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ANTHROPOMETRIC DETERMINANTS OF PERFORMANCE
IN THE STANDING LONG JUMP

presented by

David A. Kinnunen

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Major Professor's Signature

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ANTHROPOMETRIC DETERMINANTS OF PERFORMANCE IN THE STANDING LONG JUMP

by

David A. Kinnunen

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ABSTRACT

ANTHROPOMETRIC DETERMINANTS OF PERFORMANCE IN THE STANDING LONG JUMP

by

David A. Kinnunen

The purpose of this study was to examine the relationship of structural-maturational (SM) variables to performance in the standing long jump from a dynamic systems perspective. The SM variables to be studied were: weight, standing height, sitting height, acrom-radiale length, radio-stylion length, biacromial width, bicristal width, arm girth, thigh girth, calf girth, triceps skinfold, subscapular skinfold, and umbilical skinfold. Derived variables included in the study were: body mass index, sum of skinfolds, triceps + subscapular skinfolds, sit/stand ratio and hip/shoulder ratio. Dynamic systems theory predicts that change results when one or more control parameters are altered (Clark & Phillips, 1993; Peitgen, Jurgens, & Saupe, 1992; Thelen, 1985; Kelso, 1984). Haubenstricker and Branta (1997) suggested that further research into jumping behavior should concentrate on determining the variables, or control parameters, that enhance or limit performance. An analysis of the anthropometric measures on the standing long jump aids in identifying the factors that may drive changes in performance. A systems approach allows us to look at how the many subsystems involved act together to impact performance and at the same time identifies the subsystems where small changes may influence development or performance. In order to fully understand the changes in developing systems, the system sensitive control

parameters (e.g., changes in the muscular-skeletal system, the masses and length of the limbs, or other physical characteristics) that drive the system to reorganization should be examined (Clark, 1986). This study included 487 Caucasian participants, 234 males (47%) and 258 females (53%), a subset of the longitudinal Motor Performance Study (MPS) at Michigan State University. Ages ranged from 7 through 18 years. Data were longitudinal in nature and collected semi annually. Regression analysis suggested the following factors act as control parameters for females at age 7 – radio-stylion length; females at age 12 – triceps + subscapular skinfolds; females at age 16 – sum of skin folds and standing height. The percent variance explained by the variables was 10.6%, 9.5%, and 15.3% respectively. The results for the study suggested the following factors act as control parameters for males the age groups and corresponding factors were: at age 7 – subscapular skinfolds; age 14 – triceps skinfolds, biacromial width and umbilical skinfolds; age 18– triceps + subscapular skinfolds and sitting height. The percent varianv\ce explained by the variables was 11.8%, 25.9%, and 19.4% respectively.

This work is dedicated to my parents, my mother Barbara, and my father James. They gave me so much over the year, I never knew just how much. They continue to do so in my heart. Everything I am or shall ever be I owe to them. I love you both, you are always with me. Most of all, this work is dedicated to Dawn-Kimberly, you never gave up on me. You caught me when I fell and held me up by the strength of your love. For that, and so much more...thank you. Thank you for loving me the way I have always dreamed it could be. You have my love, now, forever, and always....

'....I have promises to keep, and miles to go before I sleep...'
(Robert Frost)

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CHAPTER 1

INTRODUCTION

Rationale

Dynamic systems theory is an attempt to understand and explain complex, nonlinear change over time (Ulrich, 1989; Clark & Phillips, 1993, Thelen & Ulrich, 1991; Crutchfield, Farmer, Packard, & Shaw, 1987; Rosen, 1970). Dynamic systems theory views human motor development as behavior that arises from the collective dynamics of contributing subsystems, including the central nervous system and the musculoskeletal system, and predicts that change may result when one or more control parameters are altered (Clark & Phillips, 1993; Peitgen, Jurgens, & Saupe, 1992; Thelen, 1985; Kelso, 1984). For example, these systems are thought to be dynamic, relational, and multileveled in nature (Fentress, 1986). Systems theory proposes that any new organization, or reorganization, of a system can only come about from perturbations that disrupt the stability of an older system (Brown, 1995; Thelen & Ulrich, 1991; Kelso, Schroner, Scholz & Haken, 1987). These perturbations may include properties of the environment or the organism (Hamilton, Pankey & Kinnunen, 2003; Goldfield, Kay, & Warren, 1993; Newell, 1986). Specifically, they may include environmental surfaces and objects, gravity, the central nervous system, the musculoskeletal system, and the masses and length of the limbs (Kinnunen, 2001; Goldfield, Kay, & Warren, 1993).

The study of motor development from a dynamic systems perspective is still relatively new (Ulrich 1989; Clark & Phillips, 1993). Although physical growth and motor development achievements may not have changed significantly over recent years, further study of the factors influencing growth, development, and performance is needed

(Halverson, 1966; Pipho, 1971; Wilson, 1993). Movement is made possible by the musculoskeletal system (Ford & Lerner, 1999). This system provides the strength and structural stability that allows the body to generate movement. These movements or patterns must be coordinated dynamically with a flow of environmental events, requiring coordination between action and environment (Ford & Lerner, 1992). For example, these patterns are controlled by a complex interaction between the central nervous system and psychological processes (Garcia-Ruiz, Louis, Meakin, & Sander, 1993; Kelso, Holt, Rubin, & Kugler, 1981). These patterns are achieved by combining conceptual information with perceptions regarding the environmental dynamics and the movements or patterns themselves (Ford & Lerner, 1992). Traditional approaches, such as information processing and maturational theories, have not satisfactorily explained the mechanisms of change underlying human development or performance (Thelen, 1986). While motor development tends to follow a sequential order much like physical development, the timing and rate of development varies among individuals (Garrison, 1952; Pipho, 1971). A systems approach allows researchers to look at how the many subsystems involved act together to impact performance and at the same time identifies the subsystems where small changes may influence larger development or performance. Dynamic systems theory holds that one component or subsystem might be the key determinant in forcing a system into some type of change (Haubenstricker & Branta, 1997; Ulrich, 1989).

The use of longitudinal data offers two advantages when employing a dynamic systems perspective. First, because development occurs on such a long time scale, the assembly and tuning processes, such as the central nervous system, the musculoskeletal system, the masses and length of the limbs (Goldfield, Kay, & Warren, 1993), practice, strength, motivational changes, sensory or perceptual abilities, or physical characteristics (Thelen & Ulrich, 1991), may cause change to occur in any of the variables themselves, particularly when looking for the emergence of sudden changes. Secondly, changes in constraints may drive the system changes (Goldfield, Kay, & Warren, 1993), and these changes may be more readily observable with longitudinal research.

Background of the Study

The idea for this study originated in fall of 1993 while observing two seminal figures in the field of motor development discuss and contrast their theoretical perspectives regarding motor skill performance and how it develops and changes over time. It struck me that there must be some type of bridge between the component and composite models of motor development. The motor development writing group at Michigan State provided a number of perspectives concerning motor development and performance, including both the composite and component views, along with the influence of dynamic systems as a means of examining both perspectives. This study is an attempt to look at motor performance from a dynamic systems perspective. Now completing its 36th year, the Motor Performance Study (MPS) was begun in December of 1967. The MPS is a longitudinal project examining the impact of physical growth and biological maturation on motor performance. Data for the MPS are collected semi-annually during June/July and December/January. Semi-annual growth measurements are taken on the participants beginning at the age of two years. Data are collected on thirteen measures of growth. These structural-maturational variables include: weight, standing height, sitting height, biacromial width, bicristal width, acrom-radiale length, radio-stylion length, arm girth, thigh girth, calf girth, triceps skinfold, subscapular skinfold, and umbilical skinfold. Semi-annual motor performance data are also collected on the participants. Data were taken on seven motor performance tasks (flexed arm hang, jump and reach, thirty yard dash, sit and reach, agility shuttle run, standing long jump, and an endurance shuttle run). The subjects continued in the study until they showed little or no growth in height for three consecutive measurement periods.

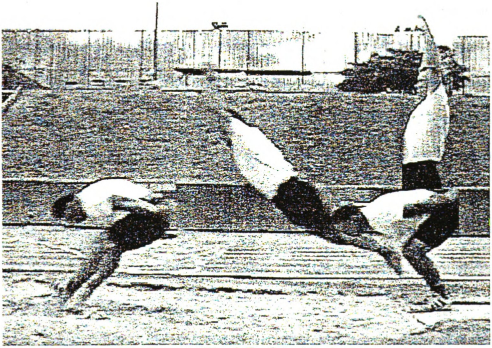
Purpose of the Study

The purpose of this present study was to examine the relationship of structural-maturational (SM) variables to performance in the standing long jump from a dynamic systems perspective. The SM variables studied were: weight, standing height, sitting height, sit/stand ratio, hip/shoulder ratio, acrom-radiale length, radio-stylion length, biacromial width, bicristal width, arm girth, thigh girth, calf girth, triceps skinfold, subscapular skinfold, umbilical skinfold, body mass index, sum of skinfolds, and triceps + subscapular skinfolds. The performance measure was the distance attained on the standing long jump.

Description of the Standing Long Jump

The standing long jump has been studied by a number of researchers. The jump is an explosive movement that requires a coordinated effort of all parts of the body (Gallahue & Ozmun, 2002). A standing long jump is performed, by first taking a starting position behind a mark or line on the ground. This starting position begins with the toes of both feet at the very edge of the takeoff line. The jumpers should bend their knees slightly as they swing their arms in a back and forth rocking motion in order to build as much forward momentum as possible. Inexperienced jumpers may find it difficult not to take a preliminary step forward with one of the feet, almost as a preparatory movement (Gallahue & Ozmun, 2002). The takeoff portion of the jump is accomplished by the simultaneous extension of the knees combined with a vigorous forward arm swing (Phillips, Clark & Petersen, 1985). The forward swing of the arms will help to pull the jumper up and outward. In flight, the legs should be brought forward and extended in order to gain as much distance as possible. Landing should be made with the knees slightly bent and the heels of the feet as even as possible. Overall, the total jump distance evaluates performance in the standing long jump, which is the horizontal distance from the takeoff line to the nearest point of contact made by the heels at landing.

Figure 1- Standing long lump



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Significance of the Study

Traditional research in motor development has focused on describing the actions involved in the development of specific movement patterns. Frequently, these descriptions have been in the form of developmental sequences (Clark, Phillips, & Petersen, 1989; Roberton, 1989a). Over the last century, little longitudinal motor development research has examined the processes underlying changes and movement sequences (Roberton, 1989b). Few contemporary motor development researchers take the opportunity to study age changes, as opposed to age differences, or the processes involved in those changes (Roberton, 1989b).

The principles of dynamic systems suggest that development is not an outcome, but a transitional state. Dynamic systems theorists hold that the primary thrust of development is to generate new structures and behaviors (Peitgen, Jurgens, & Saupe, 1992; Thelen & Smith, 1994). This development is driven by parallel developing subsystems, each with its own trajectory (Thelen, 1988; Thelen & Ulrich, 1991). While in theory each subsystem is an equal contributor, the system as a whole may be more sensitive to changes in certain subsystems rather than in others at any given point in time (Thelen & Ulrich, 1991). As such, certain subsystems may act as control parameters on the system as a whole. These subsystems must therefore change in order to drive the system to reorganize.

For nonlinear systems, certain parameter changes can alter the system's behavior qualitatively. At critical points of reorganization, the system is said to undergo a phase transition. By examining a range of parameters, one can determine the structural stability of particular systems and learn about transitions from one phase to another (Goldfield, Kay, & Warren, 1993; Clark, 1995).

These phase transitions, known in dynamic systems as shifts or bifurcations, generally result from increasing amounts of noise to a system (Peitgen, Jurgens, & Saupe, 1992; Thelen & Smith, 1994). Noise can come from a number of variables, such as practice; strength, motivational changes, sensory or perceptual abilities, or physical characteristics (Thelen & Ulrich, 1991), and may cause change to occur in any of the variables themselves. There may even be critical values within each of the component subsystems where the stability of the entire system is overwhelmed and is driven to reorganize (Gleick, 1987; Peitgen, Jurgens, & Saupe, 1992; Thelen & Smith, 1994). These changing internal or external variables drive the system into new behavioral configurations (Thelen & Ulrich, 1991). These changes may include environmental factors, the central nervous system, the musculoskeletal system, the mass of the body as a whole and the masses and length of the limbs (Goldfield, Kay, & Warren, 1993).

These variables can be regarded as either rate limiters or rate attractors, depending on the particular impact they have on the system as a whole. The changes these variables create, or contribute to, are referred to as phase shifts (Gleick, 1987). Phase shifts may result in increased variability, as the system displays changes from, or wobbles within, its current relatively stable state. These phase shifts may be driven by changes in anthropometric measures that may also impact motor performance. It is the interactions of these factors that determine the next level of reorganization. However, little is known about the relations between these factors and their effect on performance (Thelen, 1986).

The concept of nonlinearity associated with dynamic systems theory suggests such changes in the subsystems may not be smooth. These changes, rather than following a simple trajectory, may occur with spurts, plateaus, and even regressions (Thelen & Smith, 1994). Bernstein held that there must be a close and mutual link between the brain and the mechanical properties of the body, they must act and develop together (Lockman & Thelen, 1993; Bernstein, 1967).

The key for using dynamic systems to study motor development is to identify the variables involved, to describe the associated attractor states as they change over time, and to discover phase shifts where the system is assuming new forms (Thelen & Smith, 1994). The manner in which complex biological systems are coordinated to produce movement remains one of the great-unsolved problems of biology (Fentress, 1986; Schoner & Kelso, 1988). It is important that research in motor development begin to employ a dynamic systems perspective to understand the underlying physical causes of changes in movement (Zernicke & Schneider, 1993). Research by Haubenstricker and Branta (1997) found that age, gender, and the developmental level of the movement patterns used impacted the distance young children achieved in long jumping. Their findings also suggested that factors other than age, gender, and developmental level, such as body size or body fat, might influence jumping performance (Haubenstricker & Branta, 1997). Haubenstricker and Branta (1997) also suggested that further research into jumping behavior should concentrate on determining the variables, or control parameters, that enhance or limit performance. Because one specific component might be the critical element driving a system developmentally, the factors controlling the periods of stability and transition need to be better understood (Haubenstricker & Branta, 1997).

The identification of phase shifts is of importance because it is at these points where we learn more about what drives the system to reorganize (Thelen, 1995). The question becomes what is changing that generates a shift into new forms? Can specific rate attractors or rate limiters, also known as control parameters, be identified through longitudinal anthropometric data? Phase shifts can be driven by changes in certain physical variables (Thelen & Ulrich, 1991); therefore, understanding developmental change through dynamic systems involves identifying the control parameters that enable or drive phase shifts. While it is well established that jumping performance generally improves across the growing years, attempts should be made to determine what factors underlie or drive this improvement (Glassow & Kruse, 1960).

The scale and composition of the body imposes important constraints on movement (Thelen, 1986; Clark, 1995). An analysis of anthropometric measurements on the standing long jump will aid in identifying the factors that may drive changes in performance. The control parameters that are responsible for shifts in the system remain to be identified (Clark, Phillips, & Petersen, 1990; Thelen & Smith, 1994). The objective is to discover the points of change so that underlying control parameters that drive the phase shifts can be identified. In order to understand the changes in developing systems, the system sensitive control parameters (changes in the muscular-skeletal system, the masses and length of the limbs, or other physical characteristics) that drive the system to reorganization should be examined (Clark, 1986).

Research Questions

The primary purpose of the present study was to assess the influence of specific anthropometric characteristics on performance of the standing long jump. Dynamic systems research suggests that it should be possible to identify the various components that may influence the performance of specific motor skills. Little of the motor development research has examined the underlying changes that drive performance. An additional purpose was to attempt to determine if anthropometric control parameters exist, and if so, could they be specifically identified.

A systems approach should allow investigators to examine how many subsystems or factors act together to impact performance and at the same time help to identify the subsystems influencing that performance. Specifically, this investigation attempts to determine if anthropometric control parameters can be identified with regards to the standing long jump. Newell (1984) suggested that various factors can and will greatly influence the task at hand. Dynamic systems theory holds that one component or subsystem or group of subsystems might be the key determinants influencing a system (Haubenstricker & Branta, 1997; Ulrich, 1989). This investigation is an initial step in an attempt to utilize dynamic systems theory to identify variables acting as control parameters and the various subsystems that might influence or control performance in the standing long jump.

Research Questions

This study will address the following questions:

1. To what extent were the selected anthropometric parameters related to the performance variations on the standing long jump (Clark, 1986)?
2. Can the subsystems that influence performance in the standing long jump be identified?
3. Can one or more of the selected anthropometric variables be identified as a control parameter in performance of the standing long jump.

Delimitations of the Study

The study is delimited by the following factors: Only subjects who participated in the Michigan State University Motor Performance Study are included; only subjects with complete data records are included; only Caucasian participants were selected.

Limitations of the Study

The study was conducted under the following limitations:

1. Subjects may not have given their best effort even though assessors provided positive encouragement during the skill testing.
2. Any additional practice, training, or experience by the subjects outside of the testing setting could not be controlled.
3. Data were collected and recorded by different individuals over the length of the study. Although each assessor was given training by a senior investigator some measurement error may be present in the data.

Definitions

Attractor State - a mode of behavior a system prefers above all others (For example, the definitive stages of fundamental motor skills may be viewed as attractor states).

Body mass index - a method for calculating the relationship between weight and stature (weight in kilograms divided by stature in centimeters squared).

Chaos - study of nonlinear systems that change.

Control parameter - a variable that controls changes in performance or the overall collective behavior of the system.

Dynamic systems - the theoretical perspective that new forms of behavior emerge from the cooperative interactions of multiple subsystems.

Fractals - geometric shapes found and used in higher math, nature, chaos theory and dynamic systems.

Girth – the relative diameter.

Growth - an increase in the size of the body as a whole or the size attained by specific parts of the body.

Hip/shoulder ratio – a derived variable, a ratio of the hip width divided by standing height. This measure provides a relative idea about the overall proportions of the subject. Scores would typically fall between .6 and 1.4.

Horizontal decalage – a type of hierarchical system ordering where no one factor or variable lays claim to being in control

Mass – a measure of weight. Mass equals the weight of an object or individual, divided by gravity (32.2 feet per second squared).

Performance portrait - An overview of performance results viewed as a scatter plot, or longitudinal distance curve.

Perturbation - disruptions in stability, can be either natural or induced.

Phase shift – system reorganizations resulting from small changes in one or a few component variables - changes or shifts in performance directly related to changes in the anthropometric measures.

Phase portrait – similar to a performance portrait. May be comprised of scatter plots or distance curves depending on the data being plotted and observed.

Rate attractor - a component that pushes the reorganization of a system or changes in performance.

Rate controller – similar to the control parameter. May be a single variable or a combination of varibles

Rate limiter - a component that prevents or slows the reorganization of a system or changes in performance.

Sit/stand ratio – sitting height divided by standing height, this provides an idea of the relative contribution of the lower body to overall stature.

Skinfold - an indicator of subcutaneous fat, calipers are used to measure the thickness of a double fold of skin and the subcutaneous tissue at various sites.

State space - an abstract construct of a space whose coordinates define the components of a system (Thelen & Smith, 1994).

Sum of skinfolds (sumsf) – a derived variable, a total of the skinfold measurements. This measure is a reflection of the relative level of adipose tissue present.

Trisubsf – a derived variable, triceps + subscapular skinfold. This measure is a reflection of the relative level of adipose tissue present.

CHAPTER 2

REVIEW OF LITERATURE

Background

The standing long jump may be defined as a jump in which the take-off is from both feet and the landing is on both feet simultaneously (Pipho, 1971). It is a somewhat complicated modification of the movement patterns previously established through walking and running. In her study on the development of jumping skills in children, Wilson (1945) observed that a two-foot take-off and landing appeared at about the age of three or four years in a series of short jumps. Hellebrandt, Rarick, Glassow, and Carne (1961) studied the growth and development of horizontal jumping using the standing long jump. Their research indicated that the level of performance is related to a variety of factors, such as height, weight, and fitness. They further suggested that these factors should be identified, specifically those that impact the performance of the standing long jump (Hellebrandt, Rarick, Glassow & Carne, 1961; Pipho, 1971). Quantifying these variables might help in identifying the cause and significance of typical and atypical motor development.

Traditionally, developmental changes in motor ability were attributed to maturational processes in the central nervous system (Bushnell & Boudreau, 1993; McGraw, 1940, 1941, 1943). Although interest in motor development began as part of the field of child development (Roberton, 1989a), the research was primarily descriptive, and closely connected to the question of the effects of maturation versus environment. Pioneering developmental scientists such as Shirley, Gesell, and McGraw spent the 1920s through the 1940s researching how control is gained over movements (Thelen, 1995, 1986a; McGraw, 1940, 1941, 1943; Gesell, 1928, 1933, 1939).

Much of the work was longitudinal, and the appearances of stage-like sequences of new motor milestones were taken as evidence for the hierarchical maturation of the brain (Schneider, Zenicke, Ulrich, Jensen, & Thelen, 1990; Roberton, 1989a; McGraw, 1932). Gesell (1928, 1933, 1939) was particularly clear in assigning developmental control to the changes in the nervous system. Perceptual and social incentives and information-processing theories were also used to explain motor development (Bower, 1974; Bruner, 1973; Zelazo, 1976). Although not recognized at the time, Bernstein's (1923 – translated in 1967) work in the early part of this century also examined the way in which systems helped to organize and control movement. Von Holst conducted other early work regarding interlimb phase control during the 1930s (von Holst, 1973).

Dynamic systems is grounded in the belief that movements are not represented centrally in a motor program, schema, or other form, but are an emergent property of the dynamics of the underlying systems (Abernathy & Sparrow, 1992). From a dynamic systems perspective, motor development is not seen as pre-programmed behavior, rather motor development proceeds due to adjustments and reorganizations of components intrinsic to the functioning motor system (Bushnell & Boudreau, 1993). For the purposes of this study, the components undergoing adjustments and reorganizations consist of the selected anthropometric parameters.

Traditional descriptive or information processing approaches has not satisfactorily explained the underlying mechanisms of change involved in movement (Thelen, 1986). From the traditional points of view, motor development is viewed as a derivative of processes that occur at some higher level. This traditional neuro-maturational perspective is lacking in two ways. First, there is no account for process, of how new form and function are realized over time; and second, there is no consideration for how the central nervous system learns to control limbs and body segments (Schneider, Zenicke, Ulrich, Jensen, & Thelen, 1990). Although the maturation of the central nervous system is certainly essential to motor development, the inherent determinism and singular causality implied by the neuro-maturational perspective has been questioned over the past few years (Clark, Phillips, & Petersen, 1989).

Plasticity

Motor systems remain plastic throughout life, ready to compensate for change (Sporns & Edelman, 1992). There is overwhelming evidence that the emergence of coordinated movements is tied to the growth and maturation of the musculoskeletal system (Schoner & Kelso, 1988). Schneider et al. (1990) confirmed that the development of skill involved the efficient use of inter-segmental dynamics. Other recent findings reveal that well understood neural circuits show a surprising degree of plasticity (Schoner & Kelso, 1988), and may ultimately be related to other concepts of nonlinearity (Peitgen, Jurgens, & Saupe, 1992).

Variations in neuro-structural components were major factors contributing to changes in performance. Edelman (1992) proposed a theory of neuronal group selection (TNGS) to integrate neuro-anatomy, neuro-embryology, and developmental psychology. TNGS holds that in the central nervous system (CNS), categories of actions are self-organizing, in that the system is attracted to one preferred configuration out of many possible states. For example, stages of fundamental motor skills may be thought of as preferred configurations or attractor states. Additionally, TNGS holds that these categories of actions are as dependent on the morphology of non-neural structures as on the CNS (Ulrich, 1989). TNGS places a large emphasis on the structural variability of the brain's circuitry.

During development, neuronal circuits are not precisely wired at a micro anatomical level. Therefore, the brain allows for structural variability that can give rise to dynamic variability in its output. These variant circuits form what Edelman calls neuronal groups (Sporns & Edelman, 1993). These groups are considered to be the basic functional units of selection, and tend to share functional properties and discharge in a temporally correlated fashion (Sporns & Edelman, 1993). These groups have been identified in several cerebral cortical areas (Gray & Singer, 1989; Sporns & Edelman, 1993).

