators have shown that the inclusion of skeletal age in the prediction of MA reduced the error when compared to the use of chronological age (CA) alone (Marshall, 1974; Marshall and de Limongi, 1976). The standard deviation for SA at menarche was .39 years, while that for CA at menarche was .84 years. In Marshall's (1974) study, 85% (50 of 59) of the females experienced menarche when their skeletal age was between 13-14 years. The regression equation was:

$$MA = 13.3 - .68\ (SA-CA),$$

with a residual standard deviation of .656. Frisancho, et al. (1969) correlated menarche with the appearance of the thumb adductor sesamoid (r = .751). The sesamoid appeared an average of twenty-two months before MA. Their regression equation was:

$$MA = .550 + 1.120\ (\text{Appearance of sesamoid}),$$

with a standard error of .14. Nicholson and Hanley (1953) found a correlation of .85 between MA and age at reaching SA 12.75 years. Deming (1957) looked at the fusion of the capitellum of the humerus (first long bone epiphysis to close) and reported a correlation of .93 with MA. The correlation of this epiphyseal fusion with APHV was .93 for females and .86 for males. In addition, correlations with the onset of secondary sex characteristics were .78 (females) and .56 (males). She also found significant sex differences in the timing of the fusion of the capitellum. For females the fusion occurred approximately seven months after PHV; for males the average interval was 17½ months.

Skeletal age seems to have a varied effect on growth parameters. Simmons and Greulich (1943) reported that girls who experienced menarche early had SA greater than CA at menarche, while those who reached menarche at a later age had SA less than CA at menarche. Females delayed in SA also reached PHV at a later age (Onat and Ertem, 1974). Marshall (1974) stated that wide variations occurred in SA at times of PHV and the onset of secondary sex characteristics, with variations as great as five years or more at times.

Skeletal age, then, is intimately related to the various aspects of the growth cycle. However, the use of x-rays to assess development is not practical in most situations. The cost of equipment and personnel to administer and read the individual x-rays would be prohibitive to most school districts wishing to assess growth. Many parents could not afford to have non-insured radiographs taken and, if they could, experienced radiologists usually are not readily available for a reading of SA. Parental permission may be difficult to obtain because of the negative image, fear, and health risk associated with exposure to radiation. Therefore, a safer, quicker, more convenient, less expensive, and practical method of assessing maturity status would be a valuable aid in classifying children in various educational and recreational settings.

Predictions Based upon Secondary Sex Characteristics

The appearance of the secondary sex characteristics has been used to predict ensuing events of the growth cycle. On the average, menarche occurs two years after the breast begins developing and pubic hair appears (Reynolds and Wines, 1948; Tanner, 1952; Marshall and Tanner, 1969). Reynolds and Wines (1948) reported correlations of .86 and .70 between MA and the appearance of the breast bud and pubic hair, respectively. If Marshall and Tanner's (1969) stages of breast development are used, the menarche usually occurs during stages B3 and B4 with the following prediction equation:

$$\text{MA} = 13.46 + .46\ (\text{Age at B2} - 11.17) \pm 1.9 \text{ years.}$$

Because of the large standard error, these authors stated that the age of onset of breast development was not a useful indicator of MA.

Point systems and regression techniques have been used to determine MA. The degree of maturity of the breasts, uterus, pubic and axillary hair, as well as a hormone-cytologic assay have been assessed. Menarche occurred at a mean of thirteen points and B3 stage of breast development (Borsos, et al., 1977). Zacharias , et al. (1970) combined breast budding and appearance of pubic hair and published this regression:

$$\text{MA} = 57.8 + .373\ (\text{Age in months of onset of breast bud}) + .286\ (\text{Age in months of appearance of pubic hair}) \pm 2S,$$

where S equals the standard error of the estimate of 11.1 months. Thus, the 95% prediction interval for any particular female would span 44.4 months.

It appears that the use of the onset of secondary sex characteristics is not a precise predictor of MA. The limits of normal variation for individuals are too great for these events to be a useful or practical tool in the assessment of developmental status. Since the ultimate goal is to be able to divide females into groups of early, average, or late maturers, another combination of growth measures might be more useful in predicting APHV and/or MA.

Predictions Based upon Height, Weight, and Body Build

Significant differences occur among the maturity groups when height, weight, and body build are included in the analyses. Early maturers are consistently taller and heavier than other groups throughout childhood and have greater proportions of muscle, bone, and fat from ages 7-13 years. Conversely, late maturers are usually smaller than early maturers from 6-15 years and have the more linear constitution (Shuttleworth, 1937, 1949a, 1949b; Richey, 1937; Lindgren, 1978). When girls were classified by height at a particular age, significant differences existed between the tall (greater than eighty-fourth percentile) and the short (less than sixteenth percentile) female, with the taller having the earlier menarche (Kantero and Widholm, 1971). Onat and Ertem (1974) noted that the girls who were advanced in height for age reached PHV earlier than shorter individuals. Reynolds and Wines (1948) reported a negative relationship between height at age eight years (H8) and MA, while Deming (1957) obtained a significant, but weak, correlation (-.489) between APHV and H8 for females. However, Tanner, et al. (1976) noted that age of menarche was independent of body size both at onset of the growth spurt as well as at maturity. Lindgren (1978) reported that the mean height and weight of females for each of the three maturation stages differed at PHV but not at menarche.

The inclusion of measures of weight for predicting maturity status should be considered. Onat and Ertem's (1974) weight index for age correlated better with APHV than did their height index for age. They also noted a direct relationship ($r = .30$) between weight attained at PHV and APHV. This should be expected because the greater the age at PHV, the more time those persons have to grow and the heavier they will be at the time of PHV. However, Lindgren (1978) reported that mean height and weight did not differ at peak weight velocity (PWV) nor at MA for early, average, and late maturers, even though there was a significant difference at PHV. She also found that no significant difference existed between APWV and MA among maturity groups classified according to APHV. The average time interval between APWV and MA was $.6 \pm .05$ years. The magnitude of the PWV was the same for early, average, and late developing females. This finding supports that of Frisch and Revelle (1971a, b) who found that early and late maturers gain the same mean amount of weight, about 17 kg, from APMSV to MA. These investigators also reported that the height and weight spurts began one year before the appearance of the secondary sex characteristics and approximately 3.2 years before menarche. They proposed the "critical weight hypothesis" whereby a girl had to attain a certain weight (48kg) in order to experience menarche. This hypothesis has been discredited by other investigators who found that the weight limits were too highly variable to reasonably predict an individual's MA (Lindgren, 1978; Billewicz, et al., 1976; Marshall and de Limongi, 1976; Cameron, 1976; Johnston, et al., 1975; Johnston, et al., 1971).

Lindgren (1978) stated that it is better to consider a critical time of approximately .6 years after PWV when menarche will occur. She showed that the time interval between PWV and PHV differed significantly by .9 years for early maturers, .5 years for average, and .2 years for late females. Mean weights for the three maturity groups differed significantly at each age from 10-16 years. Early maturers also evidenced a consistently larger weight/height index throughout childhood than the late maturers. In 1976, Lindgren reported a correlation of .61 between MA and APWV, while Bodzar (1977) reported significant differences in the weights of menstruating and non-menstruating females.

Body weight alone is not the most critical parameter involved in prediction of menarche (Neyzi and Alp, 1975). Their subjects were divided by percentiles of weight into three groups: (1) less than the twenty-fifth percentile, (2) between the twenty-fifth and seventy-fifth percentiles, and (3) greater than the seventy-fifth percentile. Next, each weight class was divided into three height categories using the same percentile groupings. The results showed that menarche occurred earliest in the "big" girl, whose weight and height both were in the seventy-fifth or higher percentile. The second earliest menarche appeared in females who were in the heaviest weight category and the middle height category ($p < .02$). Menarche showed a relative delay in all low weight groups. These authors concluded that body type rather than body weight per se was an important determinant of onset of menstruation (Neyzi and Alp, 1975).

The various proportions of the body segments have been used often as predictors of maturity level. In the study of Kantero and Widholm (1971), the mesomorphic females reached menarche first, the endomorphs second, and the ectomorphs latest. The menarche of the mesomorph was 4.8 months before that of the endomorph, while 11.4 months separated the date between mesomorphs and ectomorphs ($p < .001$). Kralj-Cercek (1956) found that MA differed according to the body build of the subjects. Those females classified as "feminine" attained menarche at 12.93 years, those in the "medium" category at 13.5 years, while those of linear build had their first menstruation at 14.6 years of age. Bayley (1943) published bi-iliac/height curves for early, average, and late maturers, while another investigator developed the body build index:

$$\frac{\text{sitting height x weight/height}}{\text{shoulder width/hip width}}$$

High values for this index would reflect heavy people with short legs and wide hips. Low values would indicate lean, long-legged individuals with broad shoulders (Deming, 1957). High scores characterize the early maturers, while a low index is reflective of the later developer. However, no significant correlations between APHV and the body build index were found. Jacobson (1954) computed values for three proportions: (1) $\frac{\text{radius length}}{\text{tibia length}}$ (2) $\frac{\text{bi-iliac breadth}}{\text{bi-acromial breadth}}$ (3) $\frac{\text{bi-iliac breadth}}{\text{radius length}}$ He found no differences in scores for these indices between groups divided by MA. However, significant differences in the absolute lengths of the tibia and radius and in a fat factor occurred between the early and late maturing groups. The early maturers had shorter bones and a larger fat factor. McNeill and Livson (1963) accounted for differences in the maturation rate between groups by using the ponderal index (height/cube root of weight) at age eight years. This index was also used by Hillman, et al. (1970) where a higher value indicated a delayed MA ($p < .00005$). Differences in height and weight, in height to weight, and in the height to width ratios also were found among the three maturity groups. It appears that these measures would probably be critical in successfully predicting the developmental status of females.

Recall of Menarche

Menarche is one growth parameter that cannot be measured. Its occurrence must be noted and then calculated as to the girl's age at the time of menarche (MA). If the exact date of her first menstruation is unknown and no longitudinal record has been kept by either the researchers, parents, or girl, it becomes necessary to calculate the menarche on the basis of recall of the event.

The question, then, is how accurate and reliable are menarcheal data obtained by the recall method? Correlations between recalled and actual MA have ranged from .60 to .84 (Damon and Bajema, 1974; Livson and McNeill, 1962; Bergsten-Brucefors, 1976; Barker and Stone, 1936). A large proportion of females recollect MA in terms of whole or half-years. Bergsten-Brucefors (1976) found slight clustering around ± twelve months of actual MA with eleven percent of the girls being in error by exactly ± one year. Thus, it seemed easier to recall the month than the actual year of MA. Because there is a tendency to report MA in whole years, there is a systematic underestimation of actual age at first menstruation (Bojlen, *et al.*, 1954; Livson and McNeill, 1962; Poppleton and Brown, 1966; Zacharias, *et al.*, 1970). For example, a girl might have her menarche anytime during the thirteenth year of her life (twelve years, four months; twelve years, seven months; twelve years, ten months), and each of these ages would probably be reported as twelve years old. The recollective method leads to an average reported MA that is six months to one year lower than the status-quo method. To compensate for this weakness, several investigators have adjusted the recalled MA by + one-half year for the imprecise data--those responses not corroborated by a specific event or date or not stated in exact years and months of age (Livson and McNeill, 1962; Poppleton and Brown, 1966; Zacharias, et al., 1970).

Recall of MA becomes more reliable as the interval of time between menarche and recollection decreases. In 1954, Bojlen, et al. reported that in a group of fourteen year old females, 68% gave precise responses concerning recalled MA; whereas, only 22% of the nineteen year old females knew precise dates of menarche. The correlations between remembered and previously recorded dates are higher (r = .84, .81) when recall is from one to six years after menarche (Barker and Stone, 1936; Bergsten-Brucefors, 1976) when compared to those (r = .75, .60) from a longer interval of 17-39 years after the event (Livson and McNeill, 1962; Damon, 1974).

Summary

The cycle of growth in females was reviewed with respect to four areas: (1) the growth in height, (2) the growth parameters associated with the adolescent spurt, (3) the relationship of menarche to other variables of physical growth, and (4) the reliability of menarcheal data obtained via the recall method.

The distance graph depicts four phases of growth in stature for females. Infancy is a time of rapid growth that preceeds childhood, a period of steady, uniform development when predictions of future growth would be more reliable than those made during infancy. The adolescent period follows childhood and is marked by a sharp increase in height gain. The period surrounding the adolescent growth spurt is one of great change in young people and is a time of great variability in physical characteristics and abilities among individuals. Adulthood is the final phase of the human growth cycle and marks cessation of growth in height.

Because exact onset, intensity, and duration of the spurt are extremely difficult to ascertain via the distance graph, the characteristics of the velocity curve were discussed. The velocity graph shows incremental changes from year to year and, hence, specific parameters of growth such as peak height velocity and onset of the spurt are easily identified. Several characteristics of the growth cycle were defined with relation to the velocity graph, their variability in onset was documented, and techniques for interpolating these records were discussed.

The magnitude of the growth spurt is related to the age at maximum rate of growth. The greatest amount of evidence shows that early maturing females have a significantly more intense spurt than the average or late maturers. Other studies have shown no significant differences in spurt intensity.

Evidence concerning duration of the adolescent spurt and the relationship between age at menarche and age at peak height velocity is inconclusive. Some researchers have reported that the early maturer has a longer spurt than the later maturer, while others have published opposite findings. Investigators have also found variation in length of time between age at peak height velocity and age at menarche. The bulk of the evidence supports the contention that the earlier the time of peak velocity, the longer the interval to menarche. Earlier studies, though, indicated that the late maturing female experienced a longer interval between the two events than the early maturer.

Prediction of menarche and age at maximum growth based on skeletal age, secondary sex characteristics, and body size were discussed. Skeletal age is intimately related to the various aspects of the growth cycle and, when used to predict age at menarche, reduces the error when compared to inclusion of only chronological age. However, the use of x-rays to assess development is not practical in most situations.

The appearance of the secondary sex characteristics has been used to predict ensuing events of the growth cycle, though it appears that their onset is not a precise predictor of menarche. The limits of normal variation for individuals are too great for these events to be a useful or practical tool in the assessment of developmental status.

Significant differences occur among the maturity groups when height, weight, and body build are included in the prediction of menarche and age at peak height velocity. Early maturers are consistently taller and heavier than other groups throughout childhood, while late maturers are generally smaller than early maturers from 6-15 years of age and have the more linear constitutions. Differences in height and weight, in height to weight, and in the height to width ratios among the three maturity groups suggest that these measures would probably be critical in successfully predicting developmental status of females.

Menarcheal data obtained via recall are not entirely accurate. Because there is a tendency to report age at menarche in whole years, a systematic underestimation of actual age at first menstruation occurs. To compensate for this error, data on age at menarche that is not corroborated by a specific event or date should be adjusted by adding one-half year to the reported age.

CHAPTER III

RESEARCH METHODS

The specific aims of this investigation were to (1) determine if combinations of physical measures taken during childhood could be useful in predicting age at peak height velocity and onset of menstruation; (2) investigate differences in the magnitude and duration of the adolescent peak height spurt for early, average, and late maturing females; and (3) examine the relationship between age of menarche and age at peak height velocity among the three maturity groups. Longitudinal data on five parameters of growth and recall data on menarche were used to evaluate developmental patterns and maturation rates of the female subjects. Because individuals can readily be divided into early, average, or late maturers at the onset of adolescence, it seemed appropriate to study the interrelationships of physical characteristics preceeding and surrounding the growth spurt to determine if predictions of maturity could be made from these growth variables.