Neuronal groups are arranged in the cortex in neural maps. While these maps may be functionally segregated and occupy specific regions of the cortex, they are coupled through reciprocal long-range connections (Sporns & Edelman, 1993). This reciprocal arrangement between neuronal groups in distant sensory and motor regions gives rise to new dynamic properties and temporal correlations (Sporns & Edelman, 1993).

Neuronal groups are subject to selection when their activation in a given context matches given environmental and internal constraints. Particular groups may be selected for their contributions to specific tasks. Selection in the nervous system is done through synaptic change, leading to the amplification or dimming of neuronal group responses.

This selection ultimately allows for the discrimination and categorization of sensory input and the integration of sensory and motor processes in order to result in adaptive behavior (Sporns & Edelman, 1993). According to Edelman's selection model, stable categories of behavior can emerge over time. As actions are repeated over and over, synaptic connections will be strengthened. Therefore, efficacious movements would be gradually carved out from the myriad of less functional options. Dynamic systems theory predicts that, under such conditions, systems will automatically seek stable solutions (Thelen, 1989).

The study of classic dynamics is concerned with how various forces in a system evolve over time in order to produce motion (Goldfield, Kay, & Warren, 1993). When dynamics are used to analyze the human body and its movements, the segments of the body are approximated as rigid bodies or interconnected links (Zernicke & Schneider, 1993; Bernstein, 1967). The complex multi-joint nature of normal human movement means that results utilizing dynamics are not intuitively obvious, due to the fact there are no simple relationships between the movements of individual segments of the body (Zernicke & Schneider, 1993). Schneider et al. (1989) confirmed Bernstein's concept that becoming skilled involved the efficient use of inter-segmental dynamics.

Dynamic Systems

Systemic research into motor behavior is typically thought to have begun during the 1930s (Bushnell & Boudreau, 1993), with the work of Gesell and McGraw (Gesell, 1933; McGraw, 1940). Although the concept of general systems theory is typically credited to Ludwig von Bertalanffy (Laszlo & Laszlo, 1997; Bertalanffy, 1968; Brown, 1995), some researchers point to the concepts, ideas, and results of the French mathematician Poincare (Peitgen, Jurgens, & Saupe, 1997; Brown, 1995). Poincares' theory of dynamics was concerned with understanding the nature and origin of the properties within a system (Peitgen, Jurgens, & Saupe, 1997; Brown, 1995: Kugler, 1986). Thompson proposed a theory of growth and form, arguing that the form of an object is intimately linked to its dynamic properties (Thompson, 1917/1942; Kugler, 1986). Thompson argued that understanding dynamic properties required an examination of the system's geometry.

Bernstein's work (1967) regarding the coordination and regulation of movement is also viewed as pioneering the concept of dynamic systems theories as they apply to increasing understanding of the organization and plasticity of development (Thelen, 1995). In any event, long before the time of Bernstein and Von Bertalanffy, researchers recognized that there must be a link between the movements of the body and neural control (Schneider, Zernicke, Ulrich, Jensen, & Thelen, 1990).

Since that time, there has been an increasing interest in the area of motor development across the lifespan (Bushnell & Boudreau, 1993). Researchers have attempted to link coordinated human movements to the concepts of nonlinear systems theory (Sporns & Edelman, 1993; Kelso & Tuller, 1984; Schoner & Kelso, 1988). These nonlinear theories imply that coordinated movement is made with a number of interacting and related components, creating a nonlinear system capable of attaining a number of dynamic states (Sporns & Edelman, 1993).

Systems theory developed out of a number of areas of study (Levine & Fitzgerald, 1992), including engineering, mathematics, and biology. In the late 1920s, Cannon (1939) noted that animals seek to maintain their state conditions, even when faced with major variations in their environment. A systems approach to research attempts to view the world in terms of irreducibly integrated systems, focusing attention on both the whole and the complex interrelationships (Laszlo & Laszlo, 1997).

Von Bertalanffy's first statements on the subject date from 1925-1926, at about the same time as Bernstein was beginning to formulate his ideas and theories (Laszlo, 1972a; Laszlo & Laszlo, 1997). Von Bertalanffy recognized relationships between several areas in biology, and in 1937 referred to the concept as general systems theory (Levine & Fitzgerald, 1992). General systems theory stresses looking at wholes composed of many different but interrelated parts or systems (Levine & Fitzgerald, 1992; Peitgen, Jurgens, & Saupe, 1997). Systems theory predicts that transitions from one stable phase to another may not be linear or continuous (Thelen, 1986). Small changes in one element or factor may be a product of the dynamic, relational, multileveled interaction of those systems.

While Von Bertalanffy's work was originally presented in 1937, it was not until after World War II that his first writings on the subject began to be published (Laszlo & Laszlo, 1997; Fivaz, 1997). By the late 1940s and early 1950s, Cannon's animal work began to be linked to other areas of research (Levine & Fitzgerald, 1992) involving biological state changes, feedback and control, and dynamic relationships among variables.

By the early 1960s, systems theory had begun to be recognized as a serious attempt to integrate a variety of theories from across scientific fields (Gleick, 1987; Laszlo & Laszlo, 1997; Peitgen, Jurgens, & Saupe, 1992). An early area of concentration was in the prediction of weather. Edward Lorenz's now famous work attempting to predict long-range weather patterns may have been one of the first studies to utilize what is now referred to as dynamic systems (Gleick, 1987).

During the mid 1960s, Von Bertalanffy and others began to suggest that growth and development could also be examined using dynamic systems theories (Levine & Fitzgerald, 1992). Bernstein's central insight regarding systems was that motor development emerged from continual and intimate interactions between the nervous system and the limbs and body (Lockman & Thelen, 1993). By the early 1970s, researchers argued that developmental change in motor skills resulted from the increased ability to integrate movement subroutines into larger units of action (Clark & Whitall, 1989; Bruner, 1973).

Bernstein's work has had a dramatic effect on the field of motor development. One of Bernstein's theories of motor development is that movement patterns emerge through a dynamic interaction between the organism and the environment (Zernicke & Schneider, 1993). Therefore, movement is not believed to be imposed on the organism by an autonomously developing brain, but blended into the neuromuscular system by interactions with various feedback mechanisms and other forces (Thelen, Zernicke, Schneider, Jensen, Kamm, & Corbetta, 1992).

This dynamic process is one in which functional strategies are formed in the context of change. This change consists of the reorganization of various parameters, including environmental and internal influences, in order to simplify the control required by reducing the number of parameters needing to be coordinated (Zernicke & Schneider, 1993). This reduction of parameters has come to be referred to as reducing the degrees of freedom involved in movement.

Nonlinear dynamic systems demonstrate that motor activity demonstrates periods of regularity and irregularity, demonstrated as stability and instability (Lockman & Thelen, 1993). It is possible these periods of stability and instability are the system's attempt at controlling the degrees of freedom (Schoner & Kelso, 1988; Clark & Philips, 1993).

Dynamic systems theory specifically offers a set of principles for studying the emergence of new forms. It attempts to explain change. Included among these principles are attempts to identify the collective variable involved, the points of transition, and to identify potential control parameters (Thelen & Ulrich, 1991). Without reducing the study to physics, a dynamic system offers a powerful conceptual approach for understanding the interrelationships that exist in motor development (Laszlo & Laszlo, 1997).

By definition, a dynamic system is one that changes over time (Rosen, 1970). In dynamic systems, specific propositions are made about the relative stability or loss of stability (Schoner & Kelso, 1988). An unstable system is said to be in transition, allowing the system to move to another stable attractor state. Unstable systems demonstrate increased variability when compared to stable systems. A system may move into transition when a control parameter crosses a critical threshold. Evidence that a specific parameter acts as a control may be found by looking at that parameter's effect on the system as a whole when the parameter changes (Clark & Philips, 1993).

Dynamic systems theory predicts that change results from the scaling of one or more control parameters (Clark & Philips, 1993), and that a period of instability would occur at the onset of a new form. Then, over time, the system can be expected to stabilize into an attractor state (Clark & Philips, 1993). Esther Thelen, perhaps the most well known proponent of using dynamic systems to study motor development, emphasizes the importance of all the subsystems, rather than a dominant central nervous system (Clark & Whitall, 1989).

Development might be best understood as a temporal sequence of attractor states (Thelen, 1990). The transition from one state, stable or unstable, to another is under the control of any number of developmental control parameters. These control parameters may have a single component or several, and there is no one-to-one relationship between subsystems and their components (Levine & Fitzgerald, 1992). Any one subsystem or component may act as a rate-limiting factor (Soll, 1979; Thelen, 1986). Certain elements related to performance, may change or appear early, and initially seem to be disassociated from the performance in question, or used for another function.

Thelen identifies stable states as attractors, because the system settles into that pattern from a wide variety of initial positions and tends to return to that pattern if perturbed (Thelen, 1995). Thelen believes a developing system is dynamic in that patterns of behavior act as attractor states for the component parts within the environment and task constraints. These attractor patterns are preferred under certain circumstances. Other patterns are possible but performed with more difficulty and are more easily disrupted or perturbed. The relative stability of a behavioral system is a function of its history, current status, the intention of the individual, and the context (Thelen, 1993).

The use of a dynamic systems perspective places an emphasis on process, rather than the more traditional performance variables. Process accounts provide explanations of not just what behaviors are performed, but how they are assembled and how they change over time (Lockman & Thelen, 1993; Whitall & Clark, 1994). The advantage of systems sciences is the potential for providing a cross-disciplinary framework for critical exploration of relationships (Laszlo & Laszlo, 1997). In order to understand a dynamic, relational, multileveled system, it is necessary to try to identify the rate-controlling components involved and their interactions (Thelen, 1986). Performance is the system's product of the changes in status of the individual components. No one component determines the overall performance of the system. However, in combination, one component may support, inhibit, or mask the expression of another component (Thelen, 1986; Schoner & Kelso, 1988; Zernicke & Schneider, 1993). Over time, these relationships may shift and flow, depending on the rate of development of the various components. Because of the dynamic, relational, multileveled relationship of the system, even small changes in one component may alter the entire performance or system (Thelen, 1986; Schoner & Kelso, 1988; Zernicke & Schneider, 1993). Dynamic systems allows us to view how many levels may act together and at the same time identify the subsystems where small changes result in major consequences (Thelen, 1986).

Shifts in long jump performance can be examined to determine if they are influenced by anthropometric measurement data. Performance can be represented in terms of a position in state space (Smith, 1994; Thelen & Smith, 1994). State space is defined as an abstract construct of a space whose coordinates define the components of a system (Thelen & Smith, 1994). Conceptually, it is similar to a three dimensional Cartesian coordinate system. A specific performance, or an average, on the long jump can be located or represented by a point on a graph. A dynamic system refers to this point as existing in state space. A scatter plot can illustrate the individual or group performance. The scatter plot of these performances is made, the locations of the responses are found, and then the performance area is identified (Smith, 1994). These scatter plots, representing state space, serve as an index of the developmental landscape. The shape of this landscape is determined by the location of the various performances on the scatter plot. The size of the performance area indicates the shape of the developmental landscape. An area that appears as a narrow and deep valley indicates that all the performances were similar and a strong attractor or attractors are suggested. A broad shallow plain indicates the performances were scattered widely and a weak attractor, or attractors, is suggested. An overview of the results is referred to as a phase portrait. The parameters responsible for shifts in the system remain to be identified (Thelen & Smith, 1994). The point is to discover the points of change so the underlying control parameters directing the phase shifts can be identified.

Growth and Dynamic Systems

Developmental changes are not planned but come about as the product of a number of developing elements (Thelen, 1995). These elements, or constraints, are typically structural in nature (Newell, 1986) and include variables such as body weight, height, strength, mass, or limb length (Goldfield, Kay, & Warren, 1993; Jensen, Phillips & Clark, 1994). From a nonlinear systems perspective, certain parameter changes can alter the entire system's behavior (Goldfield, Kay, & Warren, 1993; Schoner, Haken & Kelso, 1986). Maturational changes in these constraints differ over the course of growth and development (Goldfield, Kay, & Warren, 1993) resulting in different organization at various times or stages.

Changes in growth and form are particularly evident in infancy, early childhood, and adolescence (Newell, 1986). These changes may have an impact on the constraints involved in action or performance. A major consequence of growth is the change in the absolute and relative size of respective body parts (Newell, 1986; Malina & Bouchard, 1991). These changes in size may act as rate limiters or rate attractors on the constraints of the system. Thelen (1985) noted that components may compete with, inhibit, or facilitate each other with implications for performance, and any one component may act as a rate-limiting factor. Von Hofsten (1989) agreed, implying that when a critical value in size is reached, the stability of a movement pattern is disrupted. In fact, size can be viewed as a scaling factor, if the system is scaled to some critical value; the system changes (Clark, 1986). Thelen suggests physical size might be a sensitive scaling factor, disrupting the entire system when changes occur (Thelen, 1984; Clark, 1986). These overall changes are due to the system reorganizing in response to specific changes in size and mass. This disruption forces the system to find a new more stable state. However, because all aspects of the system are not subject to change, identifying those aspects that actually change and those that do not becomes increasingly important (Von Hofsten, 1989).

One example of this type of change or organization involving growth is the concept of adolescent awkwardness. The term adolescent awkwardness has been used to describe a period of time during the adolescent growth spurt where a temporary disruption in motor performance may occur (Garcia-Ruiz, Louis, Meakin, & Sander, 1993; Malina & Bouchard, 1991). This disruption does not appear universally and does not seem to impact males and females equally. The awkwardness or reorganization may reflect a period of readjustment due to the relatively rapid changes that may be occurring in the body at this time.

Developmental change can be seen as a series of stability, instability, and phase shifts, with change being predicted by a loss of stability (Thelen, 1995). Each component in the system is both cause and product (Thelen, 1995). Bones and muscles are continually in a state of change, although some changes that occur may take place at a slower pace and therefore be more difficult to observe. While dynamic systems theory can provide an explanation for why transitions occur, it cannot tell us when those changes occur, or their time course (Von Hofsten, 1989). The states of the factors feeding into the system at a specific time are generally not known.

While many aspects of motor development have been studied, a logical step would be to define the component elements that may influence performance of specific motor skills (Pipho, 1971). A classic study by Rarick and Oyster (1964) was one of the first to determine that a number of factors might have an influence on performance. This study looked at the effects of physical maturity and muscular strength on motor performance in boys (Rarick & Oyster, 1964; Erbaugh, 1997). Rarick and Oyster found that age, height, and weight had an impact on strength. Espenschade (1963) looked at the relationship of height and weight and motor performance within age groups. Earlier work by Seils (1951) revealed no significant relationship between stature, body weight and performance in the standing long jump. The findings of other studies have been inconsistent with the effects of various factors (Pipho, 1971, Latchaw, 1954, Berg, 1968). Malina (1975) summarized much of the research concerning development and motor performance. Research by Malina indicated that fatness has a negative impact on motor performance in tasks involving movement of the body through space (Malina, 1975; Erbaugh, 1997). Additionally, Malina's work found that body size is positively related to performance on tasks requiring strength.

Further research has examined the influence of somatotype, body composition, and size on motor performance (Slaughter, Lohman, & Misner, 1980). These findings indicated that lean body mass was a key predictor of performance. In 1982, Hensley, East, and Stillwell looked at the relationship between body fatness and motor performance, and found significant performance differences between boys and girls in some tasks.

Erbaugh (1984) investigated the relationship between the physical growth and stability performance of preschool children. Much like Malina's (1975) earlier work, the results of this study found that body composition, diameters, and circumference measurements were the most important variables. Malina and Bushang (1985) examined growth, strength, and motor performance in groups of children from Mexico and Philadelphia and found that little performance variation was explained by a number of anthropometric variables. However, Eoff (1985) found that performance was influenced by structural-maturational variables, specifically, the length and weight of a limb was found to have an effect on overall performance in throwing for both boys and girls.

Developmental change may be linear and gradual, such as the usual growth increments in body weight or size (Thelen, 1992; Thelen & Ulrich, 1991). But developmental change may frequently show discontinuities. A phase shift suggests a transition from one stable mode to another, with the intermediate stage being more unstable and transitory (Turvey & Fitzpatrick, 1993; Kapitianiak, 1990). Only one or a few of the components of the system control parameters can bring about these phase shifts (Thelen, 1992; Thelen & Ulrich, 1991).

The study of motor development and performance from a dynamic systems perspective is still relatively new (Ulrich 1989; Clark & Phillips, 1993). The purpose of this study ass to examine the relationship of structural-maturational variables to performance in the standing long jump from a dynamic systems perspective. Dynamic systems research suggests that it should be possible to identify the various subcomponents that may influence the performance of specific motor skills. A systems approach should allow investigators to examine how many subsystems or factors act together to impact performance and at the same time help to identify the subsystems influencing that performance. In addition, this investigation attempted to determine if anthropometric control parameters could be identified with regards to the standing long jump. Newell (1984) suggested that various factors can and will greatly influence the task at hand. Dynamic systems theory holds that one component or subsystem or group of subsystems might be the key determinants influencing a system (Haubenstricker & Branta, 1997; Ulrich, 1989). This investigation was an initial step in an attempt to utilize dynamic systems theory to identify variables acting as control parameters and the various subsystems that might influence or control performance in the standing long jump.

CHAPTER 3

METHODS

Participants

A sub-sample of 487 participants in the Michigan State University Motor Performance Study (MPS) was chosen for the investigation. The majority (97.5%) of the subjects in the Motor Performance Study are Caucasian; therefore, only Caucasian participants were selected for this study. The subjects included 224 males (46%) and 263 females (54%), ranging in age from 14 months to nearly 23 years of age (M = 10.897) years. The participants selected for this study presented consistent participation records over time, missing no testing or measurement periods. The minimum performance data recorded for a participant selected for this study was five years while the maximum was twenty years. The subjects continue in the study until they show little or no growth in height for three consecutive measurement periods. Semi-annual growth measurements are taken on the participants beginning at the age of two years. Data are collected on thirteen measures of growth. These structural-maturational variables include: weight, standing height, sitting height, biacromial (shoulder) width, bicristal (hip) width, acrom-radiale (upper arm) length, radio-stylion (lower arm) length, arm girth, thigh girth, calf girth, triceps skinfold, subscapular skinfold, and umbilical skinfold.

Semi-annual motor performance data are also collected on the participants beginning at the age of five years. Data are collected on seven motor performance tasks, including: flexed arm hang, jump and reach, thirty yard dash, sit and reach, agility shuttle run, standing long jump, and an endurance shuttle run. For the purpose of this study only the standing long jump was examined. The 487 participants provided a total of 12,752 standing long jump records. .

Data Collection

Structural-maturational data on each subject were obtained prior to performance data. All measurements were taken from the left side of the body. Research suggests the consequences of taking anthropometric measurements on one or the other side of the body is limited and does not seem to be biologically significant (Moreno, Rodríguez, Guillen, Rabanaque, Leon & Arino, 2002). All measurements were rounded to the nearest one half millimeter with the exception of weight, which is rounded to the nearest pound, and skinfolds which were rounded to the nearest half millimeter. Growth and motor performance measurements for participants in the MPS were collected semi-annually (June/July and December/January). Descriptions of how each structural maturational measurement was taken are provided in Appendix A.

During measurement, the subjects were barefoot and wore swimsuits, or shorts and a light shirt. Performance data were obtained after the structural-maturational measures were completed. The motor performance tasks were performed in the following order: flexed arm hang, jump and reach, thirty yard dash, sit and reach, agility shuttle run, standing long jump, and endurance shuttle run. All performance data were collected in a gymnasium setting.

For the purposes of this study, only the long jump was utilized. The protocol for the standing long jump consists of three trials, with the subjects beginning with the toes of both feet placed behind a starting line. A two-foot takeoff and landing are required.

The takeoff is from behind a restraining line on the floor, and the landing is on a two-inch thick mat. Following the jump the measurement is taken with the back of the heels marking the actual distance covered. Distance is rounded to the nearest one/half inch. All of the successful jumps are recorded, with the participant's longest recorded jump being used for this study

Data Analysis

The structural-maturational measures and the additional derived variables of body mass index, sit/stand ratio, hip/shoulder ratio, triceps + subscapular skinfold measurements and sum of skinfolds served as independent variables. The motor performance task, the standing long jump distance, was the dependent variable. All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS Version 10.0/10.4). Descriptive statistics, correlations, and regression analysis were conducted to address the hypotheses and research questions for this study. The significance level for all cases throughout the various analyses was set at the .05 level.

The participants were divided into age groups corresponding with the testing periods plus or minus three months. None of the participants exceeded the age groupings or categories listed, however, certain age groups were subsequently removed from analysis due to extremely low numbers of participants having performance records during those time periods. For the males, the age groupings removed from analysis were 33 - 35. These groupings constituted a total of five subjects being removed from the analysis and represented approximately the ages of twenty one to twenty two years of age. Therefore, the analysis for male participants stops at age group 32, which represents long jump performance from 243 to 248 months or approximately twenty years of age.

For females, the ages removed from analysis were nineteen to twenty years. Twelve subjects were removed from the analysis.

CHAPTER 4

RESULTS

The results of this study are presented in regard to performance on the standing long jump. First, age categories used for analysis are listed with the mean and standard deviations regarding performance on the standing long jump by age category. Second, descriptive statistics for the anthropometric variables are presented. Third, the correlations for the total group, male participants, and female participants are presented. Fourth, regression analyses for the male and female participants are discussed regarding performance on the SLJ performance.

The MPS groupings listed in Table 1 were used for analyses regarding performance in the standing long jump for this study. All numbers represent months in age, i.e., LJ 57-62 refer to long jump performances for a participant or group of participants at 5-years of age. Table 2 presents mean long jump performances for males across the age groups. Table 3 presents means and standard deviation long jump performances for females across the age groups. Table 4 presents means and standard deviations for the anthropometric variables.

Table 1

Age groupings in six month categories

Age category	Long jump record/age in months	Age in months/years
5	LJ 81-86	84 months = 7 years
6	LJ 87-92	
7	LJ 93-98	96 months = 8 years
8	LJ 99-104	
9	LJ 105-110	108 months = 9 years
10	LJ 111-116	
11	LJ 117-122	120 months = 10 years
12	LJ 123-128	
13	LJ 129-134	132 months = 11 years
14	LJ 135-140	
15	LJ 141-146	144 months = 12 years
16	LJ 147-152	
17	LJ 153-158	156 months = 13 years
18	LJ 159-164	
19	LJ 165-170	168 months = 14 years
20	LJ 171-176	
21	LJ 177-182	180 months = 15 years
22	LJ 183-188	
23	LJ 189-194	192 months = 16 years
24	LJ 195-200	
25	LJ 201-206	204 months = 17 years
26	LJ 207-212	
27	LJ 213-218	216 months = 18 years
28	LJ 219-224	

Table 2

Means and standard deviations on the standing long jump for males by age

Long Jump Record/Age in Months		Mean	Standard deviation	N
7	LJ 93-98	36.71	8.19	107
8	LJ 99-104	39.25	6.46	123
9	LJ 105-110	41.56	6.61	139
10	LJ 111-116	43.79	6.89	141
11	LJ 117-122	46.57	7.63	152
12	LJ 123-128	48.96	7.58	169
13	LJ 129-134	50.61	8.31	177
14	LJ 135-140	52.93	7.96	185
15	LJ 141-146	54.51	7.95	193
16	LJ 147-152	56.69	8.95	198
17	LJ 153-158	58.59	7.96	202
18	LJ 159-164	60.67	8.44	204
19	LJ 165-170	61.24	8.54	210
20	LJ 171-176	63.65	8.06	211
21	LJ 177-182	65.46	8.57	214
22	LJ 183-188	66.83	8.23	216
23	LJ 189-194	68.61	8.51	218
24	LJ 195-200	70.94	8.93	216
25	LJ 201-206	73.71	9.04	213
26	LJ 207-212	76.06	8.96	214
27	LJ 213-218	78.90	8.74	218
28	LJ 219-224	81.62	8.83	213

Mean long jump performance increases as the age of the participant increases. There are variations in standard deviation exhibited through out the male age groups. In general, though, the standard deviation increases as age and the number of participants increase.