Background of the Study

The current study was one portion of a larger endeavor, the Motor Performance Study (MPS), that is in its twelfth year of operation at Michigan State University. The MPS is a longitudinal investigation that seeks to determine the influence that physical growth and biological maturity have on motor skill performance. The longitudinal nature of the MPS has resulted in an accumulation of data on rates of growth, maturity, and motor development.

The semi-annual assessment of physical growth in children begins at the age of two years, whereas the assessment of motor performance is begun at approximately five years of age. Table 3-1 lists the thirteen measures of growth and the seven variables of motor performance that are obtained every six months. In addition to those variables, periodic

Table 3-1: Motor Performance Study:
Measures of Physical Growth and Motor Performance

Measures of Physical Growth	Measures of Motor Performance
Weight	Bent arm hang
Standing height	Thirty yard dash
Sitting height	Sit and reach
Biacromial diameter	Jump and reach
Biiliac diameter	Agility shuttle run
Acrom-radiate	Standing long jump
Radio-stylion	Endurance shuttle run
Arm girth	
Thigh girth	
Calf girth	
Triceps skinfold	
Subscapular skinfold	
Umbilical skinfold	

filmings of motor patterns in children and youth have been scheduled as well as assessment of skeletal age via a hand-wrist x-ray. Two programs operate within MPS: (1) the research program whereby data on growth and motor performance are obtained from ages two to twenty years; and (2) the instructional program whereby children age five to fourteen years are taught fundamental motor patterns, sports skills, and dances.

Three broad objectives that guided the program at its inception are still in force today. They are:

1. To provide a research setting for the study of physical growth and motor development during infancy, childhood, and adolescence.

2. To provide a laboratory setting for undergraduate students with majors and minors in physical education for the observation and teaching of elementary school children.

3. To provide an opportunity for the enrollees of the program to learn the sports skills and dances of their culture under the supervision of competent instructors.

Sampling Procedures

Sample selection involved identifying those females whose data were relevant to the present endeavor from those who were members of the MPS. This section first describes the sample of the MPS and then the criteria by which the sub-sample was obtained.

Sample of the Motor Performance Study

The MPS began in January, 1968, with an initial enrollment of eighty children in the instructional program, equally divided between boys and girls, ranging in age from five to eight years. In addition, thirty 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. The pilot operation during the winter and spring terms of 1968 was followed by an expanded summer program during which the age range was extended to include children nine and ten years of age. Concurrently, forty children were added at the kindergarten level. Presently, children are measured starting at age two years until cessation of their growth, while they are enrolled in the skills instruction only from kindergarten through seventh grade.

To date, over 1200 children have been enrolled in the programs. The subjects are primarily white and have a socio-economic status of middle to upper class.

Parents register their child before he/she is two years of age and make an extended commitment to the longitudinal study. In addition, a tuition fee of eighteen dollars per term is assessed to the first child of each family during his/her enrollment in the skills program. Additional children of the same family pay one-half of the usual fee. Therefore, 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 tuition from kindergarten through seventh grade for the instructional program.

Sub-sample of the Motor Performance Study

Because this investigation was delimited to analyses of the growth patterns and measurements of females, the sub-sample was limited to those families enrolled in the longitudinal study and for whom necessary data were available or obtainable. Criteria for inclusion in the sub-sample were (1) growth data were available beginning at age nine years for the subjects, (2) the individual's data encompassed the adolescent growth spurt, and (3) menarche data were obtainable from the subjects. The application of these criteria to the data resulted in a total sample of sixty-five females. Of the total, twenty-one were early maturers, twenty-eight were average developers, and sixteen were late maturers.

Experimental Design

The research model used was designed to compare three groups of females who were divided by APHV into early, average, or late developers.

Multivariant analyses were set up to differentiate among the groups on indices of body build at specific ages during childhood, the magnitude and duration of the peak height spurt, and the time interval between APHV and MA (Table 3-2). In addition, multiple regression and correlation techniques were used to study the predictability of APHV and MA from growth data taken at young ages.

Table 3-2: Research Model

Age at Peak Height Velocity		
Early	Average	Late
X_1	X_1	X_1
X_2	X_2	X_2
X..	X..	X..

X = Various growth parameters
Age at menarche
Peak height of spurt
Duration of spurt
Body build at age nine years

Dependent Variables

The dependent variables used in this study were the measures of growth taken semi-annually, age at menarche, the magnitude of the height spurt, the duration of the growth period, and various combinations of all of these. Several confounding variables may have affected the results. These were diet, illness, or competitive sports' activity. No absolute controls for these factors were set up; however, due to the frequency with which most children were seen and also to the relationships established with the families in the longitudinal program, several checks on these extraneous influences were inherent in the design. First, as noted earlier, the socio-economic status was basically average to upper middle class. Therefore, diet most likely was not a negative factor. Secondly, if a child had been seriously ill for a time, parents usually reported this occurrence at the six-month visit. In addition, extended absence of a child in the instructional program was noted and questioned at the yearly parental conference. Thirdly, the involvement of subjects in highly competitive training programs was noted on their data sheets. Thus, the data of swimmers, for example, could be compared to those who did not compete regularly. It was believed, then, that these possibly confounding influences were controlled as adequately as possible in a longitudinal study.

Independent Variable

Maturation rate (early, average, late) was chosen as the independent variable in this study. Maturity level was identified by first determining the APHV for each girl and then assigning her data to the appropriate group. Because APHV ranges from 10.5-13.5 years, early maturers were defined as those girls with PHV less than 11.5 years, average maturers between 11.5 and 12.5 years, while late developers attained their PHV after 12.5 years (Deming, 1957; Tanner, et al., 1966a; Bock, et al., 1973).

Conduct of Treatments

Protocol for the semi-annual measurements involved several steps. In June-July and December-January, a time was arranged for assessment of each child's growth. Each subject's data record was procured from the files and arranged in order of appointment. A sample form for the recording of growth data can be found in Appendix B. When the subject arrived, current grade in school, chronological age, and the date of measurement were entered onto the form by the recorder. At that time, measurement commenced.

Description of Measurements

For measurement of physical growth each child wore a bathing suit and was barefooted. Measurements were taken on the left side of the subject. All values were read to the nearest millimeter except weight, which was recorded to the nearest pound. A detailed description of the actual measurements follows in the order of their assessment.

1. Weight: The subject stood with arms hanging freely at the sides of the body in the middle of the platform scale.

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

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

4. Biacromial breadth: The subject stood with the back to the examiner. The acromion processes were first palpated with the index fingers. One end of the sliding calipers was placed just to the left acromion process. The free end was moved until it was just to the right of the right acromial process. The caliper was held so that the ends pointed up slightly. No pressure was applied.

5. Biiliac breadth: The subject stood with the back to the examiner. The iliac crests were located by palpation. The points of the caliper were placed on the lateral side of each crest and pressed firmly in order to depress the fat over the bone.

The recorder compared each reading with the previously documented one and, if a discrepancy existed, asked for clarification and/or remeasurement. After completing all measurements, the examiner reviewed the data sheet for possible errors and conducted a short parental conference.

Procurement of Menarche Data

Unlike the growth parameters, menarche data were obtained only once by the recall method. A letter explaining the study and requesting the age and/or date at first menstruation was sent to the girls and/or their mothers. A form was also included for recording the menarche data (Appendix A). Several guidelines (i.e., season of the year, special event) were mentioned in the letter to facilitate the accurate recording of the specific date or time of menarche. Subjects were asked to be as specific as possible regarding year and month of onset. A telephone call was then made to each mother to discuss her and her daughter's willingness to provide the data as well as to prompt accuracy in recording and speed in response. If no data were received within two weeks, a second call was made to remind the subjects. If no data were received after the letter and two telephone calls, the subjects were approached as they came for their next measurements. After that, no further contact was attempted, and individuals who did not comply with the request were excluded from the list of potential subjects. A total of 154 subjects were contacted. Of these, 132 (95 menstruating, 37 non-menstruating) replied to the query for a percentage of 85.7%. As noted previously (p. 38), the application of the criteria for inclusion in the sub-sample resulted in a total sample of 65 females. Thirty records for which MA was obtained revealed incomplete growth data

Processing the Data

After procuring the data, additional steps were followed to ensure accurate analyses. This section will detail the sequence of processing the growth data, then the techniques of preparing the menarche data, and, finally, the procedures for statistical analyses.

Preparation of Data on Physical Growth

Following each measurement period, all data were placed on Holarith cards, verified, and maintained on the subject's data form. Four steps, adapted from Tanner, et al. (1966a), were then taken to determine APHV (Figure 2-4, p. 15).

1. The individual measurements of standing height were plotted as a distance graph.
2. A curve was drawn through the points via linear interpolation.
3. Increments from this distance curve were plotted.
4. A velocity curve was drawn through these points.

After the finalized velocity graph was obtained, the curve was labeled according to the parameters adapted from Largo, et al. (1978) that were discussed in Chapter II (p. 11). These values were also added to the individual's data cards.

Preparation of Data on Menarche

Menarche data were divided into precise and imprecise responses. Precise responses were those that noted a specific date of menarche or had a calculated year and month of menarche. Imprecise data were those that were not calculated specifically. To compensate for the documented tendency for MA to be reported in whole years, six months was added to the MA for each imprecise response. Of the 132 subjects who replied to the survey, ninety-five had attained menarche. Ninety of these (94.7%) recorded precise responses, necessitating adjustments on only five cases, 5.3% of the total. The MA was then added to each subject's card file.

Procedures for Statistical Analyses

All data were analyzed on the Michigan State University Control Data Corporation 6500 (CDC 6500) computer using routines from the Statistical Packages for the Social Sciences (SPSS). Multiple regression and correlation techniques were used to study the predictability of APHV and MA from growth data of childhood. Multivariate analyses (MANOVA) were conducted to differentiate among the three maturity levels on the dependent variables. Discriminant analyses, univariate F's, and step-down F's were examined to identify the dependent measures that contributed to the variances among maturity levels. Scheffé post hoc tests were used to evaluate differences between pairs of means whenever a significant univariant F-ratio was obtained. The 0.05 level of significance was established for the MANOVA and AOV analyses, while the .10 level was used in the Scheffé procedures due to the low power of these multiple comparisons tests.

Summary

A longitudinal design was employed to study the growth and development of sixty-five females. The subjects were a subsample chosen from individuals in the MPS. Measurements were taken at six-month intervals on five indices of growth, and girls were categorized by APHV into early, average, or late maturers. Menarche data were obtained via letter or telephone, adjusted if imprecise, and added to the records. After the data were procured, processed, and checked, they were subjected to multivariate analyses and correlation and regression techniques to determine differences among the maturity levels.

CHAPTER IV

RESULTS AND DISCUSSION

This study investigated the predictability of age at peak height velocity and the onset of menstruation in females from measures of height, weight, and body size taken during childhood at age nine years. In addition, this research effort examined differences in specific aspects of the adolescent growth spurt (i.e., magnitude, duration) among early, average, and late maturing females divided according to their ages at peak height velocity. Data were obtained semi-annually on the subjects during a twelve year longitudinal growth study.

In this chapter, the results will be presented in three sections. First, the findings from the regression analyses that determined the predictability of age at peak height velocity and age at menarche will be reviewed and discussed. Second, the results from the multivariate analyses will be presented and examined in relationship to the three maturity groups. Third, the findings will be discussed and compared to the responses of previous investigators.

Predictability of Age at Peak Height Velocity and Menarche

It was hypothesized that a selected number of childhood measures including height, weight, and breadths can account for a substantial percentage of the variance in age at peak height velocity and age at menarche. Therefore, five absolute measures of growth and four indices of body shape on sixty-five females were used to determine if age at

Table 4-1: Means and Standard Deviations of the Variables Used to Predict Age at Peak Height Velocity and Menarche (n = 65)

Variable	Mean	Standard Deviation
Standing height (9 years)	132.7 cm	5.17 cm
Sitting height (9 years)	70.8 cm	2.53 cm
Biacromial width (9 years)	29.1 cm	1.29 cm
Biiliac width (9 years)	20.5 cm	1.10 cm
Weight (9 years)	28.5 kg	3.89 kg
Ponderal index	13.18	.43
Iliac/height ratio	.15	.01
Trunk breadth index	.71	.03
Body build index	10.75	1.60
APHV	11.96 yr	1.03 yr
MA	13.29 yr	1.18 yr

peak height velocity (APHV) and age at menarche (MA) could be predicted during childhood (Table 4-1). The overall variable means and standard deviations indicate that, in general, the body size indices do not vary greatly throughout the sample. The index of body build (see Chapter 2, page 29) had a standard deviation of 1.60, while the ponderal index showed .43, the trunk breadth measured .03, and the iliac/height ratio .01. Moreover, when the four indices were entered together into a regression analysis separate from the absolute growth measures, none of the ratios made a significant contribution to the prediction of APHV and MA. Consequently, no predictive equations were established ($p > .05$).

The findings indicate that good predictions of APHV and MA may be difficult to obtain from measures of physical growth taken at nine years of age. In general, low relationships existed between all the variables and the ages at PHV and menarche (Table 4-2). Of the four indices used,

Table 4-2: Intercorrelation Coefficients of Growth Measures and Body Size Indices at Nine Years, Age at Peak Height Velocity, and Menarche (n = 65)

	Standing height	Sitting height	Biacromial width	Biiliac width	Weight	Ponderal index	Iliac height	Trunk breadth	Body build	APHV
Sitting height	.84									
Biacromial width	.68	.63								
Biiliac width	.57	.55	.68							
Weight	.67	.67	.68	.70						
Ponderal index	.27	.09	-.09	-.26	-.53					
Iliac/height ratio	-.19	-.08	.21	.70	.24	-.54				
Trunk breadth index	.00	.03	-.21	.58	.18	-.25	.69			
Body build index	.55	.64	.53	.77	.95	-.60	.44	.44		
APHV	-.22	-.16	-.33	-.10	-.16	-.05	.08	.23	-.06	
MA	-.10	-.10	-.37	-.21	-.21	.15	-.15	.13	-.15	.68

the highest correlation obtained was .23 between trunk breadth and APHV. The correlations of the five growth measures with APHV and MA were slightly higher than those of the indices, with the highest coefficient being -.37 between biacromial width and MA. Furthermore, all correlations among the individual growth measures, as well as some among the indices of body shapes, were moderate to high. The correlation between APHV and MA was .68. This result, coupled with the fact that the coefficients of correlations for APHV and MA were similar for all variables, indicate that predictive equations for these two dependent variables probably are similar.