Table 3

Means and standard deviations on the standing long jump for females by age

Long Jump Record/Age in Months		Mean	Standard deviation	N
5	LJ 81-86	11.00	0.00 **	138
6	LJ 87-92	31.87	4.31	150
7	LJ 93-98	35.37	5.77	163
8	LJ 99-104	37.78	6.16	170
9	LJ 105-110	40.31	6.35	184
10	LJ 111-116	43.48	6.44	192
11	LJ 117-122	45.84	6.63	197
12	LJ 123-128	47.96	7.26	206
13	LJ 129-134	49.98	7.03	211
14	LJ 135-140	51.70	6.69	223
15	LJ 141-146	53.71	6.70	230
16	LJ 147-152	55.57	6.61	240
17	LJ 153-158	57.37	6.62	249
18	LJ 159-164	59.23	6.82	252
19	LJ 165-170	60.51	6.86	254
20	LJ 171-176	62.00	7.18	260
21	LJ 177-182	63.35	6.96	257
22	LJ 183-188	65.11	7.17	253
23	LJ 189-194	66.48	7.16	257
24	LJ 195-200	67.69	7.16	256
25	LJ 201-206	68.51	7.66	258
26	LJ 207-212	69.83	7.39	253
27	LJ 213-218	69.91	7.65	247
28	LJ 219-224	70.46	7.73	252

** - only one valid long jump record for this age group

Mean long jump performance for females increases as the age of the participant increases. There are also variations in standard deviation through out the female age groups. In general, the standard deviation increases as age and the number of participant records increase. The standard deviation for females, in general, is lower than that for males at each age.

Table 4

Means and standard deviations for anthropometric variables

Variable	Total Group M(SD)	Males M(SD)	Females M(SD)
Weight	86.44 (39.68)	93.95 (42.99)	79.68 (35.10)
Standing height	143.64 (25.21)	148.18 (25.89)	139.55 (23.84)
Body mass index	17.87 (2.98)	18.23 (3.01)	17.54 (2.91)
Sitting height	76.35 (11.64)	78.33 (11.87)	74.57 (11.13)
Sit/stand ratio	.53 (.02)	.53 (.02)	.53 (.02)
Biacromial width	31.71 (5.59)	32.78 (5.91)	30.74 (5.10)
Bicristal width	22.53 (4.06)	22.92 (3.93)	22.18 (4.14)
Hip/shoulder ratio	.71 (.04)	.70 (.03)	.72 (.04)
Acrom-radiale length	27.71 (5.40)	28.60 (5.48)	26.91 (5.20)
Radio-stylion length	23.52 (4.63)	24.57 (4.76)	22.57 (4.30)
Arm girth	21.29 (4.11)	22.02 (4.41)	20.64 (3.70)
Thigh girth	40.83 (8.00)	41.51 (8.04)	40.23 (7.91)
Calf girth	28.95 (5.22)	29.71 (5.31)	28.26 (5.05)
Triceps skinfold	10.78 (3.88)	9.77 (3.45)	11.69 (4.01)
Subscapular skinfold	7.38 (3.73)	6.80 (3.22)	7.90 (4.07)
Umbilical skinfold	9.03 (5.88)	8.44 (5.77)	9.57 (5.93)
Triceps/subscapular skinfold	18.16 (6.90)	16.57 (5.88)	19.60 (7.43)
Sum of skinfolds	27.21 (12.25)	25.01 (11.18)	29.17 (12.82)

Group anthropometric variables are presented in order to provide information to compare with the means and standard deviations for both male and female participants. With the exception of the hip/shoulder ratio and skinfold measurements, male means are larger than female means. Female skinfold means were larger than male skinfold means. Sit/stand measurements were exactly the same for all three groups (M = .53, SD = .02). The data were rechecked in order to verify these statistics and seemed to be accurate. This finding is highly suspect and may reflect a statistical anomaly unique and specific to these data or that an error in data gathering or entry is being reflected in both the raw data and subsequent related statistical analyses. Means and standard deviations for females and males by age group are presented in Appendices C and D.

Correlation matrices for the entire group were created in order to determine the inter-relationships between performance on the standing long jump and the selected variables for the female and male participants. Correlations among variables were examined to determine which variables might be the most closely associated with performance on the standing long jump and to avoid any difficulties with colinearity among the variables. Due to the dynamic systems approach of this investigation, age, the variable most strongly correlated with group performance in the standing long jump ($r = .83$), was not included in further analysis. Pearson correlations for the entire group are listed in Table 5. Correlations for each age group, the selected anthropometric variables and performance on the standing long jump are presented in Appendix D. All correlations presented were significant at the .05 level.

Table 5

Group correlations between the standing long jump and the anthropometric variables

	LJ	WT	Stndht	Bmi	Sitht	Sitstnd	Biacrm	Bicrist	Shldrhp	Acrmrad	Rdsty	Armgr	Thigr	Clfgr	Tricp	Subscap	Umbil	Trisub	Sumsf
Long jump	1.0																		
Weight	.75	1.0																	
Standing height	.82	.93	1.0																
Body mass index	.50	.86	.65	1.0															
Sitting height	.81	.94	.98	.69	1.0														
Sit/stand ratio	-.48	.13	-.57	-.27	-.27	1.0													
Biacromial width	.82	.95	.97	73	.97	-.67	1.0												
Bicristal width	.74	.94	.95	.75	.95	-.64	.95	1.0											
Hip/shoulder ratio	-.12	.05	.01	.14	.02	.07	-.07	.22	1.0										
Acrom-radiale length	.80	.93	.98	.66	.97	-.75	.96	.95	.01	1.0									
Radio-stylion length	.81	.93	.98	.67	.97	-.75	.97	.94	-.01	98	1.0								
Arm girth	.67	.94	.85	.90	.86	-.50	.88	.87	.04	.85	.85	1.0							
Thigh girth	.67	.95	.89	.88	.91	.91	.91	.92	.10	.89	.89	.94	1.0						
Calf girth	.70	.96	.91	.85	.92	-.60	.92	.20	.07	.90	.91	.94	.96	1.0					
Triceps skinfold	-.15	.23	.10	.47	.12	-.04	.11	.20	.29	.10	.10	.36	.36	.30	1.0				
Subscapular skinfold	.16	.58	.41	.76	.44	-.15	.45	.53	.28	.42	.41	.65	.64	.59	.64	1.0			
Umbilical skinfold	.12	.09	.56	.40	.42	-.19	.42	.49	.24	.41	.40	.64	.63	.57	.67	.85	1.0		
Trisep +subscapular skinfold	.01	.45	.28	.67	.30	-.10	.30	.40	.31	.30	.28	.56	.55	.49	.91	.90	.83	1.0	
Sum of skinfolds	.06	.52	.35	.73	.37	-.15	.37	.46	.29	.37	.35	.62	.61	.55	.83	.91	.95	.96	1.0

These correlations suggest that the factors strongly correlated with long jump performance include: standing height r = .82, biacromial width r = .82, sitting height r = .81, radio-stylion length r = .81, acrom-radiale length r = .80, weight r = .75, and bicristal width r = .74. Dynamic systems theory suggests that strong correlations may be indicators of the existence of system control parameters (Kugler, 1986; Von Hofsten, 1989; Van Geert, 1994). All of the factors correlated with performance in the standing long jump to some degree with the exception of triceps and subscapular skinfolds combined which had a correlation of r = .01. Negative correlations were found for three factors: sit/stand (the ratio between sitting and standing height) r = -.48, triceps skinfold r = -.15, and hip/shoulder ratio r = -.12.

A number of strong inter-correlations exist among the anthropometric factors. Weight was strongly associated with calf girth (r = .96), biacromial width and thigh girth (both r = .95), bicristal width, sitting height and arm girth (all r = .94), and other measures of growth and maturation (standing height, acrom-radiale length, radio-stylion length, and body mass index). Standing height was strongly correlated with sitting height, acrom-radiale length, and radio-stylion length (all r= .98), biacromial width (r = .97), calf girth (r = .91). Body mass index was strongly correlated with arm girth (r = .90). Sitting height was correlated with biacromial width, acrom-radiale length, and radio-stylion length (all r = .97), bicristal width (r = .95), calf girth (r = .92) and thigh girth (r = .91). Sit stand ratio was positively correlated with thigh girth (r = .91). Biacromial width was correlated with radio-stylion length (r = .97), acrom-radiale length (r = .96), bicristal width (r = .95), calf (r = .92) and thigh girth (r = .91). Bicristal width was most strongly correlated to acrom-radiale length (r = .95), radio-stylion length (r =

.94) and thigh girth (r = .92). Acrom-radiale length was most strongly correlated with radio-stylion length (r = .98) and calf girth (r = .90). Radio-stylion length was most strongly correlated with calf girth (r = .91). The strongest correlations for arm girth were found with both thigh and calf girth (both r = .94). Thigh girth was most strongly correlated with calf girth (r = .96). Triceps skinfold measurements were strongly correlated with triceps + subscapular skinfolds (r = .91). Subscapular skinfold correlated the highest with sum of skinfolds (r =.91) and triceps + subscapular skinfolds (r = .90). Umbilical skinfold correlated the highest with sum of skinfolds (r = .95). Triceps + subscapular skinfolds also correlated the highest with sum of skinfolds (r= .96).

Correlations for males (Table 6) suggest that the factors most directly related to male performance in the standing long jump include: standing height r = .84, biacromial width r = 85, sitting height r = .84, radio-stylion length r = .83, acrom-radiale length r = .82, weight r= .79, and bicristal width r= .81. All of the factors correlated with performance in the standing long jump to some degree with the exception of triceps + subscapular skinfolds which had a correlation of r = .01. Negative correlations were found for three factors: sit/stand (the ratio between sitting and standing height) r = -.46, triceps skinfold r= -.21, and hip/shoulder r = -.26.

Table 6

Correlations between the standing long jump and the anthropometric variables: Males

	LJ	WT	Stndht	Bmi	Sitht	Sitstnd	Biacrm	Bicrist	Shldrhp	Acrmrad	Rdsty	Armgr	Thigr	Clfgr	Tricp	Subscap	Umbil	Trisub	Sumsf
Long jump	1.0																		
Weight	.79	1.0																	
Standing height	.84	.94	1.0																
Body mass index	.59	.88	.69	1.0															
Sitting height	.84	.95	.98	.73	1.0														
Sit/stand ratio	-.46	-.56	-.74	-.29	-.61	1.0													
Biacromial width	.85	.96	.97	.76	.98	-.65	1.0												
Bicristal width	.81	.95	.96	.77	.96	-.65	.96	1.0											
Hip/shoulder ratio	-.26	-.21	-.24	-.13	-.25	.14	-.33	-.08	1.0										
Acrom-radiale length	.82	.93	.99	.70	97	-.75	.97	.96	-.24	1.0									
Radio-stylion width.	83	.94	.99	.71	.97	-.74	.97	.95	-.26	.99	1.0								
Arm girth	.73	.96	.87	.92	.89	-.49	.90	.89	-.21	.87	.87	1.0							
Thigh girth	.73	.96	.91	.89	.92	-.49	.92	.92	-.20	.91	.91	.95	1.0						
Calf girth	.75	.96	.92	.87	.92	-.59	.93	.93	-.20	.91	.92	.94	.97	1.0					
Triceps skinfold	-.21	.08	-.03	.30	-.04	-.60	-.04	.02	.08	.01	-.01	.20	.19	.15	1.0				
Subscapular skinfold	.24	.60	.44	.75	.47	-.18	.48	.51	.01	.45	.45	.67	.63	.60	.55	1.0			
Umbilical skinfold	.13	.52	.38	.69	.38	-.22	.39	.43	.04	.39	.39	.60	.59	.54	.65	.84	1.0		
Triceps + subscapular sf	.01	.38	.23	.59	.23	-.12	.24	.29	.11	.24	.24	.48	.46	.41	.89	.87	.84	1.0	
Sum of skinfolds	.08	.47	.31	.67	.32	-.18	.33	.37	.08	.33	.33	.56	.55	.50	.80	.89	.96	.96	1.0

These correlations suggest that the factors most directly related to male performance in the standing long jump include: standing height r = .84, biacromial width r = 85, sitting height r = .84, radio-stylion length r = .83, acrom-radiale length r = .82, weight r= .79, and bicristal width r= .81. All of the factors correlated with performance in the standing long jump to some degree with the exception of triceps + subscapular skinfolds which had a correlation of r = .01. Negative correlations were found for three factors: sit/stand (the ratio between sitting and standing height) r = -.46, triceps skinfold r= -.21, and hip/shoulder r = -.26.

A number of strong correlations were revealed among the anthropometric factors themselves. Weight was strongly associated with calf girth (r = .96), biacromial width (r = .96), thigh girth (r = .96), bicristal width (r = .95), sitting height (r= .95), and arm girth (r = .96). Standing height was strongly correlated with sitting height (r =.98), acrom-radiale and radio-stylion length (both r= .99), biacromial width (r = .97), bicristal width (r = .96), calf girth (r = .92), and thigh girth (r = .91). Body mass index was strongly correlated with arm girth (r = .92). Sitting height was correlated with biacromial width (r = .98), acrom-radiale and radio-stylion length (both r = .97), bicristal width (r = .96), calf girth (r = .92) and thigh girth (r = .92). Biacromial width was correlated with radio-stylion length (r = .97), acrom-radiale length (r = .97), arm girth (r = .90), calf (r = .93) and thigh girth (r = .92). Bicristal width was most strongly correlated with acrom-radiale length (r = .96), radio-stylion length (r = .95), thigh girth (r =. 92) and calf girth (r = .93). Acrom-radiale length was most strongly correlated with radio-stylion length (r = .99), thigh and calf girth (both r = .91). Radio-stylion length was most strongly correlated with thigh girth (r = .91) and calf girth (r = .92). The strongest correlations for arm girth were

Table 7

Correlations between the standing long jump and the anthropometric variables: Females

	LJ	WT	Stndht	Bmi	Sitht	Sitstnd	Biacrm	Bicrist	Shldrhp	Acrmrad	Rdsty	Armgr	Thigr	Clfgr	Tricp	Subscap	Umbil	Trisub	Sumsf
Long jump	1.0																		
Weight	.67	1.0																	
Standing height	.79	.92	1.0																
Body mass index	.39	.85	.61	1.0															
Sitting height	.77	.94	.99	.66	1.0														
Sit/stand ratio	-.50	-.57	-.75	-.24	-.64	1.0													
Biacromial width	.77	.94	.97	.69	.97	-.70	1.0												
Bicristal width	.71	.96	.95	.74	.96	-.63	.96	1.0											
Shouldrhip ratio	.16	.41	.30	.42	.34	-.03	.23	.50	1.0										
Acrom-radiale length	.77	.92	.99	.63	.97	-.76	.97	.95	.30	1.0									
Radio-stylion length	.77	.93	.99	.63	.97	-.76	.97	.95	.30	99	1.0								
Arm girth	.54	.94	.82	.90	.84	-.51	.85	.87	.38	.82	.83	1.0							
Thigh girth	.61	.96	.89	.87	.90	-.56	.91	.92	.38	.88	.89	.95	1.0						
Calf girth	.64	.96	.90	.84	.92	-.59	.92	.93	.38	.90	.90	.94	.96	1.0					
Triceps skinfold	.03	.50	.31	.69	.34	-.11	.35	.40	.28	.32	.32	.65	.56	.53	1.0				
Subscapular skinfold	.20	.68	.46	.83	.50	-.18	.52	.59	.40	.47	.48	.75	.69	.66	.69	1.0			
Umbilical skinfold	.20	.67	.47	.82	.51	-.21	.52	.58	.37	.48	.49	.75	.70	.66	.68	.86	1.0		
Triceps + subscapular sf	.12	.65	.42	.83	.45	-.16	.47	.54	.37	.43	.43	.76	.68	.65	.92	.92	.84	1.0	
Sum of skinfolds	.16	.69	.46	.86	.50	-.19	.51	.58	.38	.47	.48	.79	.72	.68	.85	.93	.95	.97	1.0

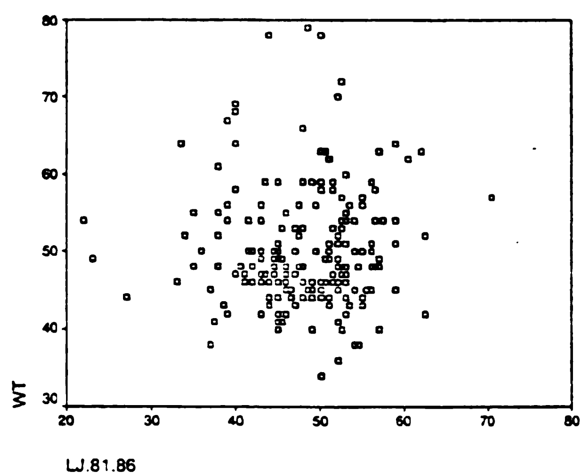
Correlations for females (Table 7) suggest that the factors strongly correlated with female long jump performance include: standing height r = .79, biacromial width r = .77, sitting height r = .77, radio-stylion length r = .77, acrom-radiale length r = .77, weight r = .67, and bicristal width r= .71. All of the factors correlated with performance in the standing long jump to some degree, while the sit/stand ratio had a negative correlation (r = -.50)

A number of strong correlations were revealed among the anthropometric factors themselves. Weight was strongly associated with bicristal width (r = .96), thigh and calf girth (both r = .96), biacromial width (r = .94), arm girth (r = .94), sitting height (r = .94), standing height (r = .92), acrom-radiale length (r = .92) and radio-stylion length (r = .93). Standing height was strongly correlated with sitting height, acrom-radiale length, and radio-stylion length (all r= .99), biacromial width (r = .97), bicristal width (r = .95), calf girth (r = .90). Body mass index was strongly correlated with arm girth (r = .90). Sitting height was correlated with biacromial width (r = .97), acrom-radiale length, and radio-stylion length (both r = .97), bicristal width (r = .96), calf girth (r = .92) and thigh girth (r = .90). Biacromial width was correlated with radio-stylion length (r = .97), acrom-radiale length (r = .97), bicristal width (r = .96), calf (r = .92) and thigh girth (r = .91). Bicristal width was most strongly correlated to acrom-radiale length (r = .95), radio-stylion length (r = .95), thigh girth (r =. 92) and calf girth (r = .93). Acrom-radiale length was most strongly correlated with radio-stylion length (r = .99) and calf girth (r = .90). Radio-stylion length was most strongly correlated with calf girth (r = .90). The strongest correlations for arm girth were found with thigh girth (r = .95) and calf girth (r = .94). Thigh girth was most strongly correlated with calf girth (r = .96). Triceps skinfold measurements were strongly correlated with triceps + subscapular skinfolds (r = .92).

Subscapular skinfold correlated the highest with sum of skinfold (r =.93) and triceps + subscapular skinfolds (r = .92). Umbilical skinfold correlated the highest with sum of skinfolds (r = .95). Triceps + subscapular skinfolds also correlated the highest with sum of skinfolds (r =.97).

No discernible patterns were apparent within the correlations that would indicate that performance in the standing long jump was being determined by changes in the selected variables. Random individual plots and group plots for males and females were created for each of the variables and performance on the standing long jump. In dynamic systems, an overview of performance can be viewed as a scatter plot, and are referred to as performance portraits. An example of a performance portrait for 7-year-old females comparing performance on the standing long jump by weight is presented in Figure 2. Shifts in long jump performance can then be examined to determine if any influence by anthropometric measurement data reveals itself (Smith, 1994; Thelen & Smith, 1994).

Figure 2 – Sample scatter plot/performance portrait



Because no discernible patterns were apparent from the scatter plots (Figure 2) or the longitudinal changes across variables (Appendix E), it was determined that further analysis should include a representative selection of age groups for male and female participants. The selected groupings were based on an age in childhood (age 7 years), age at peak height velocity (12 years of age for females and 14 years of age for males) and two years post peak height velocity (16 years of age for females and 18 years of age for males). The 7-year-old age group was selected for analysis as a breakpoint between early and late childhood, an age at which the participants will have had several years experience in the test protocol. The 12 and 14 year ages were selected as a time of major growth and maturational change. As these times are close to peak height velocity, motor performance is the most variable. The 16 and 18 year old ages were selected as a time near the end of growth and performance would be more stable.

Additional correlation matrices were created in order to determine the relationships between performance on the standing long jump and the selected variables for the female and male participants. These correlations were between performance on the standing long jump, the selected anthropometric variables, and the specific age groups selected for both males and females. Correlations among variables were examined to determine which variables had the highest correlation with performance on the standing long jump. In addition, the variables selected displayed the lowest degree of colinearity with and among the other variables. The age group matrices for females are displayed in Tables 8 through 10, while those for males are shown in Tables 11 through 13.
All correlations were significant at the .05 level. Age group correlation matrices can be found in Appendix F.

Table 8

<u>Correlations between the standing long jump and the anthropometric variables: 7-year-old females</u>

	LJ	WT	Stndht	Bmi	Sitht	Sitstnd	Biacrm	Bicrist	Shldrhp	Acrmrad	Rdsty	Armgr	Thigr	Clfgr	Tricp	Subscap	Umbil	Trisub	Sumsf
Long jump	1.0																		
Weight	.03	1.0																	
Standing height	.79	.77	1.0																
Body mass index	.02	.81	.26	1.0															
Sitting height	.08	.73	.87	.31	1.0														
Sit/stand ratio	.08	-.19	-.40	.06	.10	1.0													
Biacromial width	.13	.72	.68	.47	.61	-.23	1.0												
Bicristal width	.13	.70	.66	.46	.64	-.15	.69	1.0											
Hip/shoulder ratio	.01	.05	.05	.03	.10	.08	-.30	.47	1.0										
Acrom-radiale length	.04	.70	.83	.30	.64	-.47	.67	.61	-.01	1.0									
Radio-stylion length	.10	.70	.83	.31	.66	-.45	.66	.57	-.04	.83	1.0								
Armgirth	-.01	.84	.49	.84	.48	-.08	.52	.49	.03	.47	.42	1.0							
Thigh girth	-.07	.86	.51	.83	.48	-.14	.53	.53	.06	.49	.45	.88	1.0						
Calf girth	-.07	.85	.57	.79	.52	-.17	.56	.55	.05	.49	.47	.81	.86	1.0					
Triceps skinfold	-.15	.46	.17	.53	.16	-.03	.19	.15	-.04	.19	.08	.64	.58	.49	1.0				
Subscapular skinfold	-.14	.53	.18	.63	.17	-.05	.23	.21	.01	.18	.13	.63	.60	.49	.62	1.0			
Umbilical skinfold	.13	.62	.27	.67	.27	-.03	.25	.21	-.01	.23	.22	.68	.67	.55	.56	.79	1.0		
Triceps + subscapular sf	-.16	.53	.19	.63	.18	-.04	.23	.19	-.02	.21	.11	.70	.65	.54	.94	.84	.72	1.0	
Sumof skinfolds	-.16	.62	.24	.70	.24	-.04	.25	.21	-.01	.23	.17	.75	.71	.58	.84	.88	.91	.94	1.0

Table 9

Correlations between the standing long jump and the anthropometric variables: 12-year-old females

	LJ	WT	Stndht	Bmi	Sitht	Sitstnd	Biacrm	Bicrist	Shldrhp	Acrmrad	Rdsty	Armgr	Thigr	Clfgr	Tricp	Subscap	Umbil	Trisub	Sumsf
Long jump	1.0																		
Weight	-.17	1.0																	
Standing height	.03	.69	1.0																
Body mass index	-.24	.88	.28	1.0															
Sitting height	.01	.75	.87	.44	1.0														
Sit/stand ratio	-.04	.07	-.29	.28	.21	1.0													
Biacromial width	.07	.73	.72	.52	.70	-.07	1.0												
Bicristal width	-.10	.80	.67	.64	.72	.06	.72	1.0											
Hip/shoulder ratio	-.22	.38	.20	.36	.29	.16	-.01	.68	1.0										
Acrom-radial length	-.01	.62	.86	.33	.69	-.36	.69	.65	.21	1.0									
Radio-stylion length	.01	.67	.86	.35	.68	-.39	.69	.60	.15	.86	1.0								
Arm girth	-.14	.82	.37	.86	.47	.17	.52	.58	.29	.37	.40	1.0							
Thigh girth	-.21	.90	.47	.91	.56	.16	.59	.68	.36	.47	.47	.85	1.0						
Calf girth	-.18	.91	.55	.86	.60	.08	.63	.68	.32	52	.55	.82	.89	1.0					
Triceps skinfold	-.42	.60	.16	.70	.23	.12	.27	.40	.29	.19	.19	.70	.68	.62	1.0				
Subscapular skinfold	-.37	. 72	.18	.80	.34	.21	.39	58	.41	.24	.25	.68	.73	.66	.73	1.0			
Umbilical skinfold	-.38	.69	.20	.80	.29	.17	.34	.47	.32	.24	.24	.71	.74	.65	.73	.84	1.0		
Triceps + subscapular sf	-.43	.71	.20	.81	.30	.18	.35	.53	.38	.23	.23	.74	.76	.69	.93	.93	.84	1.0	
Sum of skinfolds	-.43	.73	.21	.84	.31	.18	.36	.53	.37	.25	.25	.76	.78	.70	.87	.92	.95	.97	1.0

Table 10

Correlations between the standing long jump and the anthropometric variables: 16-year-old females

	LJ	WT	Stndht	Bmi	Sitht	Sitstnd	Biacrm	Bicrist	Shldrhp	Acrmrad	Rdsty	Armgr	Thigr	Clfgr	Tricp	Subscap	Umbil	Trisub	Sumsf
Long jump	1.0																		
Weight	.30	1.0																	
Standing height	.44	.70	1.0																
Body mass index	.01	.78	.12	1.0															
Sitting height	.38	.71	.82	.28	1.0														
Sit/stand ratio	-.20	-.14	-.49	.23	.08	1.0													
Biacromial width	.47	.75	.72	.42	.67	-.23	1.0												
Bicristal width	-.11	.53	.39	.39	.42	-.04	.41	1.0											
Hip/shoulder ratio	-.53	-.19	-.29	-.03	-.22	.18	-.53	.54	1.0										
Acrom-radial length	.31	.64	.83	.17	.62	-.51	.65	.43	-.20	1.0									
Radio-stylion	.45	.68	.88	.19	.64	-.57	.74	.32	-.37	.84	1.0								
Arm girth	.27	.84	.38	.84	.47	.05	.58	.32	-.24	.37	.43	1.0							
Thigh girth	.04	.76	.24	.85	.36	.12	.41	.42	.01	.28	.25	.74	1.0						
Calf girth	.17	.82	.45	.76	.50	-.03	.54	.42	-.11	.40	.44	.72	.76	1.0					
Triceps skinfold	-.50	.18	-.20	.44	-.08	.23	-.14	.24	.34	-.08	-.21	.28	.40	.25	1.0				
Subscapular skinfold	-.42	.31	-.18	.59	.01	.34	-.02	.32	.31	-.09	-.18	.39	.50	.31	.66	1.0			
Umbilical skinfold	-.36	.39	-.08	.62	.05	.22	.04	.27	.21	-.01	-.06	.46	.49	.36	.63	.78	1.0		
Triceps + subscapular sf	-.51	.26	.26	.56	-.05	.31	-.09	.30	.36	-.09	-.22	.36	.49	.31	.92	.90	.77	1.0	
Sum of skinfolds	-.47	.34	.34	.62	-.01	.29	-.03	.30	31	-.06	-.15	.44	.52	.35	.84	.89	.93	.95	1.0

Table 11

Correlations between the standing long jump and the anthropometric variables: 7-year-old males

	LJ	WT	Stndht	Bmi	Sitht	Sitstnd	Biacrm	Bicrist	Shldrhp	Acrmrad	Rdsty	Armgr	Thigr	Clfgr	Tricp	Subscap	Umbil	Trisub	Sumsf
Long jump	1.0																		
Weight	.04	1.0																	
Standing height	.03	.77	1.0																
Body mass index	.02	.81	.26	1.0															
Sitting height	.08	.73	.87	.32	1.0														
Sit/stand ratio	.08	-.19	-.40	.06	.10	1.0													
Biacromial width	.13	.72	.68	.47	.61	-.23	1.0												
Bicristal width	.13	.70	.66	.46	.64	-.15	.69	1.0											
Hip/shoulder ratio	.01	.05	.05	.03	.10	.08	-.30	.54	1.0										
Acrom-radial length	.03	.70	.83	.30	.64	-.48	.67	.43	.47	1.0									
Radio-stylion length	.10	.70	83	31	66	-.45	.66	.32	.61	.83	1.0								
Arm girth	-.01	.84	48	.84	.48	-.07	.52	.32	.57	.47	.42	1.0							
Thigh girth	-.07	.86	51	.84	.48	-.14	.53	.42	.49	.49	.45	.88	1.0						
Calf girth	-.07	.86	.57	.79	.52	-.17	.56	.42	.55	.49	.47	.81	.86	1.0					
Triceps skinfold	-.15	.45	.17	.53	.16	-.03	.19	.14	-.03	.19	.08	.64	.58	.49	1.0				
Subscapular skinfold	-.14	.53	.18	.63	.17	-.05	.23	.32	.22	.18	.13	.63	.60	.49	.62	1.0			
Umbilical skinfold	-.13	.62	.27	.67	.28	-.03	.25	.27	.21	.23	.22	.67	.67	.55	.56	.79	1.0		
Triceps + subscapular sf	-.16	.53	.19	.63	.18	-.04	.23	.30	.19	.21	.11	.70	.65	.54	.95	.84	.72	1.0	
Sum of skinfolds	-.16	.34	.62	.70	.24	-.04	.26	.30	.21	.24	.17	.75	.71	.59	.84	.88	.91	.94	1.0

Table 12

Correlations between the standing long jump and the anthropometric variables: 14-year-old males

	LJ	WT	Stndht	Bmi	Sitht	Sitstnd	Biacrm	Bicrist	Shldrhp	Acrmrad	Rdsty	Armgr	Thigr	Clfgr	Tricp	Subscap	Umbil	Trisub	Sumsf
Long jump	1.0																		
Weight	-.06	1.0																	
Standing height	.19	.65	1.0																
Body mass index	-.22	.86	.19	1.0															
Sitting height	.13	.71	.82	.38	1.0														
Sit/stand ratio	-.10	.13	-.24	.34	.34	1.0													
Biacromial width	.18	.70	.69	.45	.69	.04	1.0												
Bicristal width	-.14	.72	.53	.59	.63	.21	.60	1.0											
Hip/shoulder ratio	-.34	.19	-.02	.27	.11	.22	-.23	.63	1.0										
Acrom-radiale length	.08	.63	.86	.25	.67	-.27	.65	.56	.61	1.0									
Radio-stylion length	.18	.65	87	.27	.64	-.34	.68	.46	-.09	.83	1.0								
Arm girth	-.09	.87	37	.89	.47	.19	.52	.55	.16	.39	.44	1.0							
Thigh girth	-.21	.88	36	.91	.51	.28	.51	.63	.28	.39	.37	.85	1.0						
Calf girth	-.13	.86	.47	.82	.55	.17	.57	.63	.21	.46	.47	.81	.83	1.0					
Triceps skinfold	-.49	.47	-.01	.62	.11	.21	.07	.37	.37	.10	.01	.57	.60	.51	1.0				
Subscapular skinfold	-.40	.62	.07	.77	.26	.34	.23	.52	.40	.15	.07	.67	.70	.59	.74	1.0			
Umbilical skinfold	-.43	.60	.05	.74	.20	.26	.15	.42	.35	.13	.08	.67	.70	.56	.73	.83	1.0		
Triceps + subscapular sf	-.48	.58	.03	.03	.20	.29	.16	.48	.42	.13	.04	.67	.70	.59	.93	.93	.84	1.0	
Sum of skinfolds	-.47	62	.04	.04	21	.29	.16	.47	.41	.14	.06	.70	.73	.60	.88	.93	.95	.97	1.0

Table 13

Correlations between the standing long jump and the anthropometric variables: 18-year-old males

	LJ	WT	Stndht	Bmi	Sitht	Sitstnd	Biacrm	Bicrist	Shldrhp	Acrmrad	Rdsty	Armgr	Thigr	Clfgr	Tricp	Subscap	Umbil	Trisub	Sumsf
Long jump	1.0																		
Weight	.36	1.0																	
Standing height	.45	.69	1.0																
Body mass index	.14	.81	.14	1.0															
Sitting height	.46	.67	.87	.22	1.0														
Sit/stand ratio	-.11	-.24	-.53	.10	-.04	1.0													
Biacromial width	.55	.73	.73	.41	.73	-.23	1.0												
Bicristal width	.07	.58	.57	.32	.50	-.30	.48	1.0											
Hip/shoulder ratio	-.51	-.21	-.21	-.14	-27	-.04	-.57	.43	1.0										
Acrom-radiale length	.30	.65	.85	.19	.67	-59	.62	.56	-.11	1.0									
Radio-stylion length	.44	.75	.88	.32	.73	-.53	.76	.54	-.28	.83	1.0								
Arm girth	.37	.82	37	.83	.43	-.01	.58	.32	-.31	.37	.49	1.0							
Thigh girth	.13	.83	.30	.88	.34	-.01	.41	.37	-.08	.29	.38	.76	1.0						
Calf girth	.24	.80	.42	.76	.46	-.05	.50	.38	-.17	.36	.46	.70	.83	1.0					
Triceps skinfold	-.49	.08	-.18	.25	-20	.02	-.30	.09	.39	-.02	-.12	.09	.31	.18	1.0				
Subscapular skinfold	-.26	.41	-.06	.62	-.01	.10	.01	.16	.13	.02	.04	.44	55	.41	.57	1.0			
Umbilical	-.25	.41	-.03	.59	-.01	.05	.01	.14	.12	.07	.05	.41	.52	.40	.65	.83	1.0		
Triceps + subscapular sf	-.43	.27	-.14	.48	-.13	.07	-.17	.14	.31	-.01	-.05	.29	.48	.32	.90	.87	.83	1.0	
Sum of skinfolds	-.36	.35	-.09	.55	-.07	.06	-.01	.14	.23	.03	-.01	.36	.52	.37	.82	.89	.95	.96	1.0

The correlation matrices suggested the following factors should be included in a stepwise regression analysis. For females the age groups and corresponding factors chosen for analysis were: 7-years-old – radio-stylion $r = .10$, triceps $r = -.15$ and subscapular $r = -.14$ skinfolds; 12-years-old – triceps + subscapular skinfold $r = -.43$, calf girth $r = -.18$ and hip/shoulder ratio $r = -.22$; 16-years-old – standing height $r = .44$, hip/shoulder ratio $r = -.53$ and sum of skin folds $r = -.47$.

For males the age groups and corresponding factors chosen for analysis were: 7-years-old – bicristal width $r = .13$, triceps $r = -.15$ and subscapular $r = -.14$ skinfolds; 14-years-old – biacromial width $r = .18$, triceps skinfold $r = -.49$, hip/shoulder ratio $r = -.34$, subscapular $r = -.40$ and umbilical $r = -.43$ skinfolds; 18-years-old – hip/shoulder ratio $r = -.51$, sitting height $r = .46$ and triceps + subscapular $r = -.43$ skinfolds. These choices were based on the strength of the correlation of each individual variable with performance on the standing long jump within the specific age group along with low (or lower) colinearity with other variables.

Regression analysis was conducted on the specific age groups for both males and females and the specific factors identified as being most closely associated with performance on the standing long jump while avoiding colinearity among the variables. Age groupings, descriptive statistics, correlations and regression analyses are presented as they pertain to the analyses conducted. If rounded (some data are exact), the decimal points ending in .05, .005, etc. are rounded up, decimal points ending in less than .05, .005, etc. are rounded down.

While each of the variables did correlate to some degree with performance on the standing long jump for both males and females, the extent to which each of the variables might contribute to performance or act as either rate limitors or rate attractors remains to be determined. Dynamic systems theory holds that strong correlations between specific factors and performance can be an indicator of a potential control parameter. However, given the strong colinearity exhibited by many of the factors contained in this analysis, determining whether or not specific factors are potential control parameters in performance of the standing long jump is unclear.

Regression analysis

Stepwise regression analysis for both male and female participants at each of the selected age groups was conducted in order to identify any potential control parameters that might exist within the selected variables and to determine how much of the variance in performance of the standing long jump might be explained by the specific variables included. Means and standard deviations for each age group are presented, followed by the regression analysis for each age group.

Means and standard deviations for the females in the 7-year-old age group and the variables selected for stepwise regression analysis are presented in Table 14.

Table 14

Means and standard deviations for 7-year-old females

	M	SD	N
LJ 81-86	35.37	5.78	47
Radio-stylion length	16.98	.96	47
Triceps skinfold	10.27	2.50	47
Subscapular skinfold	5.71	1.89	47

These variables were selected based on the strength of their relationship with the standing long jump in the specific age group and the lower levels of colinearity they expressed.

A stepwise multiple regression analysis for the variables in this age group was conducted in order to address the research question regarding the identification of control parameters for the standing long jump (Table 15), $F_{1, 45} = 5.31$, $p < .01$.

Table 15

Regression analysis of selected anthropometric factors for 7-year-old-females

Variable	b	SE	R	R^2
Radio-stylion length	.325	.852	.325	.106

Results for this age group indicate that radio-stylion measurements are the best predictor of performance in the standing long jump for females in this age group, accounting for 10.6 percent of the variance explained by this model. The subscapular and triceps skinfold variables failed to enter the model.

Means and standard deviations for the male participants in the 7-year-old age group and the variables selected for stepwise regression analysis are presented in Table 16.

Table 16

Means and standard deviations for 7-year-old males

	M	SD	N
LJ 81-86	39.20	6.48	85
Bicristal width	17.78	.87	85

Means and standard deviations for the male participants in the 7-year-old age group and the variables selected for stepwise regression analysis are presented in Table 16.

Table 16

Means and standard deviations for 7-year-old males

	M	SD	N
LJ 81-86	39.20	6.48	85
Bicristal width	17.78	.87	85
Triceps skinfold	9.60	2.59	85
Subscapular skinfold	4.87	1.34	85

These variables were selected based on the strength of their relationship with the standing long jump in the specific age group and the lower levels of colinearity they expressed with the other variables in the analysis.

A stepwise multiple regression analysis for males in the 7-year-old age group containing the variables triceps skinfold, bicristal width and subscapular skinfold was conducted (Table 17) in order to address the research question regarding the identification of control parameters for the standing long jump.

Table 17

Regression analysis of selected anthropometric factors for 7-year-old males

Variable	b	SE	R	R^2
Subscapular skinfold	-.343	.498	.343	.118

Results for males in this age group show that subscapular skinfold measurements are the best predictor of performance in the standing long jump (Table 17), $F_{1, 83} = 11.06$, $p < .01$. The bicristal width and triceps skinfold variables failed to enter the model. Overall, the model explains 11.8% of the variance in performance for males in the 81-86 month age group.

Means and standard deviations for females in the 12-year-old age group and the variables selected for stepwise regression analysis are presented in Table 18.

Table 18

Means and standard deviations for 12-year-old females

	M	SD	N
LJ 141-146	51.70	6.69	210
Triceps + subscapular skinfold	16.44	4.95	210
Calf girth	25.51	2.01	210
Hip/shoulder ratio	.71	.03	210

These variables were selected based on the strength of their relationship with the standing long jump in the specific age group and the lower levels of colinearity they expressed with the other variables in the analysis.

A stepwise multiple regression analysis for females in the 12-year-old age group and the selected variables: triceps + subscapular skinfold, calf girth, and hip/shoulder ratio was conducted (Table 19) in order to address the hypothesis regarding the identification of control parameters for the standing long jump.

Table 19

Regression analysis of selected anthropometric factors for 12-year-old females

Variable	b	SE	R	R^2
Triceps + subscapular skinfold	-.309	.089	.309	.095

Results for females in this age group suggest that triceps + subscapular skinfold measurements are the best predictor of performance in the standing long jump (Table 19), F 1, 208 = 21.93, $p < .01$. Hip/shoulder and calf-girth measurements failed to enter the model. The model explains 9.5 percent of the variance for female long jump performance in the female 12-year-old age group.

Means and standard deviations for males in the 14 year old age group and the variables selected for regression analysis, biacromial width, triceps skinfold, hip/shoulder ratio, subscapular and umbilical skinfolds, are presented in Table 20.

Table 20

Means and standard deviations for 14-year-old males

	M	SD	N
LJ 165-170	61.25	8.54	200
Biacromial width	31.22	1.46	200
Tricepsskinfold	11.05	4.14	200
Hip/shoulder ratio	.70	.03	200
Subscapular skinfold	6.62	4.32	200
Umbilical skinfold	8.82	6.72	200

The selection of these variables was based on the strength of their relationship with the standing long jump in the specific age group and the lower levels of colinearity they expressed with the other variables in the analysis.

A stepwise multiple regression analysis for males in the 14-year-old age group and the selected variables was conducted (Table 21) in order to address the research question regarding the identification of control parameters for the standing long jump.

Table 21

Regression analysis of selected anthropometric factors for 14-year-old males

Variable	b	SE	R	R^2	R^2 change
Triceps skinfold	-.292	.221	.417	.174	.174
Biacromial width	.310	.398	.485	.235	.061
Umbilical skinfold	-.278	.142	.509	.259	.023

Results for the males in this age group suggest that triceps skinfold measurements are the best predictor of performance in the standing long jump (Table 21), F 1, 196 = 22.79, $p < .01$, accounting for 17.4% of the variance. The addition of biacromial width to the model added 6.1% to the explained variance. Adding umbilical skinfold measurements explained an additional 2.3% to the explained variance. The subscapular skinfold and hip/shoulder measurements failed to enter the model. Overall the model explained 25.9% of the variance in standing long jump performance for the 14-year-old age group.

Means and standard deviations for 16-year-old females and the variables selected for the stepwise regression analysis are presented in Table 22.

Table 22

Means and standard deviations for 16-year-old females

	M	SD	N
LJ 189-194	66.48	7.18	231
Standing height	156.10	7.13	231
Hip/shoulder ratio	.73	.04	231
Sum of skinfolds	32.37	13.58	231

These variables were selected based on the strength of their relationship with the standing long jump in the specific age group and the lower levels of colinearity they expressed with the other variables in the analysis.

A stepwise multiple regression analysis for the 16 year old female age group and the selected variables was conducted (Table 23) in order to address the research question regarding the identification of control parameters for the standing long jump.

Table 23

Regression analysis of selected anthropometric factors for 16-year-old females

Variable	b	SE	R	R^2	R^2 change
Sum of skinfolds	-.381	.033	.353	.124	.124
Standing height	.171	.062	.391	.153	.028

Results for the females in this age group suggest that sum of skinfold measurements are the best predictor of successful performance in the standing long jump (Table 23), F 1, 228 = 20.54, $p < .01$. The addition of standing height added 2.8% to the explained variance. Hip/shoulder ratio failed to enter the model. Overall the model explained

15.2% of the variance in standing long jump performance for females in the 16-year-old age group.

Means and standard deviations for males in the 18-year-old age group and the variables selected for stepwise regression analysis are presented in Table 24.

Table 24

Means and standard deviations for 18-year-old males

	M	SD	N
LJ 213-218	78.90	8.74	204
Hip/shoulder ratio	.70	.03	204
Sitting height	87.70	4.24	204
Triceps + subscapular sf	16.54	5.29	204

These variables (hip/shoulder ratio, sitting height, triceps + subscapular skinfolds) were selected based on the strength of their relationship with the standing long jump in the 18-year-old age group and the lower levels of colinearity they expressed with the other variables.

A stepwise multiple regression analysis for males in the 18-year-old age group and the selected variables was conducted and are presented in Table 25 in order to address the research question regarding the identification of control parameters for the standing long jump.

Table 25

Regression analysis of selected anthropometric factors for 18-year-old males

Variable	b	SE	R	R^2	R^2 change
Triceps + subscapular sf	-.375	.106	.328	.108	.108
Sitting height	.298	.132	.441	.194	.087

Results for the males in this age group suggest that triceps + subscapular skinfold measurements are the best predictor of performance in the standing long jump (Table 27), $F_{1, 201} = 24.27$, $p < .01$. Sitting height contributed 8.7% to the variance explained by the overall model. Hip/shoulder ratio failed to enter the model. The entire model explains 19.5% of the variance in standing long jump performance for males in the 18-year-old age group. A summary table for the regression analyses is presented in Table 26.

Table 26

Summary table of regression analyses:

7-year-old-females -variable	b	SE	R	R^2
Radio-stylion length	.325	.852	.325	.106
12 year old females - variable	**b**	**SE**	**R**	**R^2**
Triceps + subscapular skinfold	-.309	.089	.309	.095
16 year old females - variable	**b**	**SE**	**R**	**R^2**
Sum of skinfolds	-.381	.033	.353	.124
Standing height	.171	.062	.391	.153
7 year old males - variable	**b**	**SE**	**R**	**R^2**
Subscapular skinfold	-.343	.498	.343	.118
14 year old males - variable	**b**	**SE**	**R**	**R^2**
Triceps skinfold	-.292	.221	.417	.174
Biacromial width	.310	.398	.485	.235
Umbilical skinfold	-.278	.142	.509	.259
18 year old males - variable	**b**	**SE**	**R**	**R^2**
Triceps + subscapular sf	-.375	.106	.328	.108
Sitting height	.298	.132	.441	.194

Depending on the model and the specific age group, the anthropometric factors included in the regression analyses explained between 9.5% and 25.9% of the variance in performance in the standing long jump. The smallest explained variance was found in the 12-year-old female age group. The largest explained variance was found in the 14-year-old male age group. In general, more variance was explained for males than for females.

Chapter 5

DISCUSSION

The purpose of this study was to examine the relationship of structural-maturational (SM) variables to performance in the standing long jump from a dynamic systems perspective. Data were collected in an attempt to identify the SM variables that act as potential keys in forcing a system into some type of change (Haubenstricker & Branta, 1997; Ulrich, 1989).

Descriptive results

The descriptive statistics for males' (Table 2) and females' (Table 3) standing long jump performance showed an increase in jumping performance as age increases. This increase is consistent with previous findings (Clark, Phillips, & Petersen, 1989; Malina, & Bouchard, 1991). Table 4 showed that with the exception of hip/shoulder ratios and skinfold measurements means for male anthropometric variables are larger than overall means for female anthropometric variables. Overall, female skinfold means were larger than male skinfold means.

Correlations

The initial research question addressed to what extent were the selected anthropometric parameters related to the performance variations on the standing long jump. Dynamic systems theory suggests that strong correlations may be indicators of the existence of system control parameters (Kugler, 1986; Von Hofsten, 1989; Van Geert, 1994). No discernible patterns were apparent within the initial correlations that indicated that performance in the standing long jump was being determined by changes in the structural maturational variables. Further analysis suggested that a representative selection of age groups for male and female participants based on an age in childhood (age 7 years), age at peak height velocity (12 years of age for females and 14 years of age for males) and four years post peak height velocity (16 years of age for females and 18 years of age for males) should be examined. The construction of additional correlation matrices between performance on the standing long jump, the selected anthropometric variables and the specific age groups helped determine which variables exhibited the highest correlation with performance on the standing long jump.

Correlations among male and female age groups and the selected anthropometric variables were examined to determine which variables had the highest correlation with performance on the standing long jump. The variables selected for further analysis displayed the lowest degree of colinearity with and among the other variables. While no one component determines the overall performance of the system, performance is the system's product of the changes in status of the individual components. While each of the variables included in this study did correlate to some degree with performance on the standing long jump, the extent to which each of the variables might act as control parameters cannot be determined by simply examining the correlations (Thelen, 1988; Clark, Phillips, & Petersen, 1989). Therefore, regression analyses were used to analyze the degree to which specific variables were influencing the system.