Stepwise multiple regression techniques were used with standing height, sitting height, biacromial width, biiliac width, and weight as the predictor variables of APHV and MA (Table 4-3). The stepwise procedures for predicting APHV showed that weight did not contribute significantly to the regression equation. Biacromial width, followed by biiliac diameter, contributed most to the prediction ($p < .01$). The r^2 statistic reflects that 13.9% of the variance in APHV can be accounted for by these two measures. However, according to the adjusted r^2 (adjusted for changing degrees of freedom with each step), only 11.2% of the variance can be explained by measures of shoulder and hip widths taken at age nine years. Note that even though standing and sitting heights contributed significantly to the regression ($p < .05$), the multiple r and r^2 increased only minutely, and the adjusted r^2 actually decreased. In addition, the inclusion of the two height measures slightly increased the standard error of the estimate (SEE). It seems, then, that of the five growth parameters measured at nine years

Table 4-3: Stepwise Multiple Regression of Predictor Variables on APHV and MA (n = 65)

	Variable	Multiple R	R^2	Adjusted R^2 [a]	SEE	F Ratio	Regesssion Coefficient [b]
Predicting APHV							
	Biacromial width	.332	.110	.096	.978	7.80**	- .379
	Biiliac width	.373	.139	.112	.969	5.02**	.215
	Standing height	.374	.140	.098	.977	3.31*	- .256
	Sitting height	.380	.144	.087	.982	2.52*	.493
	Constant						18.474
Predicting MA							
	Biacromial width	.370	.137	.124	1.119	10.026**	- .514
	Standing height	.421	.177	.150	1.092	6.667**	.519
	Sitting height	.422	.178	.138	1.100	4.414**	.396
	Weight	.424	.180	.125	1.108	3.284*	- .227
	Biiliac width	.425	.181	.111	1.116	2.602*	.532
	Constant						18.121

*$p < .05$
**$p < .01$

[a] Adjusted $R^2 = R^2 - \left(\frac{k-1}{n-k}\right)(1-R^2)$, where k = number of coefficients estimated

[b] for final step in regression

of age, the biacromial and biiliac widths provided the best predictors of APHV, accounting for only 11.2% of the variance. Table 4-4 provides the regression coefficients, the constant, and the standard error of the coefficients (SEC) based on the inclusion of only biacromial and biiliac measures.

Table 4-4: Regression Coefficients of Predictor Variables Selected on the Basis of the Adjusted R^2 Statistic

	Variable	Resgression Coefficient	SEC
Predicting APHV			
	Biacromial width	- .389	.127
	Biiliac width	.216	.149
	Constant	18.822	2.78
Predicting MA			
	Biacromial width	- .510	.144
	Standing height	.624	.361
	Constant	19.837	3.62

The prediction of MA from the five growth parameters showed that a higher percentage of the variance was explained than in the prediction of APHV, but that a larger SEE existed (Table 4-3). All five growth variables contributed significantly to the stepwise regression on MA. However, analysis based on the adjusted r^2 indicated that biacromial width and standing height, with a multiple r of .421, explained the highest amount of variance (15.0%) with the lowest SEE (1.092) (Tables 4-3 and 4-4). These two regression analyses indicated that prediction of APHV and MA from growth variables during childhood were too low and individual variation too high to be practical. Higher multiple r's and percent variances might be found if skinfolds, circumferences, or measures of secondary sex characteristics had been included as predictor variables.

Another regression analysis was run forcing each of the five growth parameters into the prediction of APHV and MA first. After the initial variable was forced into the equation, the program was allowed to enter any of the other growth measures. Results from these regression procedures are shown in Appendix C.

Differences in the Adolescent Growth Spurt among Early, Average, and Late Maturing Females

Five aspects of the adolescent growth spurt were compared in early (EM), average (AM), and late (LM) maturing females to determine (1) if differences in adolescent growth existed among the three groups, and (2) which variables contributed most to the variance. These comparisons by level of maturity enabled the last two research hypotheses to be tested. It was hypothesized that the magnitude and duration of the adolescent growth spurt and the interval of time between APHV and MA would be greatest in the EM females, followed by that of the AM and then LM subjects. Early maturers (n=21) had PHV before 11.5 years of age, AM (n=28) reached PHV between 11.5 and 12.5 years inclusive, and LM (n=16) attained their PHV after age 12.5 years. The intercorrelation matrix of the five dependent variables is shown in Table 4-5. Interval has low correlations with the other four parameters of the growth spurt, while the relationships among the other four parameters range from low to high (.12 - .90).

Spurt height (SH), spurt duration (SD), spurt intensity (SI), peak height velocity (PHV), and the time between peak velocity and menarche (interval) were used as the dependent variables in a one-way

Table 4-5: Intercorrelation Matrix for the Five Dependent Variables of the Adolescent Growth Cycle (n = 65)

	Spurt height	Spurt duration	Spurt intensity	Peak height velocity
Spurt duration	.65			
Spurt intensity	.90	.87		
Peak height velocity	.68	.12	.43	
Interval	.06	.05	.07	-.01

multivariate analysis of variance (MANOVA), with the three levels of physical maturity (EM, AM, LM) as the independent variable. The results revealed that the maturity main effect was significant, $\underline{F}$ (10,116) = 4.90 ($p < .0001$). Univariate and stepdown F tests, as well as discriminant function analyses, were used to determine the relative contributions of the dependent variables to the significant MANOVA main effect (Table 4-6). These three analyses indicated that SH, SD,

Table 4-6: Maturity Main Effect

Dependent variable	Univariate F	Stepdown F	Standardized discriminant Function coeff.
Spurt height	1.55	1.55	1.48
Spurt duration	4.70**	3.93	-1.27
Spurt intensity	2.69	1.34	.03
Peak height velocity	4.56**	9.78***	-1.32
Interval	4.21*	3.19*	- .45

* $p < .05$
** $p < .01$
*** $p < .001$

PHV, and Interval had important roles in differentiating the three maturity groups. The two F analyses showed significant contributions of SD, PHV, and Interval to the overall effect, while the standardized coefficients from the discriminant analyses weighted SH (1.48) highest, followed by PHV (-1.32) and SD (-1.27).

The discrepancy in weightings of the variables between the stepdown and discriminant procedures probably resulted from these tests using slightly different techniques. In the stepdown analysis, each step takes into account the contribution of the preceeding variable before assigning an F value; whereas, the purpose of discriminant analysis is to find the best linear combination of the original variables such that maximum differences among groups will emerge. The values in Table 4-6 show that SH was more important when considered in linear combination with the other dependent variables than when used in a predetermined stepwise procedures. Likewise, interval is a significant variable in the stepdown techniques, but ranks fourth in the best linear combination as determined by discriminant analysis.

The fact that SI contributes little to the significant MANOVA is not surprising. In this study SI was computed by multiplying SH and SD. Therefore, one would expect that after SH and SD have been entered into the analyses, insignificant benefit would be gained by including SI.

Nevertheless, four aspects of the adolescent growth spurt (SH, SD, PHV, Interval) remained important in differentiating the three maturity groups. SD and PHV were weighted highly on all three analyses, while Interval was significant on the F tests and SH was ranked on the discriminant analyses. Although PHV includes SH, both variables were weighted heavily in the discriminant analysis, indicating that even though girls have various height velocities during childhood and at the onset of the spurt, SH and PHV still contribute significantly to differences among EM, AM, and LM.

Examination of the vector means and standard deviations of each dependent variable revealed trends among the levels of maturity on each aspect of the adolescent growth cycle (Table 4-7). In general, the EM females had the highest mean on each variable, followed by AM and then

Table 4-7: Vector Means and Standard Deviations of the Dependent Variables by Maturity Level (n = 65)

		Dependent Variables				
Maturity level		Spurt height (cm)	Spurt duration (yr)	Spurt intensity (cm^2)	Peak height velocity (cm)	Interval (yr)
Early Maturers (n = 21)	$\overline{X}$	3.4	2.58	9.51	8.8	1.77
	SD	1.4	.79	5.83	1.0	.76
Average Maturers (n = 28)	$\overline{X}$	2.8	2.26	6.90	8.1	1.17
	SD	1.1	.80	4.26	.9	.95
Late Maturers (n = 16)	$\overline{X}$	2.7	1.79	5.79	7.8	1.02
	SD	1.8	.75	5.55	1.3	.80
Sample Total (n = 65)	$\overline{X}$	3.0	2.25	7.47	8.2	1.33
	SD	1.4	.83	5.26	1.1	.90

LM. That is, EM had a higher SH, SI, and PHV and a longer SD and Interval than did the AM and LM subjects (Figure 4-1).