Regression

A second research question examined if the subsystems that influence performance in the standing long jump could be identified. The use of regression analysis in dynamic systems has been used previously (Garcia-Ruiz, Louis, Meakin, & Sander, 1993; Whitall & Clark, 1994). The stepwise regression analysis involving the specific factors that were strongly correlated with standing long jump performance suggested that radio-stylion length measurements are the best predictor of performance in the standing long jump for females in the 7-year-old age group, accounting for 10.6% of the variance in performance (Table 16). These same analyses for males in the 7-year-old age group suggest that subscapular skinfold measurements are the best predictor of performance, accounting for nearly 11.8% of the performance variance (Table 17). Children at this age are typically thought to be very similar in their physical make-up (Oesterreich, 1995). The models explain ten to twelve percent of the variance in performance at this age and therefore suggest that other factors may be acting as control parameters. These factors may include experience, motivation, seasonal effects, specific lower body measurements, balance, strength or power generation.

These findings suggest that potential control parameters for males and females exist at age seven, but may already differ somewhat between males and females. This information also suggests that anthropometric measurements impact performance differently for males and females (Schoner & Kelso, 1988; Sporns & Edelman, 1992) during childhood. Even the type of suggested control parameters differed between the males and females in this age group, with performance of males being affected by a skinfold or visceral measure while that for females being a skeletal measure. This difference may represent the dominance of percentage of body fat as a determinant of performance for males at this age, while female performance at this same age is controlled by skeletal components (Thelen, 1988; Clark, Phillips, & Petersen, 1989).

A stepwise regression analysis for females in the 12-year-old age group suggested triceps + subscapular skinfold measurements are the best predictor of performance of the standing long jump, accounting for approximately ten percent of the variance (Table 19). This finding suggests that the potential control parameters influencing performance in the standing long jump for females have changed. The shift from a structural (radio-stylion length) to a visceral (triceps + subscapular skinfold) component acting as a potential control parameter suggests that the system may be reorganizing itself (Thelen, 1988; Clark, Phillips, & Petersen, 1989; Lockman & Thelen, 1993).

Systems theory predicts that (Thelen, 1986) small changes in one element or factor of a system may be a product of the dynamic, relational, multileveled interaction of all of the systems involved. The shift from a visceral to a structural control parameter may be due to physical changes associated with the onset of puberty (Abernethy, & Sparrow, 1992). The changes in structural and physical dimensions of the body that accompany puberty may have already begun and may be reflected in the shift in the identification of potential control parameters (Butler, Mckie, & Ratcliffe, 1990) from one age group to another.

The best predictor of performance of the standing long jump for males in the 14-year-old age group (Table 21) was found to be triceps skinfold measurements, followed to a lesser degree by biacromial (shoulder) width, and umbilical skinfold measurements. The model accounted for nearly 26% of the performance variance. This finding suggests that performance in the standing long jump for males in this age group, much like the 7-year-old age group, is still dominated by skinfold measurements. Biacromial width is also indicated as an influencing factor for males at age 14; this finding may indicate that the system is beginning to reorganize itself (Schoner & Kelso, 1988; Sporns & Edelman, 1992), possibly as a reflection of the onset of changes in physical structure associated with puberty (Malina & Bouchard, 1991; Malina & Rouche, 1982). The degree of growth in shoulder width during puberty for males is remarkable. These data indicate that such a change may be influencing performance significantly.

The inclusion of the umbilical skinfold measurement as a contributing variable suggests that, much like the 7-year-old age group, performance for males at this age may still be affected by the amount of adipose tissue present (Butler, Mckie & Ratcliffe, 1990). However, the influence of biacromial width may be reflecting a subtle re-ordering (Thelen, 1988; Clark, 1995) in the potential control parameters for performance in the standing long jump by a gradual inclusion of structural variables in concert with the visceral variables (Van Geert, 1994; Von Hofsten, 1989; Turvey & Fitzpatrick, 1993).

The stepwise regression results for females in the 16-year-old age (Table 22) group suggest that sum of skinfold measurements are the best predictor of performance in the standing long jump, with the overall model accounting for 15.2% of the performance variance. Once again, the identification of sum of skinfolds as the factor most associated with standing long jump performance reflects a change in the factors identified as potential control parameters for female performance. The regression analysis suggested radio-stylion length as a control parameter for the 7-year-old age group, and triceps + subscapular skinfolds for the 14-year-old age group. These changes in the suggested control parameters are likely a representation of the system as a whole reorganizing due to sensitivity to changes in the various subsystems at any given point in time (Thelen & Ulrich, 1991; Fivaz, 1997; Kinnunen, 2000). These changes may also reflect that performance for females in two of the age groups examined is dominated by the relative amount of adipose tissue present (Hellebrandt, Rarick, Glassow, & Carns, 1961; Jensen, Phillips, & Clark, 1994) rather than any structural variables. These data are consistent with research presented by Haubenstricker, Wisner, Seefeldt, and Branta (2003). They reported that skinfolds and girths were strong primary predictors of performance often accounting for 50% or more of the variability in performance at various ages. In the present study standing height was also suggested as a potential control parameter, adding three percent to the explained variance (Table 23), and the inclusion of standing height may reflect a re-ordering (Thelen, 1988; Clark, 1995) in the control parameters by a gradual inclusion of structural variables with the visceral variables (Van Geert, 1994; Von Hofsten, 1989; Turvey & Fitzpatrick, 1993).

The regression analysis results for males in the 18-year-old age group (Table 25) suggest that triceps + subscapular skinfolds measurements are the best predictor of performance in the standing long jump, followed by sitting height. Overall the model accounted for approximately 19% of the performance variance. Finding triceps + subscapular skinfolds to be the best predictor of performance in the standing long jump for males in this age group suggests that performance for this age group continues to be controlled by the relative amount of adipose tissue. In the two younger male age groups, the suggested control parameters were subscapular skinfolds for the 7-year-old age group, and triceps skinfolds for the 14-year-old age group.

The male participants in the age groups examined show a trend in that the main potential control parameters identified as impacting performance on the standing long jump are all skinfold measures. However, the specific skinfold measure suggested as a control parameter shifts among the three males groups, from subscapular skinfolds for 7 years old, to triceps skinfolds for 14 years old, and to triceps + subscapular skinfolds for

18 years old. These shifts in the potential control parameters for males across age groups may again reflect a re-ordering of the control parameters or changes in a hierarchical nature of the variables. Dynamic systems theory does suggest that changes of this type could represent a hierarchical shift or re-ordering in the specific subsystems that coordinate performance in the standing long jump (Fentress, 1986; Kelso, & Schroner, 1988; Kapitaniak, 1990; Thelen & Ulrich, 1991). These changes in variables suggest the system as a whole reorganizes the various subsystems at various points in time in order to accommodate changes in physical growth and structure (Fentress, 1986; Thelen & Ulrich, 1991; Fivaz, 1997; Hamilton, Pankey, & Kinnunen, 2003).

The third research question of this study addressed the idea that one or more of the selected anthropometric variables could be identified as a control parameter in performance of the standing long jump. The analyses in this study explained between ten and twenty six percent of the variance in male and female performance on the standing long jump, depending on the specific model. It is remarkable that anthropometric growth parameters could be influencial in performance. However, seventy five to ninety percent (depending on the model) of the performance variance remains to be explained.

So, while it appears that certain anthropometric variables might be identified as potential control parameters, there also appear to be other factors at work that have not been accounted for in this study. The changes in the suggested control parameters for performance in the standing long jump identified in this study support the idea that certain elements related to performance, may change or be disassociated from the performance in question.

Utilizing dynamic systems theory to study motor development is still relatively new (Ulrich 1989; Levine & Fitzgerald, 1992; Clark & Phillips, 1993). Dynamic systems theory is grounded in the belief that movements are an emergent property of the underlying systems (Abernathy & Sparrow, 1992). Dynamic systems research suggests that it should be possible to identify the various sub-components that influence the performance of specific motor skills (Schoner & Kelso, 1988; Wilson, 1993). A systems approach attempts to identify the subsystems influencing performance and how the various subsystems or factors act together to impact performance. The search for factors associated with the development of jumping goes back over one hundred years (Levine & Fitzgerald, 1992; Wilson, 1993). Rarick and Oyster (1964) determined that a number of factors such as age, height, and weight might have an influence on performance. Earlier work by Seils (1951) revealed no significant relationship between stature, body weight and performance in the standing long jump. Carmichael (1960) recognized that variations in neuro-structural components were major factors contributing to changes in performance.

The results of the present study suggest that various anthropometric measurements do impact performance and that the number of variables to be accounted for may be far greater than previously considered (Levine & Fitzgerald, 1992; Wilson, 1993; Clark & Philips, 1993). In contrast to Seils' (1951) findings, the present study suggests that stature may be influential in performance on the standing long jump as sitting height and standing height were found to be related to standing long jump performance for males in the 18-year-old age group and females in the 16-year-old age group respectively.

Much of the research concerning development and motor performance summarized by Malina (1975) indicated that fatness has a negative impact on motor performance in tasks involving movement of the body through space (Erbaugh, 1997). Other research has examined the influence of somatotype, body composition, and size on motor performance (Slaughter, Lohman, & Misner, 1980; Pipho, 1971; Latchaw, 1954; Berg, 1968; Erbaugh, 1997) and indicate that lean body mass is a key predictor of performance. In 1982, Hensley, East, and Stillwell looked at the relationship between body fatness and motor performance, and found significant performance differences between boys and girls in some tasks. Erbaugh (1984) investigated the relationship between the physical growth and performance of preschool children. Much like Malina's (1975) earlier work, the results of Erbaugh's research found that body composition, diameters, and circumference measurements were the most important variables.

The present study suggests that both structural and visceral measurements impact performance and that those variables are different for males (subscapular skinfold measurements for the 7-year-old group; triceps skinfolds, biacromial width and umbilical skinfold measurements for the 14-year-old group; and triceps + subscapulars skinfolds and sitting height measurements for the 18-year-old group) and females (radio-stylion length for the 7-year-old group; triceps + subscapular skinfolds for the 12-year-old group; and sum of skinfolds and standing height for the 16-year-old group), and that the variables change across age groups. Malina and Bushang (1985) examined growth, strength, and motor performance in groups of children from Mexico and Philadelphia and found that little performance variation was explained by a number of anthropometric variables. Eoff (1985) found that performance was influenced by structural-maturational variables, specifically, the length and weight of a limb was found to have an effect on overall performance in throwing for both boys and girls.

The differences suggested for males and females may represent the existence of separate hierarchical control parameters at work. Whether or not the control parameters change across all the age groups remains to be determined. Of the six groups examined, the potential control parameters for males were dominated by skinfold measurements, while female groups showed a shift from a structural variable (radio-stylion length) acting as a control parameter to skinfolds. In both cases, it appeared as if performance is influenced by the amount of adipose tissue and this finding is consistent with prior research (Slaughter, Lohman, & Misner, 1980; Pipho, 1971; Latchaw, 1954; Berg, 1968; Erbaugh, 1997; Malina 1975; Malina and Bushang, 1985; Haubenstricker, et. al., 2003).

While many aspects of motor development have been studied, a logical step would be to define the specific component elements or combinations of subsystems that may influence performance of specific motor skills (Pipho, 1971; Schoner & Kelso, 1988; Peitgen, Jurgens, & Saupe, 1992). The results of the present study suggest that anthropometric control parameters for the standing long jump may exist and that the identification of the influence of anthropometric factors in performance of the standing long jump is possible. Because one specific component might be the critical element driving a system developmentally, the factors controlling the periods of stability and transition still need to be better understood (Haubenstricker & Branta, 1997). The results of this study suggest that the variables acting as potential control parameters change over time, just as dynamic systems theory suggests they should (Bernstein, 1967; Bruner, 1973; Thelen, 1988; Abernethy, & Sparrow, 1992); Lockman & Thelen, 1993; Whitall &

Clark, 1994; Thelen, 1990). For example, Haubenstricker and Branta (1997) found that developmental level used by preschool children age 2-5 years account for 7% (age 2), 22% (age 3), 19.5% (age 4), and 13.8% (age 5) of the variance in the distance jumped. It appears that a major variable to consider early in development is pattern, while growth changes may become more important during childhood and adolescence.

These potential control parameters may have a single component or several, and there may be no one-to-one relationship between subsystems and their components (Levine & Fitzgerald, 1992). Dynamic systems theory predicts that change results from the scaling of one or more control parameters (Clark & Philips, 1993; Gray & Singer, 1989; Sporns & Edelman, 1993) and any one subsystem or component may act as a control parameter (Soll, 1979; Thelen, 1986).

Dynamic systems theory has been used in motor development research for nearly twenty-five years (Corbetta & Vereijken, 1999). However, little progress has been made in determining the underlying factors associated with the development of jumping. Most studies regarding motor performance have focused on stage descriptions and various qualitative levels of performance (Corbetta & Vereijken, 1999). This investigation attempted to determine if anthropometric control parameters could be identified with regards to the standing long jump by using regression analysis. Newell (1984) suggested that various factors can and will greatly influence the task at hand. Dynamic systems theory holds that one component or subsystem or group of subsystems might be the key determinants influencing a system (Haubenstricker & Branta, 1997; Ulrich, 1989). This investigation is an initial step in an attempt to utilize dynamic systems theory to identify variables acting as control parameters and the various subsystems that might influence or control performance in the standing long jump.

The potential anthropometric control parameters for performance in the standing long jump suggested by this study for females include: radio-stylion length for the 7-year-old age group, triceps + subscapular skinfolds for the 12-year-old age group, and sum of skinfolds for the 16-year-old age group. For males the suggested control parameters were: subscapular skinfolds for 7-year-old age group, triceps skinfold for 14-year-old age group, and triceps + subscapular skinfolds for 18-year-old age group.

Future Research

Von Hofsten's (1989) research implied that when a critical value in size is reached, the stability of a movement pattern is disrupted. In fact, size can be viewed as a scaling factor; if the system is scaled to some critical value the system changes (Clark, 1986). Thelen suggests physical size might be a sensitive scaling factor, and components may compete with each other, disrupting the entire system when changes occur (Thelen, 1984, 1985; Clark, 1986). These overall changes are due to the system reorganizing in response to specific changes in size and mass. These disruptions may simply reflect a period of readjustment due to the relatively rapid changes occurring in the body at this time. Critical values or ratios might also exist within each of the components or subsystems where the stability of the entire system is overwhelmed and is forced to reorganize (Gleick, 1987; Peitgen, Jurgens, & Saupe, 1992; Thelen & Smith, 1994; Haubenstricker & Branta, 1997).

The specific impact of anthropometric measures on performance in the standing long jump related to incremental changes in those measures, and the degree of those changes, will require further study.

No information regarding the amount of practice or experience each participant may have had with the standing long jump is available; although due to their continued participation in the Motor Performance Study it is unlikely the task is novel to the participants. No data are available regarding the relative importance of the performance, levels of aggression, motivational state or any other motivational factors. Lower body anthropometric measurements, such as foot size and specific lower body lengths, are not available and likely to have some impact on standing long jump performance. The overall strength or power production of each participant is also not accounted for in this study.

An examination of all of the age groups included in this study might reveal subtle or additional fluctuations in the variables acting as control parameters, as they re-order themselves or represent and accommodate the changing physical dimensions of the individual. Such an investigation might reveal that control parameters are individually expressed rather than factors impacting performance for everyone. Further research into control parameters for the standing long jump (or other performance tasks) might reveal that control parameters are consistent across task, or age groups, or sex, or a combination of factors. It may be possible to identify both rate limitors, factors that hinder or delay performance, and rate attractors, those factors that help push the system or individual towards better performance on a specific task. The use of individual case studies from this data set may help to address the identification of both rate limitors and rate attractors.

These findings carry the implication that fundamental motor patterns (Hellebrandt, Rarick, Glassow, & Carns, 1961; Wickstrom, 1975) may represent deep-wells, movement patterns that are universally used for performance, or in the case of this study, the standing long jump. Although the specific variables and values that drive a system into a deep-well pattern remain to be determined, comparisons could be made between those individuals who jumped exceedingly well versus those who did not, comparing the control parameters at work for each group. It is possible that control parameters for performance in the standing long jump, and perhaps other performance tasks, will display a hierarchical structure much like the stages associated with fundamental motor skills.

Qualitative analysis of the movements utilized by the performers may also prove valuable, as the specific stage of jumping performance exhibited by both successful and less successful performers may reveal additional factors associated with standing long jump performance. It may be that the specific variables and values that drive a system into a deep-well pattern are also those demonstrated by the most mature stage of performance (Seefeldt, Haubenstricker & Branta, 1982; Haubenstricker, & Branta, 1997; Roberton, 1989a; Roberton, 1989b; Roberton, 1978). Research by Clark, Phillips, and Petersen (1989) suggests that the way movement looks qualitatively is impacted by the control parameters as they change. Recent research by Almasbakk and Hoff (1996) suggests that the coordination of the movement involved may be the most critical factor in performance.

While the variables identified in this investigation were found to be associated with performance in the standing long jump, and might tentatively be identified as control parameters, there may exist other variables within the data that remain to be uncovered. The fluctuations in the way the variables present themselves as control parameters in this study may indicate that these same variables and control parameters and subsystems are still in the process of dynamically reorganizing themselves. Further study is needed in order to determine if the anthropometric variables identified here as being associated with performance on the standing long jump are specific only to performance on the standing long jump or if they might generalize to performance on other tasks. There may be other physical factors or variables not accounted for in this study that also impact performance. Some variables may remain stable or invariant regardless of changes in other variables. Although it is possible some variables may remain stable across changes in other variables (hip/shoulder ratio, etc.), whether such factors exist or act as control parameters remains to be explored.

It may be necessary to collect data on a more frequent timetable in order to determine the timing and duration of the reorganization, and determine more clearly the variables and systems involved along with any interactions. Recent research regarding a regular series of childhood growth spurts might also lend itself to the identification of other or more precise variables associated with growth and performance (Butler, Bergmann, Bielicki, & Susanne, 1990; Ledford, & Cole, 1998) and a deeper understanding of the systems at work. Examining additional age groups in order to identify the potential control parameters each exhibits would likely identify additional shifts in the primary control parameters. Such an investigation may even allow for the identification of a common hierarchy of the specific control parameters associated with female performance in the standing long jump.

Due to the limited minority representation in this study, future attempts to identify the control parameters associated with performance should utilize a more diverse subject pool, or focus specifically on minority populations. The potential control parameters identified in this study, may not represent control parameters for other populations. In order to determine whether or not the control parameters suggested here are valid for other motor performance tasks, other motor performance data should also be examined looking for general control parameters at work or those specific to the task, environment, individual (Newell, 1986; Garcia-Ruiz, Louis, Meakin, & Sander, 1993) or even specific groups.

The search for contributing factors should also include psychological, sociological and other maturational elements (Garcia-Ruiz, Louis, Meakin, & Sander, 1993; Haubenstricker & Branta, 1997), along with information regarding the relative importance of the task to the performer or levels of motivation or aggression. All of these factors may have an impact on the performance of a task, outside of the basic anthropometric measurements of the individual (Newell, 1986). Therefore, further study regarding performance should include the influence of changes in the control parameters themselves across time. Comparisons may also be made between those individuals who jumped exceedingly well versus those who did not, comparing the control parameters at work for each group. Qualitative analysis of the movements utilized by the performers may prove invaluable, as the specific stage of jumping performance utilized by both successful and less successful performers may reveal additional factors associated with standing long jump performance (Almasbakk & Hoff ; 1996).

Additional analyses may require a more careful examination concerning the growth and maturation rate of the participants. There may be separate control parameters at work for those individuals who reflect early, average, or late maturation rates. Investigation into changes in the control parameters and subsystems on an individual or maturational status level might lead to a deeper understanding of the factors that influence and drive performance along with changes in that performance.

At that point, it may be possible to begin to address the question of to what extent are specific changes in the variables related to performance variations (Clark, 1986; Thelen & Smith, 1994). Continuing the search for the variables and subsystems that act as control parameters holds the potential to reveal the complex principles that govern movement control and coordination. This search can continue to provide information to an understanding of movement and performance that should prove helpful to children, parents and researchers.

Summary

Developmental changes are not planned but come about as the product of a number of developing elements (Thelen, 1995). These elements, or constraints, are typically structural in nature (Newell, 1986) and include variables such as body weight, height, strength, mass, or limb length (Goldfield, Kay, & Warren, 1993; Jensen, Phillips, & Clark, 1994). The advantage of systems sciences is the potential for providing a cross-disciplinary framework for critical exploration of relationships (Laszlo & Laszlo, 1997). In order to understand a dynamic, relational, multileveled system, it is necessary to try to identify the rate-controlling components involved and their interactions (Thelen, 1986). Performance is the system's product of the changes in status of the individual components. No one component determines the overall performance of the system.

Over time, the relationships between these components may shift and flow, depending on the rate of development. Because of the dynamic, relational, multileveled relationship of the system, even small changes in one component may alter the entire performance or system (Thelen, 1986; Schoner & Kelso, 1988; Zernicke & Schneider, 1993). Dynamic systems allows us to view how many levels may act together and at the same time identify the subsystems where small changes result in major consequences (Thelen, 1986).

APPENDIX A

DESCRIPTIONS OF MEASUREMENTS

Linear measurements:

Standing height – measurements were taken with the subject standing against a wall. heels are placed together, in contact with the wall. Hands are allowed to hang freely. The head is positioned in the Frankfurt plane.

Sitting height – the subject is seated on a thirty-centimeter bench, with the back against the wall. Subject assumes the sitting position by first leaning forward and then sliding as far back as possible before sitting upright. The feet are place so the thighs are perpendicular to the trunk and parallel to the floor. Head is placed in the Frankfurt plane.

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

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

Breadth measurements:

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

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

Circumferences:

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

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

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

Skinfolds:

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

Subscapular – Measure from a line one inch below the inferior angle of the scapula.

Umbilicus – Measure approximately one inch to the left of the umbilicus.

APPENDIX B

MEANS AND STANDARD DEVIATIONS FOR MALE AND FEMALE ANTHROPOMETRIC VARIABLES BY AGE GROUP

Means and standard deviations for female anthropometric variables by age group*

Variable	7 Years M(SD)	12 Years M(SD)	14 Years M(SD)
Weight	32.76 (4.28)	60.83 (10.15)	100.40 (19.84)
Standing height	98.03 (4.38)	130.73 (5.98)	156.17 (7.23)
Body mass index	15.44 (1.18)	16.08 (1.76)	18.58 (2.77)
Sitting height	56.03 (2.56)	70.26 (2.87)	81.63 (3.80)
Sit/stand ratio	.57 (.01)	.53 (.01)	.52 (.01)
Biacromial width	22.34 (1.08)	28.76 (1.43)	34.09 (1.88)
Bicristal width	15.95 (.84)	20.25 (1.17)	24.75 (1.90)
Hip/shoulder ratio	.71 (.03)	.70 (.03)	.72 (.03)
Acrom-radiale length	18.07 (1.00)	25.00 (1.38)	30.46 (1.77)
Radio-stylion length	15.28 (.90)	20.96 (1.23)	25.62 (1.47)
Arm girth	15.89 (1.27)	19.11 (1.89)	22.57 (2.61)
Thigh girth	28.79 (2.29)	37.16 (3.47)	44.64 (4.70)
Calf girth	21.08 (1.79)	26.03 (2.03)	31.21 (2.85)
Triceps skinfold	10.29 (2.65)	11.00 (3.34)	12.21 (4.43)
Subscapular skinfold	5.81 (1.85)	6.42 (2.78)	8.77 (4.21)
Umbilical skinfold	6.07 (2.34)	7.64 (4.42)	11.71 (6.43)
Triceps/subscapular skinfold	16.10 (3.94)	17.43 (5.54)	20.98 (7.95)
Sum of skinfolds	22.18 (5.66)	25.07 (9.47)	32.70 (13.83)

* N = 138 for 7-year-old age group, N = 230 for 12-year-old age group, N = 253 for 16-year-old age group.

Means and standard deviations for male anthropometric variables by age group*

Variable	7 Years M(SD)	14 Years M(SD)	16 Years M(SD)
Weight	34.99 (4.22)	77.94 (13.22)	126.43 (20.49)
Standing height	99.62 (3.85)	143.03 (5.83)	169.81 (7.18)
Body mass index	15.98 (1.27)	17.24 (2.17)	19.84 (2.37)
Sitting height	57.25 (2.11)	75.19 (2.94)	87.70 (4.23)
Sit/stand ratio	.57 (.01)	.52 (.01)	.51 (.01)
Biacromial width	22.69 (1.01)	31.25 (1.45)	37.40 (2.06)
Bicristal width	16.40 (.84)	21.93 (1.29)	26.06 (1.61)
Hip/shoulder ratio	.72 (.03)	.70 (.02)	.69 (.03)
Acrom-radiale length	18.34 (.96)	27.64 (1.42)	33.06 (1.79)
Radio-stylion length	15.76 (.82)	23.63 (1.15)	28.61 (1.42)
Arm girth	16.36 (1.15)	20.68 (2.25)	24.89 (2.43)
Thigh girth	29.26 (2.27)	40.04 (3.88)	47.50 (4.16)
Calf girth	21.68 (1.47)	28.51 (2.38)	33.95 (2.58)
Triceps skinfold	10.29 (2.46)	10.99 (4.09)	9.06 (3.27)
Subscapular skinfold	5.47 (1.37)	6.58 (4.22)	7.42 (2.61)
Umbilical skinfold	5.52 (1.84)	8.75 (6.59)	9.43 (5.42)
Triceps/subscapular sf	15.76 (3.27)	17.58 (7.80)	16.49 (5.25)
Sum of skinfolds	21.28 (4.61)	26.33 (13.99)	25.93 (10.27)

* N = 90 for 7-year-old age group, N = 210 for 14-year-old age group, N = 218 for 18-year-old age group.

APPENDIX C

CORRELATIONS BETEWEEN PERFORMANCE ON THE STANDING LONG JUMP AND THE ANTHROPOMETRIC VARIABLES ACROSS AGE GROUPS

Correlations between performance on the standing long jump and the anthropometric variables across age groups

Age group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Weight	.17	.08	.12	.09	.03	-.03	-.03	-.04	-.04	-.07	-.12	-.12	-.11	-.11	-.16
Standing height	.21	.12	.14	.12	.03	.03	.07	.08	.06	.06	.04	.07	. 04	.06	. 02
Body mass index	.07	.01	.05	.02	.02	-.08	-.09	-.12	-.11	-.15	-.20	-.21	-.17	-.19	-.24
Sitting height	.17	.14	.13	.18	.08	.10	.11	.14	.10	.08	.09	.12	.07	.06	.01
Sit/stand ratio	-.09	.02	-.04	.10	.08	.12	.06	.09	.05	.03	.07	.08	.06	-.01	-.04
Biacromial width	.28	.20	.22	.18	.13	.09	.09	.12	.13	.08	.11	.10	.12	.09	.06
Bicristal width	.22	.18	.17	.18	.13	.09	.11	.10	.11	.03	.02	.01	-.01	-.01	-.10
Hip/shoulder ratio	-.02	.01	-.02	.01	.01	.01	.04	-.01	.01	-.04	-.08	-.11	-.16	-.10	-.22
Acrom-radiale lgt	.22	.13	.16	.15	.03	.05	.05	.08	.12	.07	.02	.03	-.01	.02	-.01
Radio-stylion lgt	.28	.17	.18	.16	.10	.09	.10	.10	.12	.08	.05	.04	.03	.06	.01
Arm girth	.08	.02	.04	.01	-.01	-.07	-.10	-.08	-.08	-.15	-.16	-.18	-.16	-.17	-.14
Thigh girth	.06	-.01	.02	-.01	-.07	-.15	-.13	-.12	-.12	-.17	-.21	-.20	-.18	-.18	-.21
Calf girth	.15	.03	.01	-.01	-.07	-.12	-.10	-.11	-.11	-.13	-.16	-.20	-.13	-.14	-.18
Triceps skinfold	-.13	-.15	-.18	-.17	-.15	-.30	-.27	-.28	-.23	-.31	-.35	-.38	-.35	-.41	-.42
Subscapular sf	-.21	-.10	-.16	-.14	-.14	-.26	-.28	-.26	-.23	-.26	-.31	-.33	-.33	-.34	-.37
Umbilical	-.18	-.14	-.17	-.12	-.13	-.23	-.18	-.27	-.23	-.26	-.28	-.31	-.29	-.32	-.38
Trisubsf	-.18	-.15	-.19	-.18	-.16	-.31	-.30	-.30	-.25	-.31	-.36	-.38	-.36	-.41	-.42
Sum of skinfolds	-.20	-.16	-.20	-.16	-.16	-.29	-.26	-.30	-.25	-.30	-.34	-.36	-.34	-.38	-.42

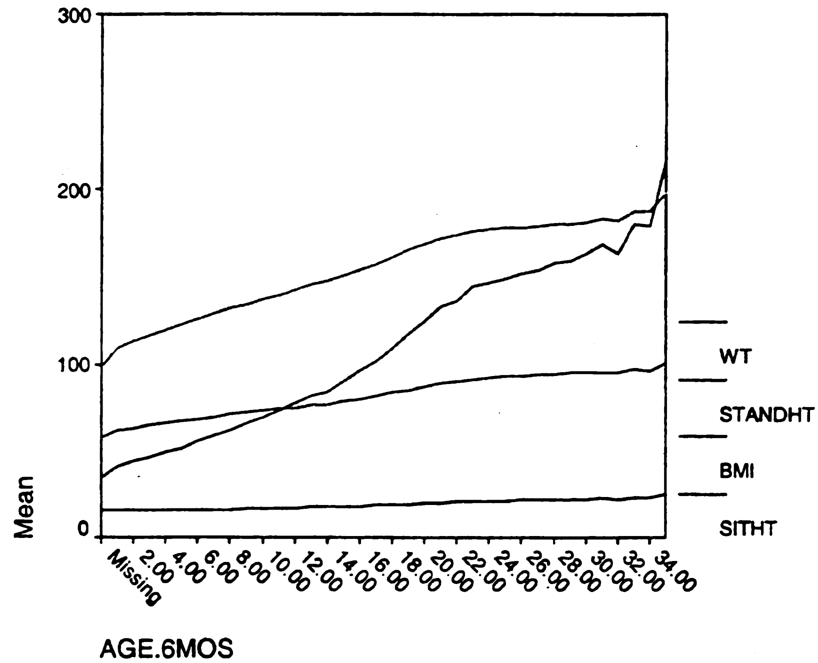
Correlations between performance on the standing long jump and the anthropometric variables across age groups (combined)

Age group	16	17	18	19	20	21	22	23	24	25	26	27	28
Weight	-.94	-.09	-.15	-.04	-.06	.05	.13	.31	.29	.28	.35	.34	.35
Standing height	.10	.10	.04	.15	.19	.29	.36	.47	.44	.50	.50	.50	.44
Body mass index	-.24	-.18	-.23	-.15	-.21	-.14	-.09	.18	.01	-.03	.03	.10	.13
Sitting height	.01	.10	.01	.07	.12	.16	.27	.38	.37	.45	.47	.43	.46
Sit/stand ratio	-.04	.01	-.08	-.11	-.10	-.20	-.16	-.19	-.20	-.14	-.17	-.20	-.10
Biacromial width	.06	.07	.06	.16	.18	.30	.34	.51	.47	.51	.56	.54	.55
Bicristal width	-.10	-.04	-.14	-.12	-.14	-.08	-.12	-.01	-.10	-.04	-.09	.02	.07
Hip/shoulder ratio	-.22	-.13	-.26	-.31	-.34	-.38	-.43	-.45	-.52	-.51	-.57	-.52	-.51
Acrom-radiale length	-.01	.01	-.01	.03	.07	.18	.21	.33	.31	.35	.35	.37	.30
Radio-stylion length	.01	.03	.03	.15	.18	.27	.31	.45	.45	.49	.49	.50	.44
Arm girth	-.14	-.15	-.19	-.09	-.09	.01	.08	.22	.27	.23	.31	.34	.37
Thigh girth	-.21	-.13	-.22	-.14	-.21	-.08	-.09	.06	.03	-.01	.04	.08	.13
Calf girth	-.18	-.10	-.16	-.11	-.12	-.02	.02	.16	.17	.13	.11	.16	.23
Triceps skinfold	-.42	-.40	-.40	-.39	-.49	-.50	-.52	-.49	-.50	-.56	-.59	-.54	-.48
Subscapular skinfold	-.37	-.33	-.37	-.34	-.40	-.40	-.39	-.32	-.42	-.45	-.44	-.34	-.25
Umbilical	-.38	-.36	-.41	-.36	-.42	-.38	-.36	-.36	-.35	-.40	-.41	-.31	-.25
Triceps + subscapular sf	-.42	-.40	-.42	-.39	-.48	-.49	-.50	-.45	-.51	-.56	-.56	-.50	-.43
Sum of skinfolds	-.42	-.40	-.43	-.39	-.47	-.46	-.46	-.43	-.47	-.51	-.52	-.44	-.36

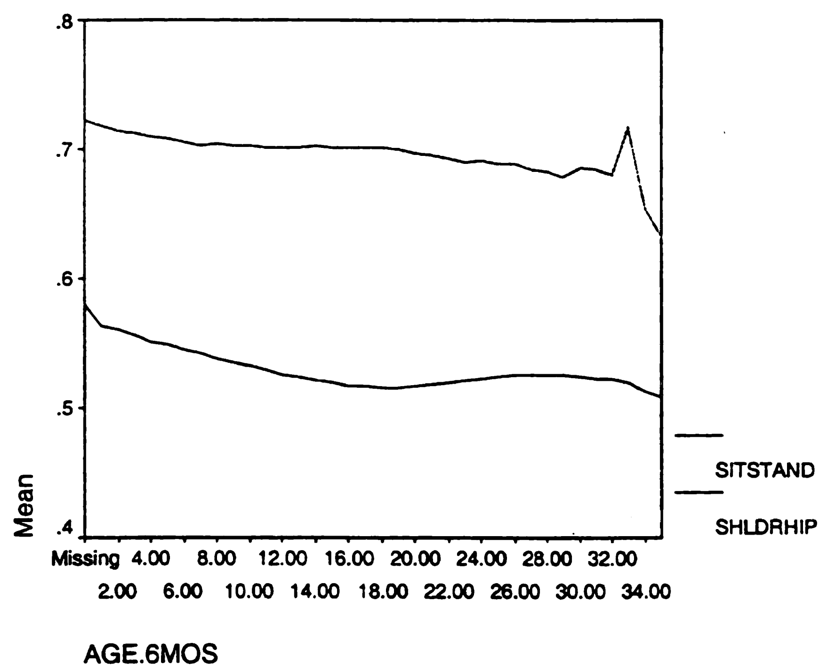
APPENDIX D

LONGITUDINAL CHANGES ACROSS VARIABLES

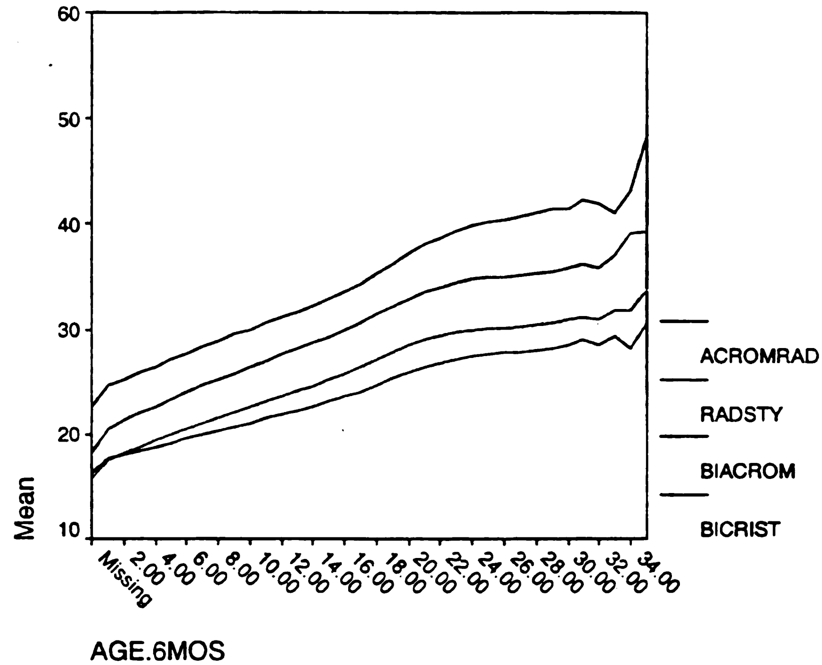
Longitudinal changes in weight, standing height, body mass index, and sitting height for males



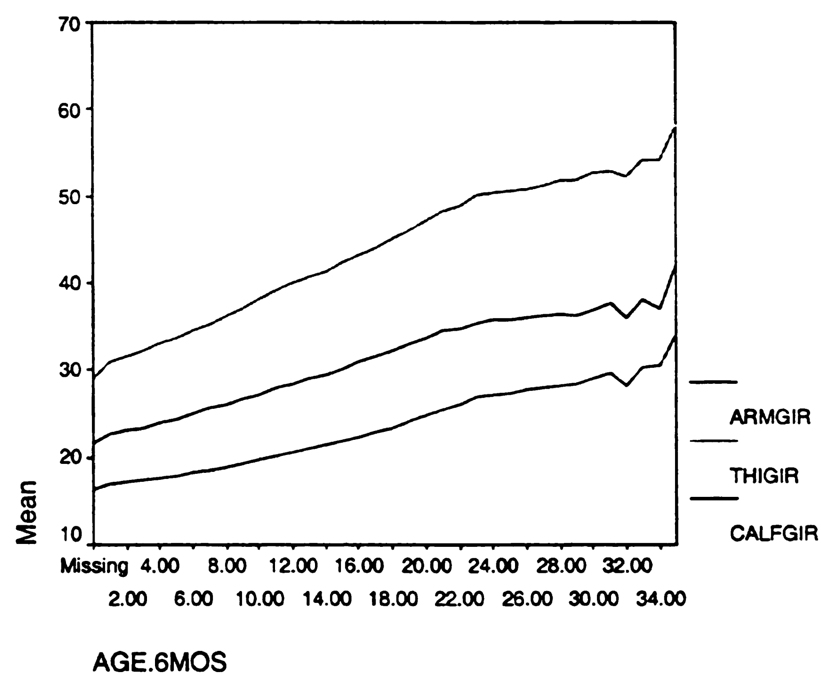
Longitudinal changes in sit/stand and hip/shoulder ratios for males



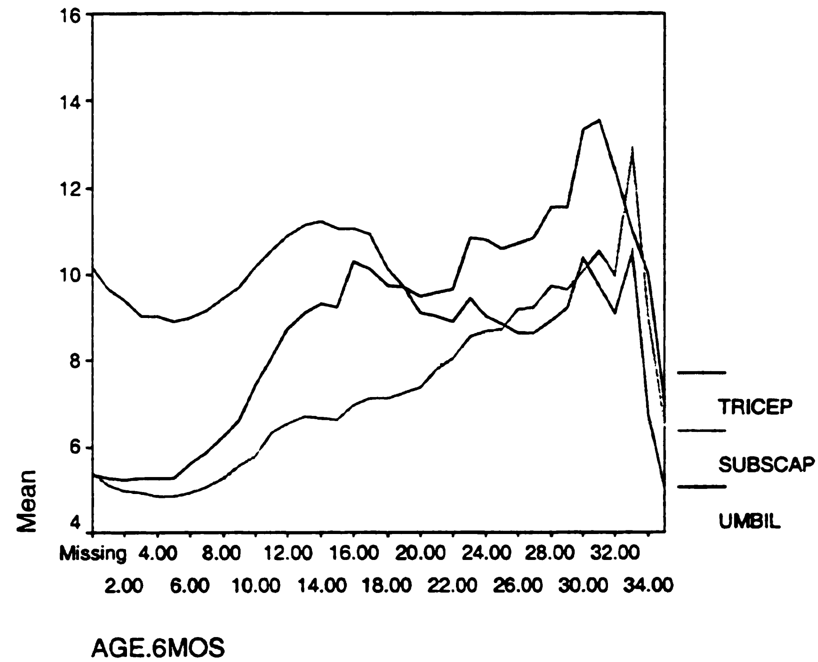
Longitudinal changes in acrom-radiale length, radio-stylion length, biacromial width and bicrist width for males



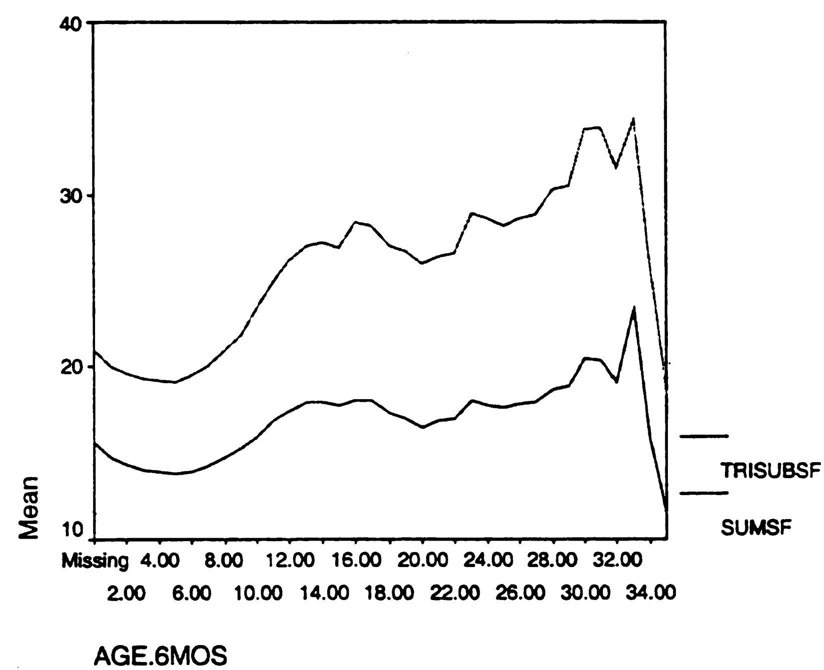
Longitudinal changes in arm, thigh, and calf girth for males



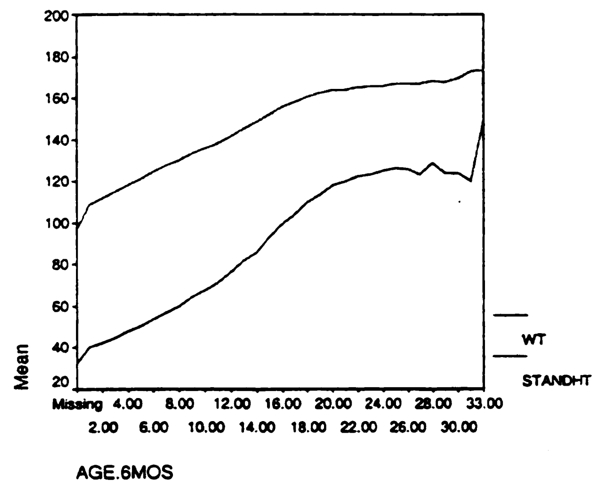
Longitudinal changes in triceps, subscapular and umbilical skinfolds for males



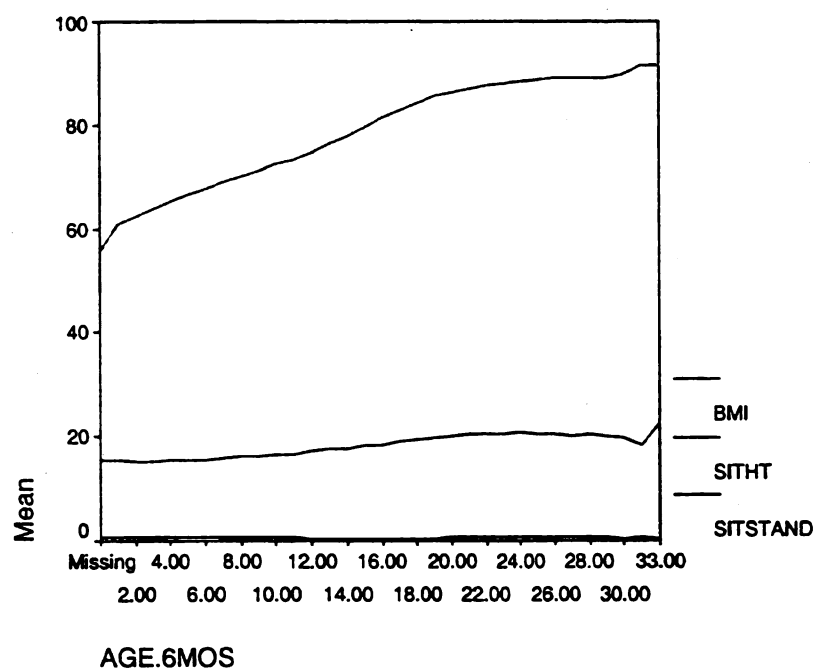
Longitudinal changes in triceps + subscapular and sum of skinfolds for males



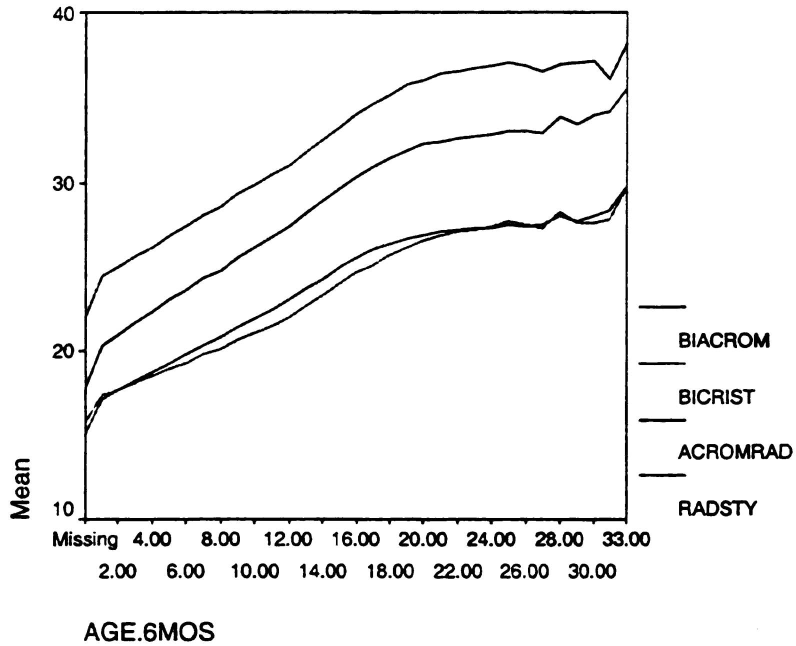
Longitudinal changes in weight and standing height for females



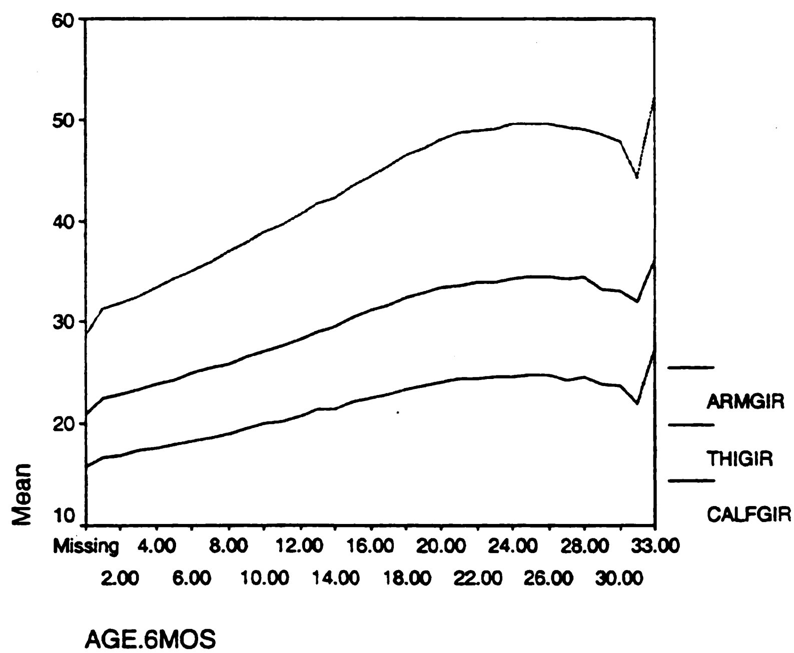
Longitudinal changes in body mass index, sitting height and sit/stand ratio for females