Scheffé post hoc procedures were conducted on the values for SD, PHV, and Interval to determine if significant differences existed among the maturity groups on these variables (Table 4-8). On all three

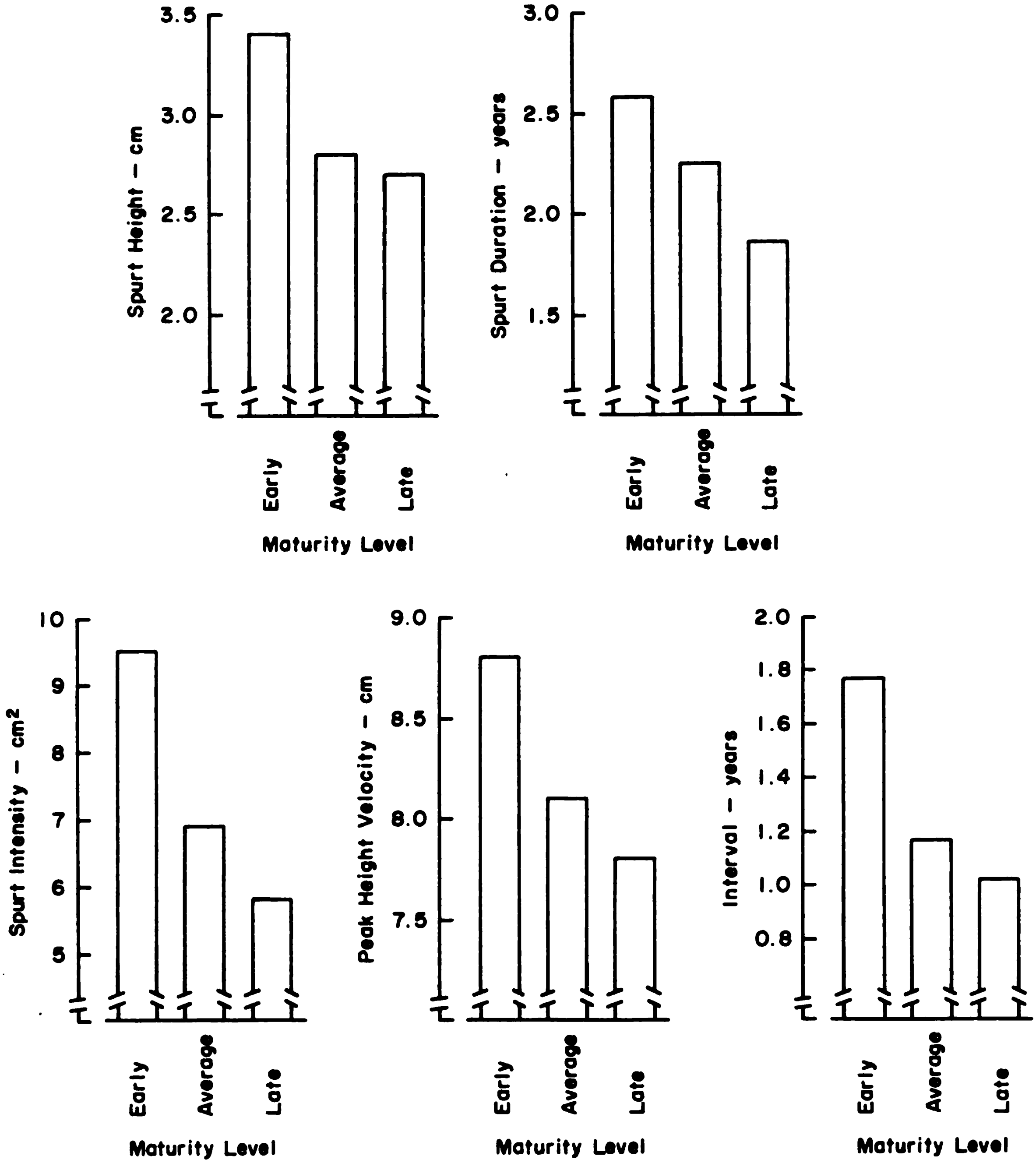

Figure 4-1: Mean Dependent Variable Scores for the Maturity Main Effect

Table 4-8: Results of the Scheffé Post Hoc Tests for the Dependent Variables that Were Affected Significantly by Maturity Level

Dependent Variable	Maturity Level		
	Early	Average	Late
Spurt duration	2.58	2.26	1.79
Peak height velocity	8.8	8.1	7.8
Interval	1.77	1.17	1.02

parameters, EM differed significantly from LM. The EM displayed a significantly higher PHV and longer SD and Interval than the LM. Moreover, the EM females also differed significantly from the AM subjects on PHV and Interval. No statistically significant differences between AM and LM emerged on any of the three variables, though the AM females had higher means than the LM individuals throughout the dependent variables studied.

Discussion

The data analyses on predictability of APHV and MA generally support the findings published by other investigators. The intercorrelation coefficients of APHV and MA with the four body build indices were low, ranging from -.15 to .23. These results agree with those of Deming (1957) and Jacobsen (1954), who found no significant correlations among the growth parameters and no significant differences among maturity groups in scores on the indices. Moreover, an inverse and weak relationship existed between standing height and APHV (-.22) and MA (-.10), agreeing with the data of Reynolds and Wines (1948) and also Deming (1957).

The predictive equations of APHV and MA from this study reveal lower standard errors of the estimate than do those from previous invesigations (Marshall and Tanner, 1969; Zacharias, et al., 1970). These scientists published regressions for MA with an SEE of approximately 1.9 years. The highest SEE from the present data is 1.09 years (predicting MA), while the lowest is .97 years (predicting APHV). Marshall (1974) presented predictions of MA with an SEE of .66, while Frisancho, et al. (1969) indicated an SEE of .14. These regressions included a skeletal age in the analyses. It seems, then, that good predictions of APHV and MA, without the inclusion of SA, or a close estimate of this variable, are too difficult to obtain from data taken during childhood. The estimates would be too highly variable to aid in individual counseling. It appears necessary to determine growth characteristics that could reasonably replace SA in predictive analyses.

In the present endeavor, the interval of time between APHV and MA differed significantly between the early maturing females and those in the two other maturity groups (EM = 1.77 yr, AM = 1.17 yr, LM = 1.02 yr., $\overline{X}$ = 1.33). These results agree closely with those of Lindgren (1978), who found significant differences among the three levels of maturity (EM = 1.6 yr, AM = 1.2 yr, LM = .7 yr, $\overline{X}$ = 1.2 yr), and support the data of Boas (1932) and Onat and Ertem (1974) who reported differences in the interval from APHV to MA by maturity group. Contradictory data have been published earlier by Simmons and Greulich (1943) and Shuttleworth (1937). It would seem that the later developing female is nearer her complete biological maturation at the time of PHV than the early maturer and, therefore, would have a shorter interval until the onset of menstruation.

Data from this investigation on the relationship of APHV to MA lend insight to the understanding of the role of spurt duration in the adolescent growth cycle. Israelsohn (1960) and Marshall and Tanner (1969) determined that menarche occurs at the point of maximum deceleration of growth in height after the PHV. Therefore, if EM have a longer interval to maximum deceleration, then it could be expected that their SD would be longer. The findings of the present study confirm this observation. Spurt duration contributed significantly to the MANOVA main effect by level of maturation and was statistically different between EM (2.58 yr) and LM (1.79 yr) subjects. These data support those of Marubini, et al. (1971) and Onat and Ertem (1974) and contradict the findings of Boas (1932) and Frish and Revelle (1971b), who indicated significant differences in the opposite direction. No significant differences in SD by maturity level were reported by others (Marshall and Tanner, 1969, 1970; Reynolds and Wines, 1948).