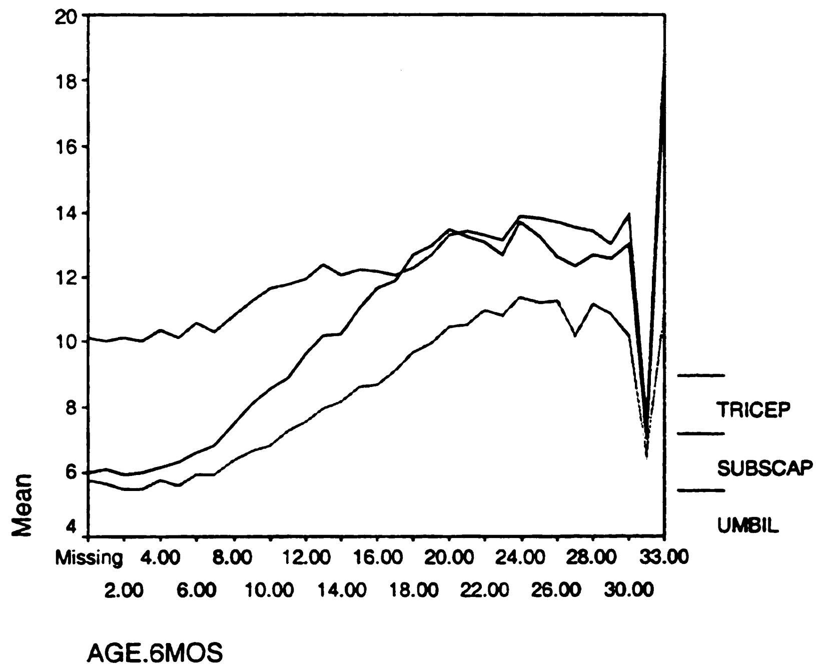
Longitudinal changes in biacromial width, bicristal width, acrom-radiale length, and radio-stylion length for females



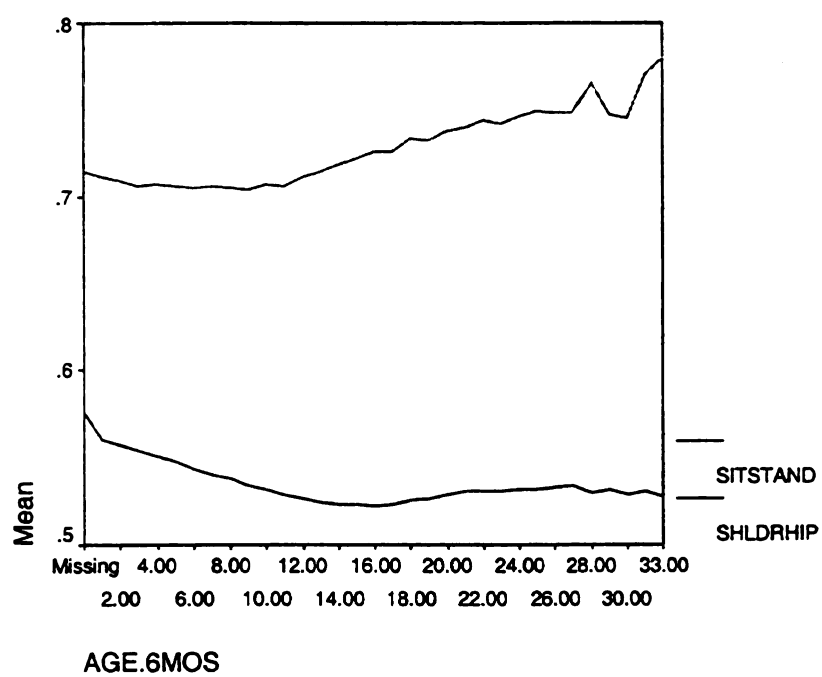
Longitudinal changes in arm, thigh, and calf girth for females



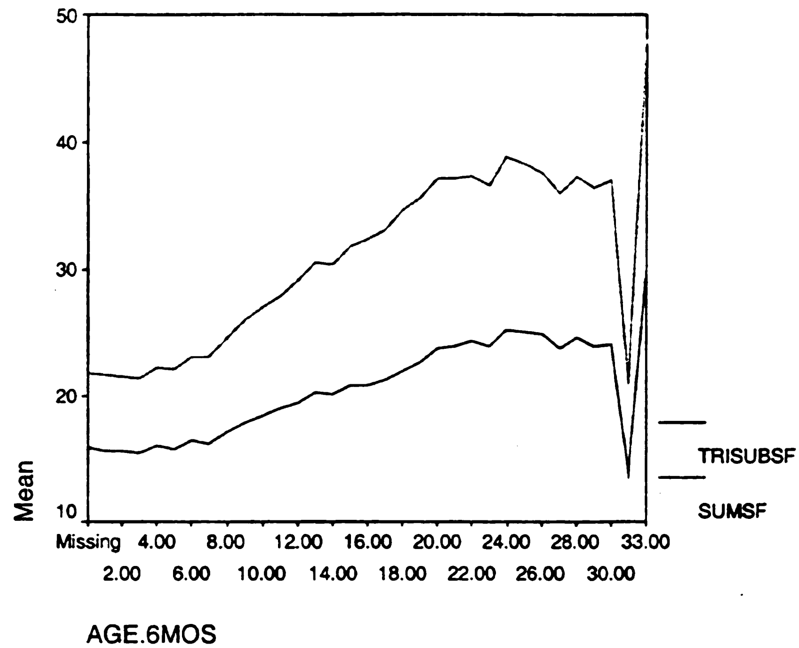
Longitudinal changes in triceps, subscapular and umbilical skinfolds for females



Longitudinal changes in sit/stand and hip/shoulder ratios for females



Longitudinal changes in triceps + subscapular and sum of skinfolds for females



APPENDIX E

SPECIFIC AGE GROUP CORRELATION MATRICES

Correlations 7 year old females

Correlations

		J.81.8	WT	TANDH	BMI	SITHT	TSTAN	ACRO	ICRIS	ILDRH	ROMR	ADST	RMGI	HIGIR	ALFGI	RICEF	JBSC	UMBIL	ISUBS	UMSF
LJ.81.8	Pearson Co	1	.022	.040	-.009	.070	.051	.130	.091	-.043	.092	.152*	-.010	-.074	-.095	-.142*	-.100	-.094	-.142*	-.132
	Sig. (2-taile	.	.761	.583	.900	.329	.477	.072	.207	.550	.200	.034	.887	.302	.187	.048	.167	.192	.048	.066
	N	195	194	195	194	194	194	194	194	194	194	194	194	194	194	194	194	194	194	194
WT	Pearson Co	.022	1	.925*	.851*	.940*	-.572*	.939*	.957*	.406*	.924*	.926*	.936*	.963*	.966*	.504*	.679*	.675*	.645*	.686*
	Sig. (2-taile	.761	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	194	6508	6508	6508	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
STANC	Pearson Co	.040	.925*	1	.612*	.987*	-.754*	.970*	.948*	.299*	.987*	.987*	.821*	.888*	.905*	.311*	.461*	.474*	.421*	.463*
	Sig. (2-taile	.583	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	195	6508	6641	6508	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
BMI	Pearson Co	-.009	.851*	.612*	1	.657*	-.241*	.688*	.743*	.422*	.627*	.632*	.903*	.869*	.842*	.692*	.831*	.823*	.830*	.862*
	Sig. (2-taile	.900	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	194	6508	6508	6508	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
SITHT	Pearson Co	.070	.940*	.987*	.657*	1	-.644*	.966*	.957*	.339*	.970*	.969*	.838*	.903*	.915*	.338*	.496*	.505*	.455*	.497*
	Sig. (2-taile	.329	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	194	6505	6505	6505	6505	6505	6504	6500	6499	6503	6501	6505	6504	6504	6504	6505	6504	6504	6504
SITSTA	Pearson Co	.051	-.572*	-.754*	-.241*	-.644*	1	-.701*	-.628*	-.033*	-.756*	-.762*	-.506*	-.562*	-.587*	-.114*	-.179*	-.205*	-.160*	-.188*
	Sig. (2-taile	.477	.000	.000	.000	.000	.	.000	.000	.008	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	194	6505	6505	6505	6505	6505	6504	6500	6499	6503	6501	6505	6504	6504	6504	6505	6504	6504	6504
BIACR	Pearson Co	.130	.939*	.970*	.688*	.966*	-.701*	1	.957*	.235*	.969*	.967*	.854*	.907*	.920*	.348*	.520*	.520*	.473*	.515*
	Sig. (2-taile	.072	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	194	6506	6506	6506	6504	6504	6506	6501	6501	6504	6502	6506	6505	6505	6505	6506	6505	6505	6505
BICRIS	Pearson Co	.091	.957*	.948*	.743*	.957*	-.628*	.957*	1	.501*	.947*	.945*	.873*	.921*	.932*	.399*	.587*	.575*	.538*	.578*
	Sig. (2-taile	.207	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	194	6502	6502	6502	6500	6500	6501	6502	6501	6500	6498	6502	6501	6501	6501	6502	6501	6501	6501
SHLDR	Pearson Co	-.043	.406*	.299*	.422*	.339*	-.033*	.235*	.501*	1	.297*	.296*	.377*	.382*	.382*	.283*	.398*	.366*	.372*	.384*
	Sig. (2-taile	.550	.000	.000	.000	.000	.008	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	194	6501	6501	6501	6499	6499	6501	6501	6501	6499	6497	6501	6500	6500	6500	6501	6500	6500	6500
ACROM	Pearson Co	.092	.924*	.987*	.627*	.970*	-.756*	.969*	.947*	.297*	1	.987*	.822*	.884*	.900*	.320*	.470*	.480*	.431*	.471*
	Sig. (2-taile	.200	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	194	6505	6505	6505	6503	6503	6504	6500	6499	6505	6501	6505	6504	6504	6504	6505	6504	6504	6504
RADST	Pearson Co	.152*	.926*	.987*	.632*	.969*	-.762*	.967*	.945*	.296*	.987*	1	.826*	.887*	.903*	.320*	.476*	.488*	.434*	.477*
	Sig. (2-taile	.034	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000
	N	194	6503	6503	6503	6501	6501	6502	6498	6497	6501	6503	6503	6502	6502	6502	6503	6502	6502	6502
ARMGI	Pearson Co	-.010	.936*	.821*	.903*	.838*	-.506*	.854*	.873*	.377*	.822*	.826*	1	.950*	.936*	.649*	.745*	.754*	.760*	.789*
	Sig. (2-taile	.887	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	N	194	6507	6507	6507	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
THIGIR	Pearson Co	-.074	.963*	.888*	.869*	.903*	-.562*	.907*	.921*	.382*	.884*	.887*	.950*	1	.963*	.561*	.690*	.697*	.682*	.717*
	Sig. (2-taile	.302	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	N	194	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6506	6505	6505	6506	6505	6505	6505
CALFG	Pearson Co	-.095	.966*	.905*	.842*	.915*	-.587*	.920*	.932*	.382*	.900*	.903*	.936*	.963*	1	.529*	.656*	.656*	.646*	.677*
	Sig. (2-taile	.187	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	N	194	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6506	6505	6506	6505	6505	6505
TRICEF	Pearson Co	-.142*	.504*	.311*	.692*	.338*	-.114*	.348*	.399*	.283*	.320*	.320*	.649*	.561*	.529*	1	.687*	.683*	.917*	.847*
	Sig. (2-taile	.048	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000
	N	194	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506
SUBSC	Pearson Co	-.100	.679*	.461*	.831*	.496*	-.179*	.520*	.587*	.398*	.470*	.476*	.745*	.690*	.656*	.687*	1	.858*	.920*	.930*
	Sig. (2-taile	.167	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	N	194	6507	6507	6507	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
UMBIL	Pearson Co	-.094	.675*	.474*	.823*	.505*	-.205*	.520*	.575*	.366*	.480*	.488*	.754*	.697*	.656*	.683*	.858*	1	.840*	.949*
	Sig. (2-taile	.192	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	N	194	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506
TRISUE	Pearson Co	-.142*	.645*	.421*	.830*	.455*	-.160*	.473*	.538*	.372*	.431*	.434*	.760*	.682*	.646*	.917*	.920*	.840*	1	.968*
	Sig. (2-taile	.048	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	N	194	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506
SUMSF	Pearson Co	-.132	.686*	.463*	.862*	.497*	-.188*	.515*	.578*	.384*	.471*	.477*	.789*	.717*	.677*	.847*	.930*	.949*	.968*	1
	Sig. (2-taile	.066	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.
	N	194	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Correlations 12 year old females

Correlations

		J14114	WT	STANDH	BMI	SITHT	SITSTA	BIACRO	BICRIS	SHLDRH	ACROMR	RADST	ARMGI	THIGIR	CALFGI	TRICEP	SUBSCA	UMBIL	TRISUB	SUMSF
J14114	Pearson C	1	-.168**	.044	-.250**	-.010	-.121	.094	-.112	-.261**	.051	.037	-.186**	-.205**	-.177**	-.395**	-.346**	-.346**	-.396**	-.391**
	Sig. (2-tailed)	.	.009	.499	.000	.878	.062	.144	.084	.000	.427	.563	.004	.001	.006	.000	.000	.000	.000	.000
	N	241	241	241	241	240	240	241	240	240	241	241	241	241	241	241	241	241	241	241
WT	Pearson C	-.168**	1	.925**	.851**	.940**	-.572**	.939**	.957**	.406**	.924**	.926**	.936**	.963**	.966**	.504**	.679**	.675**	.645**	.686**
	Sig. (2-tailed)	.009	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	241	6508	6508	6508	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
STANDH	Pearson C	.044	.925**	1	.612**	.987**	-.754**	.970**	.948**	.299**	.987**	.987**	.821**	.888**	.905**	.311**	.461**	.474**	.421**	.463**
	Sig. (2-tailed)	.499	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	241	6508	6641	6508	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
BMI	Pearson C	-.250**	.851**	.612**	1	.657**	-.241**	.688**	.743**	.422**	.627**	.632**	.903**	.869**	.842**	.692**	.831**	.823**	.830**	.862**
	Sig. (2-tailed)	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	241	6508	6508	6508	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
SITHT	Pearson C	-.010	.940**	.987**	.657**	1	-.644**	.966**	.957**	.339**	.970**	.969**	.838**	.903**	.915**	.338**	.496**	.505**	.455**	.497**
	Sig. (2-tailed)	.878	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	240	6505	6505	6505	6505	6505	6504	6500	6499	6503	6501	6505	6504	6504	6504	6505	6504	6504	6504
SITSTA	Pearson C	-.121	-.572**	-.754**	-.241**	-.644**	1	-.701**	-.628**	-.033**	-.756**	-.762**	-.506**	-.562**	-.587**	-.114**	-.179**	-.205**	-.160**	-.188**
	Sig. (2-tailed)	.062	.000	.000	.000	.000	.	.000	.000	.008	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	240	6505	6505	6505	6505	6505	6504	6500	6499	6503	6501	6505	6504	6504	6504	6505	6504	6504	6504
BIACRO	Pearson C	.094	.939**	.970**	.688**	.966**	-.701**	1	.957**	.235**	.969**	.967**	.854**	.907**	.920**	.348**	.520**	.520**	.473**	.515**
	Sig. (2-tailed)	.144	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	241	6506	6506	6506	6504	6504	6506	6501	6501	6504	6502	6506	6505	6505	6505	6506	6505	6505	6505
BICRIS	Pearson C	-.112	.957**	.948**	.743**	.957**	-.628**	.957**	1	.501**	.947**	.945**	.873**	.921**	.932**	.399**	.587**	.575**	.538**	.578**
	Sig. (2-tailed)	.084	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	240	6502	6502	6502	6500	6500	6501	6502	6501	6500	6498	6502	6501	6501	6501	6502	6501	6501	6501
SHLDRH	Pearson C	-.261**	.406**	.299**	.422**	.339**	-.033**	.235**	.501**	1	.297**	.296**	.377**	.382**	.382**	.283**	.398**	.366**	.372**	.384**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.008	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	240	6501	6501	6501	6499	6499	6501	6501	6501	6499	6497	6501	6500	6500	6500	6501	6500	6500	6500
ACROMR	Pearson C	.051	.924**	.987**	.627**	.970**	-.756**	.969**	.947**	.297**	1	.987**	.822**	.884**	.900**	.320**	.470**	.480**	.431**	.471**
	Sig. (2-tailed)	.427	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	241	6505	6505	6505	6503	6503	6504	6500	6499	6505	6501	6505	6504	6504	6504	6505	6504	6504	6504
RADST	Pearson C	.037	.926**	.987**	.632**	.969**	-.762**	.967**	.945**	.296**	.987**	1	.826**	.887**	.903**	.320**	.476**	.488**	.434**	.477**
	Sig. (2-tailed)	.563	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000
	N	241	6503	6503	6503	6501	6501	6502	6498	6497	6501	6503	6503	6502	6502	6502	6503	6502	6502	6502
ARMGI	Pearson C	-.186**	.936**	.821**	.903**	.838**	-.506**	.854**	.873**	.377**	.822**	.826**	1	.950**	.936**	.649**	.745**	.754**	.760**	.789**
	Sig. (2-tailed)	.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	N	241	6507	6507	6507	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
THIGIR	Pearson C	-.205**	.963**	.888**	.869**	.903**	-.562**	.907**	.921**	.382**	.884**	.887**	.950**	1	.963**	.561**	.690**	.697**	.682**	.717**
	Sig. (2-tailed)	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	N	241	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6506	6505	6505	6506	6505	6505	6505
CALFGI	Pearson C	-.177**	.966**	.905**	.842**	.915**	-.587**	.920**	.932**	.382**	.900**	.903**	.936**	.963**	1	.529**	.656**	.656**	.646**	.677**
	Sig. (2-tailed)	.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	N	241	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6506	6505	6506	6505	6505	6505
TRICEP	Pearson C	-.395**	.504**	.311**	.692**	.338**	-.114**	.348**	.399**	.283**	.320**	.320**	.649**	.561**	.529**	1	.687**	.683**	.917**	.847**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000
	N	241	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506
SUBSCA	Pearson C	-.346**	.679**	.461**	.831**	.496**	-.179**	.520**	.587**	.398**	.470**	.476**	.745**	.690**	.656**	.687**	1	.858**	.920**	.930**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	N	241	6507	6507	6507	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
UMBIL	Pearson C	-.346**	.675**	.474**	.823**	.505**	-.205**	.520**	.575**	.366**	.480**	.488**	.754**	.697**	.656**	.683**	.858**	1	.840**	.949**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	N	241	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506
TRISUB	Pearson C	-.396**	.645**	.421**	.830**	.455**	-.160**	.473**	.538**	.372**	.431**	.434**	.760**	.682**	.646**	.917**	.920**	.840**	1	.968**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	N	241	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506
SUMSF	Pearson C	-.391**	.686**	.463**	.862**	.497**	-.188**	.515**	.578**	.384**	.471**	.477**	.789**	.717**	.677**	.847**	.930**	.949**	.968**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.
	N	241	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations 16 year old females

Correlations

		18919	WT	TANDH	BMI	SITHT	TSTAN	ACRO	ICRIS	HLDRH	ROMR	ADST	RMGI	HIGIR	ALFGI	RICEP	JBSCA	JMBIL	ISUBS	UMSF
J18919	Pearson Cc	1	-.129	.148	-.262**	.083	-.125	.067	-.216**	-.294**	.074	.131	-.130	-.126	-.059	-.361**	-.430**	-.407**	-.446**	-.457**
	Sig. (2-taile	.	.089	.051	.000	.275	.101	.381	.004	.000	.329	.087	.087	.097	.439	.000	.000	.000	.000	.000
	N	174	174	174	174	174	174	174	174	174	174	173	174	174	174	174	174	174	174	174
WT	Pearson Cc	-.129	1	.925**	.851**	.940**	-.572**	.939**	.957**	.406**	.924**	.926**	.936**	.963**	.966**	.504**	.679**	.675**	.645**	.686**
	Sig. (2-taile	.089	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	174	6508	6508	6508	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
STAND	Pearson Cc	.148	.925**	1	.612**	.987**	-.754**	.970**	.948**	.299**	.987**	.987**	.821**	.888**	.905**	.311**	.461**	.474**	.421**	.463**
	Sig. (2-taile	.051	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	174	6508	6641	6508	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
BMI	Pearson Cc	-.262**	.851**	.612**	1	.657**	-.241**	.688**	.743**	.422**	.627**	.632**	.903**	.869**	.842**	.692**	.831**	.823**	.830**	.862**
	Sig. (2-taile	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	174	6508	6508	6508	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
SITHT	Pearson Cc	.083	.940**	.987**	.657**	1	-.644**	.966**	.957**	.339**	.970**	.969**	.838**	.903**	.915**	.338**	.496**	.505**	.455**	.497**
	Sig. (2-taile	.275	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	174	6505	6505	6505	6505	6505	6504	6500	6499	6503	6501	6505	6504	6504	6504	6505	6504	6504	6504
SITSTA	Pearson Cc	-.125	-.572**	-.754**	-.241**	-.644**	1	-.701**	-.628**	-.033**	-.756**	-.762**	-.506**	-.562**	-.587**	-.114**	-.179**	-.205**	-.160**	-.188**
	Sig. (2-taile	.101	.000	.000	.000	.000	.	.000	.000	.008	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	174	6505	6505	6505	6505	6505	6504	6500	6499	6503	6501	6505	6504	6504	6504	6505	6504	6504	6504
BIACR	Pearson Cc	.067	.939**	.970**	.688**	.966**	-.701**	1	.957**	.235**	.969**	.967**	.854**	.907**	.920**	.348**	.520**	.520**	.473**	.515**
	Sig. (2-taile	.381	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	174	6506	6506	6506	6504	6504	6506	6501	6501	6504	6502	6506	6505	6505	6505	6506	6505	6505	6505
BICRIS	Pearson Cc	-.216**	.957**	.948**	.743**	.957**	-.628**	.957**	1	.501**	.947**	.945**	.873**	.921**	.932**	.399**	.587**	.575**	.538**	.578**
	Sig. (2-taile	.004	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	174	6502	6502	6502	6500	6500	6501	6502	6501	6500	6498	6502	6501	6501	6501	6502	6501	6501	6501
SHLDR	Pearson Cc	-.294**	.406**	.299**	.422**	.339**	-.033**	.235**	.501**	1	.297**	.296**	.377**	.382**	.382**	.283**	.398**	.366**	.372**	.384**
	Sig. (2-taile	.000	.000	.000	.000	.000	.008	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	174	6501	6501	6501	6499	6499	6501	6501	6501	6499	6497	6501	6500	6500	6500	6501	6500	6500	6500
ACROM	Pearson Cc	.074	.924**	.987**	.627**	.970**	-.756**	.969**	.947**	.297**	1	.987**	.822**	.884**	.900**	.320**	.470**	.480**	.431**	.471**
	Sig. (2-taile	.329	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	174	6505	6505	6505	6503	6503	6504	6500	6499	6505	6501	6505	6504	6504	6504	6505	6504	6504	6504
RADST	Pearson Cc	.131	.926**	.987**	.632**	.969**	-.762**	.967**	.945**	.296**	.987**	1	.826**	.887**	.903**	.320**	.476**	.488**	.434**	.477**
	Sig. (2-taile	.087	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000
	N	173	6503	6503	6503	6501	6501	6502	6498	6497	6501	6503	6503	6502	6502	6502	6503	6502	6502	6502
ARMGI	Pearson Cc	-.130	.936**	.821**	.903**	.838**	-.506**	.854**	.873**	.377**	.822**	.826**	1	.950**	.936**	.649**	.745**	.754**	.760**	.789**
	Sig. (2-taile	.087	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	N	174	6507	6507	6507	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
THIGIR	Pearson Cc	-.126	.963**	.888**	.869**	.903**	-.562**	.907**	.921**	.382**	.884**	.887**	.950**	1	.963**	.561**	.690**	.697**	.682**	.717**
	Sig. (2-taile	.097	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	N	174	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6506	6505	6505	6506	6505	6505	6505
CALFG	Pearson Cc	-.059	.966**	.905**	.842**	.915**	-.587**	.920**	.932**	.382**	.900**	.903**	.936**	.963**	1	.529**	.656**	.656**	.646**	.677**
	Sig. (2-taile	.439	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	N	174	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6506	6505	6506	6505	6505	6505
TRICEI	Pearson Cc	-.361**	.504**	.311**	.692**	.338**	-.114**	.348**	.399**	.283**	.320**	.320**	.649**	.561**	.529**	1	.687**	.683**	.917**	.847**
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000
	N	174	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506
SUBSC	Pearson Cc	-.430**	.679**	.461**	.831**	.496**	-.179**	.520**	.587**	.398**	.470**	.476**	.745**	.690**	.656**	.687**	1	.858**	.920**	.930**
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	N	174	6507	6507	6507	6505	6505	6506	6502	6501	6505	6503	6507	6506	6506	6506	6507	6506	6506	6506
UMBIL	Pearson Cc	-.407**	.675**	.474**	.823**	.505**	-.205**	.520**	.575**	.366**	.480**	.488**	.754**	.697**	.656**	.683**	.858**	1	.840**	.949**
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	N	174	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506
TRISUI	Pearson Cc	-.446**	.645**	.421**	.830**	.455**	-.160**	.473**	.538**	.372**	.431**	.434**	.760**	.682**	.646**	.917**	.920**	.840**	1	.968**
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	N	174	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506
SUMSF	Pearson Cc	-.457**	.686**	.463**	.862**	.497**	-.188**	.515**	.578**	.384**	.471**	.477**	.789**	.717**	.677**	.847**	.930**	.949**	.968**	1
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.
	N	174	6506	6506	6506	6504	6504	6505	6501	6500	6504	6502	6506	6505	6505	6506	6506	6506	6506	6506

**Correlation is significant at the 0.01 level (2-tailed).

Correlations 7 year old males

Correlations

		J.81.8	WT	TANDH	BMI	SITHT	TSTAN	ACRO	ICRIS	LDRH	ROMR	ADST	RMGI	HIGIR	ALFGI	RICEP	JBSCA	JMBIL	RISUBS	UMSF
LJ.81.8	Pearson C	1	.054	.022	.056	.099	.121	.131	.173*	.065	-.043	.026	.012	-.072	-.039	-.163*	-.197*	-.181*	-.193*	-.199*
	Sig. (2-taile	.	.499	.788	.484	.218	.133	.102	.030	.419	.596	.748	.879	.367	.628	.041	.013	.023	.016	.013
	N	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157	157
WT	Pearson C	.054	1	.939*	.877*	.953*	-.564*	.958*	.952*	-.214*	.935*	.940*	.956*	.963*	.961*	.079*	.604*	.521*	.378*	.468*
	Sig. (2-taile	.499	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	157	5857	5857	5857	5855	5855	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
STAND	Pearson C	.022	.939*	1	.688*	.984*	-.736*	.973*	.963*	-.243*	.988*	.989*	.866*	.909*	.919*	-.026*	.438*	.375*	.225*	.312*
	Sig. (2-taile	.788	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.043	.000	.000	.000	.000
	N	157	5857	5977	5857	5856	5856	5854	5855	5853	5855	5856	5855	5855	5855	5856	5856	5856	5856	5856
BMI	Pearson C	.056	.877*	.688*	1	.731*	-.288*	.763*	.766*	-.132*	.696*	.708*	.916*	.894*	.869*	.302*	.752*	.692*	.591*	.667*
	Sig. (2-taile	.484	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	157	5857	5857	5857	5855	5855	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
SITHT	Pearson C	.099	.953*	.984*	.731*	1	-.608*	.975*	.960*	-.254*	.966*	.968*	.889*	.915*	.924*	-.041*	.467*	.383*	.232*	.320*
	Sig. (2-taile	.218	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.000
	N	157	5855	5856	5855	5856	5856	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
SITSTA	Pearson C	.121	-.564*	-.736*	-.288*	-.608*	1	-.646*	-.653*	.144*	-.747*	-.743*	-.491*	-.589*	-.595*	-.035*	-.178*	-.224*	-.118*	-.178*
	Sig. (2-taile	.133	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.007	.000	.000	.000	.000
	N	157	5855	5856	5855	5856	5856	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
BIACR	Pearson C	.131	.958*	.973*	.763*	.975*	-.646*	1	.964*	-.333*	.966*	.970*	.901*	.925*	.929*	-.037*	.477*	.392*	.240*	.329*
	Sig. (2-taile	.102	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.005	.000	.000	.000	.000
	N	157	5853	5854	5853	5853	5853	5854	5853	5853	5853	5854	5852	5853	5853	5854	5854	5854	5854	5854
BICRIS	Pearson C	.173*	.952*	.963*	.766*	.960*	-.653*	.964*	1	-.076*	.956*	.955*	.890*	.923*	.925*	.017	.508*	.428*	.289*	.373*
	Sig. (2-taile	.030	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.185	.000	.000	.000	.000
	N	157	5854	5855	5854	5854	5854	5853	5855	5853	5854	5855	5853	5854	5854	5855	5855	5855	5855	5855
SHLDR	Pearson C	.065	-.214*	-.243*	-.132*	-.254*	.144*	-.333*	-.076*	1	-.241*	-.263*	-.215*	-.198*	-.204*	.185*	.010	.036*	.114*	.078*
	Sig. (2-taile	.419	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.435	.006	.000	.000
	N	157	5852	5853	5852	5852	5852	5853	5853	5853	5852	5853	5851	5852	5852	5853	5853	5853	5853	5853
ACROM	Pearson C	-.043	.935*	.988*	.696*	.966*	-.747*	.966*	.956*	-.241*	1	.986*	.866*	.908*	.911*	-.003	.448*	.390*	.244*	.330*
	Sig. (2-taile	.596	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.809	.000	.000	.000	.000
	N	157	5854	5855	5854	5854	5854	5853	5854	5852	5855	5855	5853	5854	5854	5855	5855	5855	5855	5855
RADST	Pearson C	.026	.940*	.989*	.708*	.968*	-.743*	.970*	.955*	-.263*	.986*	1	.872*	.911*	.918*	-.010	.452*	.390*	.242*	.329*
	Sig. (2-taile	.748	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.447	.000	.000	.000	.000
	N	157	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
ARMGI	Pearson C	.012	.956*	.866*	.916*	.889*	-.491*	.901*	.890*	-.215*	.866*	.872*	1	.953*	.940*	.199*	.665*	.601*	.482*	.563*
	Sig. (2-taile	.879	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	N	157	5854	5855	5854	5854	5854	5852	5853	5851	5853	5854	5855	5854	5854	5854	5854	5854	5854	5854
THIGIR	Pearson C	-.072	.963*	.909*	.894*	.915*	-.589*	.925*	.923*	-.198*	.908*	.911*	.953*	1	.969*	.195*	.633*	.588*	.462*	.547*
	Sig. (2-taile	.367	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	N	157	5854	5855	5854	5854	5854	5853	5854	5852	5854	5855	5854	5855	5855	5855	5855	5855	5855	5855
CALFG	Pearson C	-.039	.961*	.919*	.869*	.924*	-.595*	.929*	.925*	-.204*	.911*	.918*	.940*	.969*	1	.147*	.599*	.537*	.415*	.495*
	Sig. (2-taile	.628	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	N	157	5854	5855	5854	5854	5854	5853	5854	5852	5854	5855	5854	5855	5855	5855	5855	5855	5855	5855
TRICEP	Pearson C	-.163*	.079*	-.026*	.302*	-.041*	-.035*	-.037*	.017	.185*	-.003	-.010	.199*	.195*	.147*	1	.549*	.649*	.888*	.802*
	Sig. (2-taile	.041	.000	.043	.000	.002	.007	.005	.185	.000	.809	.447	.000	.000	.000	.	.000	.000	.000	.000
	N	157	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
SUBSC	Pearson C	-.197*	.604*	.438*	.752*	.467*	-.178*	.477*	.508*	.010	.448*	.452*	.665*	.633*	.599*	.549*	1	.841*	.871*	.892*
	Sig. (2-taile	.013	.000	.000	.000	.000	.000	.000	.000	.435	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	N	157	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
UMBIL	Pearson C	-.181*	.521*	.375*	.692*	.383*	-.224*	.392*	.428*	.036*	.390*	.390*	.601*	.588*	.537*	.649*	.841*	1	.843*	.959*
	Sig. (2-taile	.023	.000	.000	.000	.000	.000	.000	.000	.006	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	N	157	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
TRISUB	Pearson C	-.193*	.378*	.225*	.591*	.232*	-.118*	.240*	.289*	.114*	.244*	.242*	.482*	.462*	.415*	.888*	.871*	.843*	1	.961*
	Sig. (2-taile	.016	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	N	157	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
SUMSF	Pearson C	-.199*	.468*	.312*	.667*	.320*	-.178*	.329*	.373*	.078*	.330*	.329*	.563*	.547*	.495*	.802*	.892*	.959*	.961*	1
	Sig. (2-taile	.013	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.
	N	157	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Correlations 14 year old males

Correlations

		16517	WT	TANDH	BMI	SITHT	TSTAN	ACRO	ICRIS	LDRH	ROMR	ADST	RMGI	HIGIR	ALFGI	RICEP	BSCA	UMBIL	ISUBS	UMSF
J16517	Pearson Co	1	.060	.187*	-.046	.286*	.224*	.289*	.079	-.234*	.132	.134	.009	-.050	.007	-.434*	-.257*	-.363*	-.387*	-.388*
	Sig. (2-taile	.	.402	.009	.521	.000	.002	.000	.271	.001	.065	.062	.900	.490	.924	.000	.000	.000	.000	.000
	N	197	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196
WT	Pearson Co	.060	1	.939*	.877*	.953*	-.564*	.958*	.952*	-.214*	.935*	.940*	.956*	.963*	.961*	.079*	.604*	.521*	.378*	.468*
	Sig. (2-taile	.402	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	196	5857	5857	5857	5855	5855	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
STAND	Pearson Co	.187*	.939*	1	.688*	.984*	-.736*	.973*	.963*	-.243*	.988*	.989*	.866*	.909*	.919*	-.026*	.438*	.375*	.225*	.312*
	Sig. (2-taile	.009	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.043	.000	.000	.000	.000
	N	196	5857	5977	5857	5856	5856	5854	5855	5853	5855	5856	5855	5855	5855	5856	5856	5856	5856	5856
BMI	Pearson Co	-.046	.877*	.688*	1	.731*	-.288*	.763*	.766*	-.132*	.696*	.708*	.916*	.894*	.869*	.302*	.752*	.692*	.591*	.667*
	Sig. (2-taile	.521	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	196	5857	5857	5857	5855	5855	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
SITHT	Pearson Co	.286*	.953*	.984*	.731*	1	-.608*	.975*	.960*	-.254*	.966*	.968*	.889*	.915*	.924*	-.041*	.467*	.383*	.232*	.320*
	Sig. (2-taile	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.000
	N	196	5855	5856	5855	5856	5856	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
SITSTA	Pearson Co	.224*	-.564*	-.736*	-.288*	-.608*	1	-.646*	-.653*	.144*	-.747*	-.743*	-.491*	-.589*	-.595*	-.035*	-.178*	-.224*	-.118*	-.178*
	Sig. (2-taile	.002	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.007	.000	.000	.000	.000
	N	196	5855	5856	5855	5856	5856	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
BIACR	Pearson Co	.289*	.958*	.973*	.763*	.975*	-.646*	1	.964*	-.333*	.966*	.970*	.901*	.925*	.929*	-.037*	.477*	.392*	.240*	.329*
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.005	.000	.000	.000	.000
	N	196	5853	5854	5853	5853	5853	5854	5853	5853	5853	5854	5852	5853	5853	5854	5854	5854	5854	5854
BICRIS	Pearson Co	.079	.952*	.963*	.766*	.960*	-.653*	.964*	1	-.076*	.956*	.955*	.890*	.923*	.925*	.017	.508*	.428*	.289*	.373*
	Sig. (2-taile	.271	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.185	.000	.000	.000	.000
	N	196	5854	5855	5854	5854	5854	5853	5855	5853	5854	5855	5853	5854	5854	5855	5855	5855	5855	5855
SHLDR	Pearson Co	-.234*	-.214*	-.243*	-.132*	-.254*	.144*	-.333*	-.076*	1	-.241*	-.263*	-.215*	-.198*	-.204*	.185*	.010	.036*	.114*	.078*
	Sig. (2-taile	.001	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.435	.006	.000	.000
	N	196	5852	5853	5852	5852	5852	5853	5853	5853	5852	5853	5851	5852	5852	5853	5853	5853	5853	5853
ACROM	Pearson Co	.132	.935*	.988*	.696*	.966*	-.747*	.966*	.956*	-.241*	1	.986*	.866*	.908*	.911*	-.003	.448*	.390*	.244*	.330*
	Sig. (2-taile	.065	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.809	.000	.000	.000	.000
	N	196	5854	5855	5854	5854	5854	5853	5854	5852	5855	5855	5853	5854	5854	5855	5855	5855	5855	5855
RADST	Pearson Co	.134	.940*	.989*	.708*	.968*	-.743*	.970*	.955*	-.263*	.986*	1	.872*	.911*	.918*	-.010	.452*	.390*	.242*	.329*
	Sig. (2-taile	.062	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.447	.000	.000	.000	.000
	N	196	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
ARMGI	Pearson Co	.009	.956*	.866*	.916*	.889*	-.491*	.901*	.890*	-.215*	.866*	.872*	1	.953*	.940*	.199*	.665*	.601*	.482*	.563*
	Sig. (2-taile	.900	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	N	196	5854	5855	5854	5854	5854	5852	5853	5851	5853	5854	5855	5854	5854	5854	5854	5854	5854	5854
THIGIR	Pearson Co	-.050	.963*	.909*	.894*	.915*	-.589*	.925*	.923*	-.198*	.908*	.911*	.953*	1	.969*	.195*	.633*	.588*	.462*	.547*
	Sig. (2-taile	.490	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	N	196	5854	5855	5854	5854	5854	5853	5854	5852	5854	5855	5854	5855	5855	5855	5855	5855	5855	5855
CALFG	Pearson Co	.007	.961*	.919*	.869*	.924*	-.595*	.929*	.925*	-.204*	.911*	.918*	.940*	.969*	1	.147*	.599*	.537*	.415*	.495*
	Sig. (2-taile	.924	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	N	196	5854	5855	5854	5854	5854	5853	5854	5852	5854	5855	5854	5855	5855	5855	5855	5855	5855	5855
TRICEP	Pearson Co	-.434*	.079*	-.026*	.302*	-.041*	-.035*	-.037*	.017	.185*	-.003	-.010	.199*	.195*	.147*	1	.549*	.649*	.888*	.802*
	Sig. (2-taile	.000	.000	.043	.000	.002	.007	.005	.185	.000	.809	.447	.000	.000	.000	.	.000	.000	.000	.000
	N	196	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
SUBSC	Pearson Co	-.257*	.604*	.438*	.752*	.467*	-.178*	.477*	.508*	.010	.448*	.452*	.665*	.633*	.599*	.549*	1	.841*	.871*	.892*
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.435	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	N	196	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
UMBIL	Pearson Co	-.363*	.521*	.375*	.692*	.383*	-.224*	.392*	.428*	.036*	.390*	.390*	.601*	.588*	.537*	.649*	.841*	1	.843*	.959*
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.006	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	N	196	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
TRISUB	Pearson Co	-.387*	.378*	.225*	.591*	.232*	-.118*	.240*	.289*	.114*	.244*	.242*	.482*	.462*	.415*	.888*	.871*	.843*	1	.961*
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	N	196	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
SUMSF	Pearson Co	-.388*	.468*	.312*	.667*	.320*	-.178*	.329*	.373*	.078*	.330*	.329*	.563*	.547*	.495*	.802*	.892*	.959*	.961*	1
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.
	N	196	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Correlations 18 year old males

Correlations

		21321	WT	TANDH	BMI	SITHT	TSTAN	ACRO	ICRIS	LDRH	ROMR/	ADST	RMGI	HIGIR	ALFGI	RICEF	BSCA	UMBIL	ISUBS	UMSF
J21321	Pearson Co	1	.066	.144	-.030	.191*	.042	.181*	-.045	-.219*	.055	.082	.131	.035	.089	-.304*	-.264*	-.275*	-.316*	-.304*
	Sig. (2-taile	.	.467	.113	.740	.035	.646	.046	.619	.015	.548	.369	.150	.698	.326	.001	.003	.002	.000	.001
	N	124	123	123	123	123	123	122	123	122	123	123	123	123	123	123	123	123	123	123
WT	Pearson Co	.066	1	.939*	.877*	.953*	-.564*	.958*	.952*	-.214*	.935*	.940*	.956*	.963*	.961*	.079*	.604*	.521*	.378*	.468*
	Sig. (2-taile	.467	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	123	5857	5857	5857	5855	5855	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
STAND	Pearson Co	.144	.939*	1	.688*	.984*	-.736*	.973*	.963*	-.243*	.988*	.989*	.866*	.909*	.919*	-.026*	.438*	.375*	.225*	.312*
	Sig. (2-taile	.113	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.043	.000	.000	.000	.000
	N	123	5857	5977	5857	5856	5856	5854	5855	5853	5855	5856	5855	5855	5855	5856	5856	5856	5856	5856
BMI	Pearson Co	-.030	.877*	.688*	1	.731*	-.288*	.763*	.766*	-.132*	.696*	.708*	.916*	.894*	.869*	.302*	.752*	.692*	.591*	.667*
	Sig. (2-taile	.740	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	123	5857	5857	5857	5855	5855	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
SITHT	Pearson Co	.191*	.953*	.984*	.731*	1	-.608*	.975*	.960*	-.254*	.966*	.968*	.889*	.915*	.924*	-.041*	.467*	.383*	.232*	.320*
	Sig. (2-taile	.035	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.000
	N	123	5855	5856	5855	5856	5856	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
SITSTA	Pearson Co	.042	-.564*	-.736*	-.288*	-.608*	1	-.646*	-.653*	.144*	-.747*	-.743*	-.491*	-.589*	-.595*	-.035*	-.178*	-.224*	-.118*	-.178*
	Sig. (2-taile	.646	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.007	.000	.000	.000	.000
	N	123	5855	5856	5855	5856	5856	5853	5854	5852	5854	5855	5854	5854	5854	5855	5855	5855	5855	5855
BIACR(	Pearson Co	.181*	.958*	.973*	.763*	.975*	-.646*	1	.964*	-.333*	.966*	.970*	.901*	.925*	.929*	-.037*	.477*	.392*	.240*	.329*
	Sig. (2-taile	.046	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.005	.000	.000	.000	.000
	N	122	5853	5854	5853	5853	5853	5854	5853	5853	5853	5854	5852	5853	5853	5854	5854	5854	5854	5854
BICRIS	Pearson Co	-.045	.952*	.963*	.766*	.960*	-.653*	.964*	1	-.076*	.956*	.955*	.890*	.923*	.925*	.017	.508*	.428*	.289*	.373*
	Sig. (2-taile	.619	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.185	.000	.000	.000	.000
	N	123	5854	5855	5854	5854	5854	5853	5855	5853	5854	5855	5853	5854	5854	5855	5855	5855	5855	5855
SHLDR	Pearson Co	-.219*	-.214*	-.243*	-.132*	-.254*	.144*	-.333*	-.076*	1	-.241*	-.263*	-.215*	-.198*	-.204*	.185*	.010	.036*	.114*	.078*
	Sig. (2-taile	.015	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.435	.006	.000	.000
	N	122	5852	5853	5852	5852	5852	5853	5853	5853	5852	5853	5851	5852	5852	5853	5853	5853	5853	5853
ACROI	Pearson Co	.055	.935*	.988*	.696*	.966*	-.747*	.966*	.956*	-.241*	1	.986*	.866*	.908*	.911*	-.003	.448*	.390*	.244*	.330*
	Sig. (2-taile	.548	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.809	.000	.000	.000	.000
	N	123	5854	5855	5854	5854	5854	5853	5854	5852	5855	5855	5853	5854	5854	5855	5855	5855	5855	5855
RADST	Pearson Co	.082	.940*	.989*	.708*	.968*	-.743*	.970*	.955*	-.263*	.986*	1	.872*	.911*	.918*	-.010	.452*	.390*	.242*	.329*
	Sig. (2-taile	.369	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.447	.000	.000	.000	.000
	N	123	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
ARMGI	Pearson Co	.131	.956*	.866*	.916*	.889*	-.491*	.901*	.890*	-.215*	.866*	.872*	1	.953*	.940*	.199*	.665*	.601*	.482*	.563*
	Sig. (2-taile	.150	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000
	N	123	5854	5855	5854	5854	5854	5852	5853	5851	5853	5854	5855	5854	5854	5854	5854	5854	5854	5854
THIGIR	Pearson Co	.035	.963*	.909*	.894*	.915*	-.589*	.925*	.923*	-.198*	.908*	.911*	.953*	1	.969*	.195*	.633*	.588*	.462*	.547*
	Sig. (2-taile	.698	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000	.000
	N	123	5854	5855	5854	5854	5854	5853	5854	5852	5854	5855	5854	5855	5855	5855	5855	5855	5855	5855
CALFG	Pearson Co	.089	.961*	.919*	.869*	.924*	-.595*	.929*	.925*	-.204*	.911*	.918*	.940*	.969*	1	.147*	.599*	.537*	.415*	.495*
	Sig. (2-taile	.326	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000	.000	.000
	N	123	5854	5855	5854	5854	5854	5853	5854	5852	5854	5855	5854	5855	5855	5855	5855	5855	5855	5855
TRICEF	Pearson Co	-.304*	.079*	-.026*	.302*	-.041*	-.035*	-.037*	.017	.185*	-.003	-.010	.199*	.195*	.147*	1	.549*	.649*	.888*	.802*
	Sig. (2-taile	.001	.000	.043	.000	.002	.007	.005	.185	.000	.809	.447	.000	.000	.000	.	.000	.000	.000	.000
	N	123	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
SUBSC	Pearson Co	-.264*	.604*	.438*	.752*	.467*	-.178*	.477*	.508*	.010	.448*	.452*	.665*	.633*	.599*	.549*	1	.841*	.871*	.892*
	Sig. (2-taile	.003	.000	.000	.000	.000	.000	.000	.000	.435	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	N	123	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
UMBIL	Pearson Co	-.275*	.521*	.375*	.692*	.383*	-.224*	.392*	.428*	.036*	.390*	.390*	.601*	.588*	.537*	.649*	.841*	1	.843*	.959*
	Sig. (2-taile	.002	.000	.000	.000	.000	.000	.000	.000	.006	.000	.000	.000	.000	.000	.000	.000	.	.000	.000
	N	123	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
TRISUE	Pearson Co	-.316*	.378*	.225*	.591*	.232*	-.118*	.240*	.289*	.114*	.244*	.242*	.482*	.462*	.415*	.888*	.871*	.843*	1	.961*
	Sig. (2-taile	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000
	N	123	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856
SUMSF	Pearson Co	-.304*	.468*	.312*	.667*	.320*	-.178*	.329*	.373*	.078*	.330*	.329*	.563*	.547*	.495*	.802*	.892*	.959*	.961*	1
	Sig. (2-taile	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.
	N	123	5855	5856	5855	5855	5855	5854	5855	5853	5855	5856	5854	5855	5855	5856	5856	5856	5856	5856

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

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