Some controversy has existed concerning magnitude of the growth spurt in relationship to time of maximum rate of growth. The greatest amount of evidence shows that EM females have a significantly more intense spurt than the AM or LM, while other studies have depicted either no differences or opposite trends. The present data do not fully clarify these discrepancies concerning spurt height. According to the discriminant analyses, SH is weighted the highest in contributing to the maturity main effect. The univariate and stepdown F's were not significant, though, so post hoc analyses could not be run to determine if the three maturity levels differed significantly. The EM showed the highest mean (3.4 cm), while the AM (2.8 cm) and LM (2.7 cm) had similar means for SH. Apparently, SH contributes to the MANOVA significant effect, but its true contribution might be compounded within that of PHV.

The values of PHV were weighted highly on all three analyses (univariate F, stepdown F, discriminant analysis) as significant contributors to the maturity main effect. In addition, EM (8.8 cm) had significantly higher PHV's than either AM (8.1 cm) or LM (7.8 cm). The fact that EM grow faster during childhood than AM and LM and, therefore, enter the growth spurt at a faster velocity probably helps account for the differences in PHV. It seems, though, that the SH also has an important role in differentiating the three levels of maturity.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purposes of this study were to (1) determine if childhood measures of height, weight, body size, and/or body shape could be used to predict age at peak height velocity (APHV) and the onset of menstruation (MA) in females; (2) investigate differences in the adolescent growth spurt for early, average, and late maturing females; and (3) study the relationship between age of menarche and age at peak height velocity among the three maturity groups.

The following statements summarize the findings:

1. Low relationships existed among all the physical growth variables and the ages at PHV and menarche. The highest coefficient obtained was -.37 between biacromial width and MA.
2. All correlations among the individual growth measures ranked moderate to high (.55 - .84).
3. The indices of body size did not vary greatly throughout the three levels of maturation. None of the ratios made a significant contribution to the prediction of APHV and MA and, consequently, no predictive equations were established that included these indices.
4. Of the five growth parameters measured at age nine years, the biacromial and biiliac widths provided the best

predictors of APHV, accounting for 11.2% of the variance. The regression equation was:

$$APHV = 18.822 - .389 \text{ (Biacromial)} + .216 \text{ (Biiliac)} \pm .969$$

5. The prediction of MA from the growth parameters showed a higher percentage of the variance (15.0%) was explained than in the prediction of APHV, but that a larger standard error of the estimate (SEE) existed. The best regression equation was:

$$MA = 19.837 - .510 \text{ (Biacromial)} + .624 \text{ (Standing height)} \pm 1.092$$

6. A one-way multivariate analysis of variance, with the three levels of physical maturity (early, average, late) as the independent variable, revealed that the maturity main effect was significant ($p < .0001$).
7. Univariate F procedures, stepdown F tests, and discriminant function analyses indicated that spurt height, spurt duration, peak height velocity, and interval had important roles in differentiating the three maturity groups.
8. On all five aspects of the adolescent growth spurt, early maturers displayed higher mean values than average developers who showed larger means than late maturers.
9. Significant differences occurred between early and late maturers for spurt duration, peak height velocity, and interval. Moreover, the early developing females also differed statistically from the average maturers on PHV and interval.

Conclusions

The results suggest the following conclusions:

1. Accurate predictions of APHV and MA, without the inclusion of skeletal age, may be too difficult to obtain from growth data taken at nine years of age. The two regression analyses indicated that prediction of APHV and MA from growth variables during childhood were too low and individual variation too high to be of practical value.
2. Predictive equations for APHV and MA were similar since the correlations between each of these variables with the other growth measures were similar. In addition, the correlation between APHV and MA was .68, which indicates that a prediction of MA that would include APHV would probably be more accurate than that relying only on data at age nine years.
3. Although other studies have shown no differences in spurt duration (SD) by maturity level, these results indicated that SD contributed significantly to such differences, at least between early and late maturing females. Early developers had an adolescent growth cycle of approximately 2.58 years, while that of the late maturers was 1.79 years.
4. The interval of time between peak velocity and menarche decreased as level of maturity moved from early to late. These data, together with those of SD, indicated that early maturers entered their adolescent growth cycle at a younger age but grew for a longer time before

maturity than average or late developers. It would seem that the later developing female is nearer her complete biological maturation at the time of PHV than the early maturer and, therefore, would have a shorter interval until onset of menstruation.

Recommendations

Based on this investigation, the following recommendations are tendered:

1. In order to decrease the SEE in the predictive analyses for APHV and MA, it appears necessary to determine growth characteristics that could reasonably replace skeletal age.
2. It could be beneficial to parents, teachers, physicians, and researchers if regression techniques for MA were utilized that included APHV. These data, in conjunction with that of SD, could be used during the adolescent growth spurt to estimate the time of complete maturity for a female or the amount of growth that could be expected after PHV.
3. The study should be duplicated with a larger sample in order to alleviate the possible biasing effect of deleting subjects who showed an incomplete growth spurt. Some early maturers already were into their spurt by age 9 years, while some later maturers had not yet reached maturity at the completion of the study.

4. A parallel study for males should be conducted to see if the same aspects of the adolescent spurt cause differences among the maturity levels.
5. The variables of spurt intensity and body shape indices probably could be deleted in future investigations.
6. Future research in this area should incorporate various growth measures not only during childhood, but also at PHV, MA, and adulthood.

APPENDICES

APPENDIX A

Letter of Request for Menarche Data

Form for Recording Menarche Data

MICHIGAN STATE UNIVERSITY

DEPARTMENT OF HEALTH PHYSICAL EDUCATION AND RECREATION
MOTOR PERFORMANCE STUDY · WOMEN'S INTRAMURAL BUILDING

EAST LANSING · MICHIGAN · 48824

The Motor Performance Study is currently completing its 11th year of operation. We are in the initial processes of the longitudinal data analyses and are reviewing all records of our subjects. Your daughter's record is excellent and will help us in our attempt to answer many questions in the areas of physical growth and motor performance. A xerox copy of her data record is enclosed with this letter.

As doctoral students specializing in growth and development we are interested especially in the development of females. Our study deals with the relationship of the onset of menstruation in girls to their physical growth and motor performance. We need your help in this project. Would you please record the age and/or the date of your daughter's first menstrual period on the form enclosed with this letter? Try to be as specific as possible, for example, "12 years 9 months; June, 1972." If actual dates cannot be recalled, please list a close approximation in terms of grade in school such as, "first day of 8th grade; late summer between the 6th and 7th grades; etc." If menstruation has not begun, please indicate this under Comments. A second objective of this study is to determine the predictability of the onset of maturity indicators in children from those of their parents; therefore, it would be most beneficial to have your age at first menstruation. Again, please attempt to be as specific as possible in providing the information such as, "14 years, 9 months."

After completing the enclosed form, please return it promptly in the self-addressed, stamped envelope. If you have any questions, please contact either Crystal Fountain or Molly Sapp at 353-9467.

We appreciate your time and thoughtfulness for participating in this project and for your years of diligence to the Motor Performance Study. As always, the data will be maintained in strict confidence. Thank you.

Sincerely,

Crystal Fountain Molly Sapp

With the knowledge and approval of the faculty coordinators,

Vern Seefeldt John Haubenstricker

MOTOR PERFORMANCE STUDY

Form for Menarche Data

Daughter's Name:______________________________ I.D. Number___________

Birthdate:____________________________________

Date of First Menstruation:____________________

Age at First Menstruation:_____________________

Comments (if any):

Mother's Age at First Menstruation:__________________________

Today's Date

Signature of Person Completing Form

APPENDIX B

Form for Recording Growth Data

	SEX	GRADE	CHRONOL. AGE (MO.)	SKELETAL AGE (MO.)	WEIGHT	STANDING HEIGHT	SITTING HEIGHT	BIACROMIAL DIAMETER	BIILIAC DIAMETER	DATE
0-21										
22-27										
28-33										
34-39										
40-45										
46-51										
52-57										
58-63										
70-75										
76-81										
82-87										
88-93										
94-99										
100-105										
106-111										
112-117										
118-123										
124-129										
130-135										
136-141										
142-147										
148-153										
154-159										
160-165										
166-171										
172-177										
178-183										

NAME:

NUMBER: BIRTHDATE:

APPENDIX C

DATA FROM REGRESSION PROCEDURES
THAT FORCED EACH GROWTH VARIABLE
INTO THE PREDICTIVE EQUATION FIRST

Appendix C: Data from regression procedures that forced each growth variable with the predictive equation first.

Predicting APHV		Multiple R	R^2	Adjusted R^2	F Ratio	Regression Coefficient[a]	SEC[b]
Analysis One							
Step 1	Standing height (Forced)	.220	.048	.033	3.20	-.437	.244
Step 2	Standing height	.332	.110	.081	.52	.234	.325
	Biacromial width				4.31*	-.270	.130
Step 3	Standing height	.374	.140	.098	.50	-.737	.330
	Biacromial width				6.42**	-.372	.147
	Biiliac width				2.11	.223	.154
Step 4	Standing height	.380	.144	.087	.29	-.256	.474
	Biacromial width				6.52**	-.379	.148
	Biiliac width				1.92	.215	.155
	Sitting height				.29	.493	.916
Step 5	Standing height	.380	.144	.072	.30	-.263	.480
	Biacromial width				6.30**	-.383	.152
	Biiliac width				1.47	.206	.170
	Sitting height				.24	.467	.945
	Weight				.17	.690	.524

[a] for that step only
* p .05
** p .01

[b] standard error of the coefficient for that step only

Appendix C, continued

Analysis Two							
Step 1	Sitting height (Forced)	.162	.026	.011	1.69	-.657	.505
Step 2	Sitting height	.338	.114	.085	.27	.324	.626
	Biacromial width				6.14**	-.304	.123
Step 3	Sitting height	.374	.140	.098	.48	.140	.637
	Biacromial width				8.06**	-.402	.141
	Biiliac width				1.84	.209	.154
Step 4	Sitting height	.380	.144	.087	.29	.493	.916
	Biacromial width				6.52**	-.379	.148
	Biiliac width				1.92	.215	.155
	Standing height				.29	-.256	.474
Step 5	Sitting height	.380	.144	.072	.24	.467	.945
	Biacromial width				6.30**	-.383	.152
	Biiliac width				1.47	.206	.170
	Standing height				.30	-.263	.480
	Weight				.17	.690	.524
Analysis Three							
Step 1	Biiliac width (Forced)	.100	.010	-.006	.62	-.933	.117
Step 2	Biiliac width	.373	.140	.112	2.10	.216	.149
	Biacromial width				9.33**	-.389	.127

Appendix C, continued

<u>Step 3</u>	Biiliac width	.374	.140	.097	2.11	.223	.154
	Biacromial width				6.42**	-.372	.147
	Standing height				.50	-.737	.330
<u>Step 4</u>	Biiliac width	.380	.144	.087	1.92	.215	.155
	Biacromial width				6.52**	-.379	.148
	Standing height				.29	-.256	.474
	Sitting height				.29	.493	.916
<u>Step 5</u>	Biiliac width	.380	.144	.072	1.47	.206	.170
	Biacromial width				6.30**	-.383	.152
	Standing height				.30	-.263	.480
	Sitting height				.24	.467	.945
	Weight				.17	.690	.524
<u>Analysis Four</u>							
<u>Step 1</u>	Weight (Forced)	.157	.024	.009	1.58	-.413	.329
<u>Step 2</u>	Weight	.344	.118	.090	.59	.329	.428
	Biacromial width				6.62**	-.331	.129
<u>Step 3</u>	Weight	.374	.140	.097	.24	.732	.475
	Biacromial width				8.14**	-.397	.139
	Biiliac width				1.49	.204	.167
<u>Step 4</u>	Weight	.375	.140	.084	.60	.124	.509
	Biacromial width				6.30**	-.380	.151
	Biiliac width				1.49	.207	.169

Appendix C, continued

	Standing height				.85	-.103	.354
<u>Step 5</u>	Weight	.380	.144	.072	.17	.690	.524
	Biacromial width				6.30**	-.383	.152
	Biiliac width				1.47	.206	.170
	Standing height				.30	-.263	.480
	Sitting height				.24	.467	.945
<u>Predicting MA</u>							
<u>Analysis One</u>							
<u>Step 1</u>	Standing height (Forced)	.107	.011	-.004	.73	-.245	.287
<u>Step 2</u>	Standing height	.421	.177	.150	2.99	.624	.361
	Biacromial diameter				12.47**	-.510	.144
<u>Step 3</u>	Standing height	.422	.178	.137	.90	.502	.529
	Biacromial diameter				12.35**	-.516	.147
	Sitting height				.10	.323	.102
<u>Step 4</u>	Standing height	.424	.179	.125	.94	.522	.537
	Biacromial diameter				9.68**	-.498	.160
	Sitting height				.14	.398	.106
	Weight				.91	-.163	.539
<u>Step 5</u>	Standing height	.425	.181	.111	.92	.519	.542
	Biacromial diameter				8.96**	-.514	.172
	Sitting height				.14	.396	.106

Appendix C, continued

	Weight				.15	-.227	.591
	Biiliac diameter				.77	.532	.192
Analysis Two							
Step 1	Sitting height (Forced)	.102	.010	-.005	.66	-.478	.586
Step 2	Sitting height	.408	.166	.139	2.15	.103	.700
	Biacromial width				11.58**	-.466	.137
Step 3	Sitting height	.422	.178	.138	.10	.323	.102
	Biacromial width				12.35**	-.516	.147
	Standing height				.90	.502	.529
Step 4	Sitting height	.424	.180	.125	.14	.398	.106
	Biacromial width				9.68**	-.498	.160
	Standing height				.94	.522	.537
	Weight				.91	-.163	.540
Step 5	Sitting height	.425	.181	.111	.14	.396	.106
	Biacromial width				8.96**	-.514	.172
	Standing height				.92	.519	.541
	Weight				.15	-.227	.591
	Biiliac width				.77	.532	.192
Analysis Three							
Step 1	Biiliac width (Forced)	.207	.043	.027	2.81	-.222	.132
Step 2	Biiliac width	.375	.141	.113	.26	.874	.172

Appendix C, continued

	Biacromial width				7.08**	-.390	.146
<u>Step 3</u>	Biiliac width	.421	.177	.137	.29	.295	.173
	Biacromial width				9.98**	-.523	.166
	Standing height				2.71	.611	.371
<u>Step 4</u>	Biiliac width	.423	.179	.124	.79	.536	.190
	Biacromial width				9.02**	-.512	.170
	Standing height				2.70	.654	.398
	Weight				.99	-.180	.573
<u>Step 5</u>	Biiliac width	.425	.181	.111	.77	.532	.192
	Biacromial width				8.96**	-.514	.172
	Standing height				.92	.519	.542
	Weight				.15	-.227	.591
	Sitting height				.14	.396	.106
<u>Analysis Four</u>							
<u>Step 1</u>	Weight (Forced)	.210	.044	.029	2.92	-.641	.375
<u>Step 2</u>	Weight	.374	.140	.112	.21	.224	.486
	Biacromial width				6.92**	-.385	.146
<u>Step 3</u>	Weight	.422	.178	.137	.49	-.116	.521
	Biacromial width				9.74**	-.495	.159
	Standing height				2.78	.658	.395
<u>Step 4</u>	Weight	.424	.180	.125	.91	-.163	.540
	Biacromial width				9.68**	-.498	.160

Appendix C, continued

	Standing height				.94	.522	.537
	Sitting height				.14	.398	.106
<u>Step 5</u>	Weight	.425	.181	.111	.15	-.227	.591
	Biacromial width				8.96**	-.514	.172
	Standing height				.92	.519	.542
	Sitting height				.14	.396	.106
	Biiliac width				.77	.532	.192

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