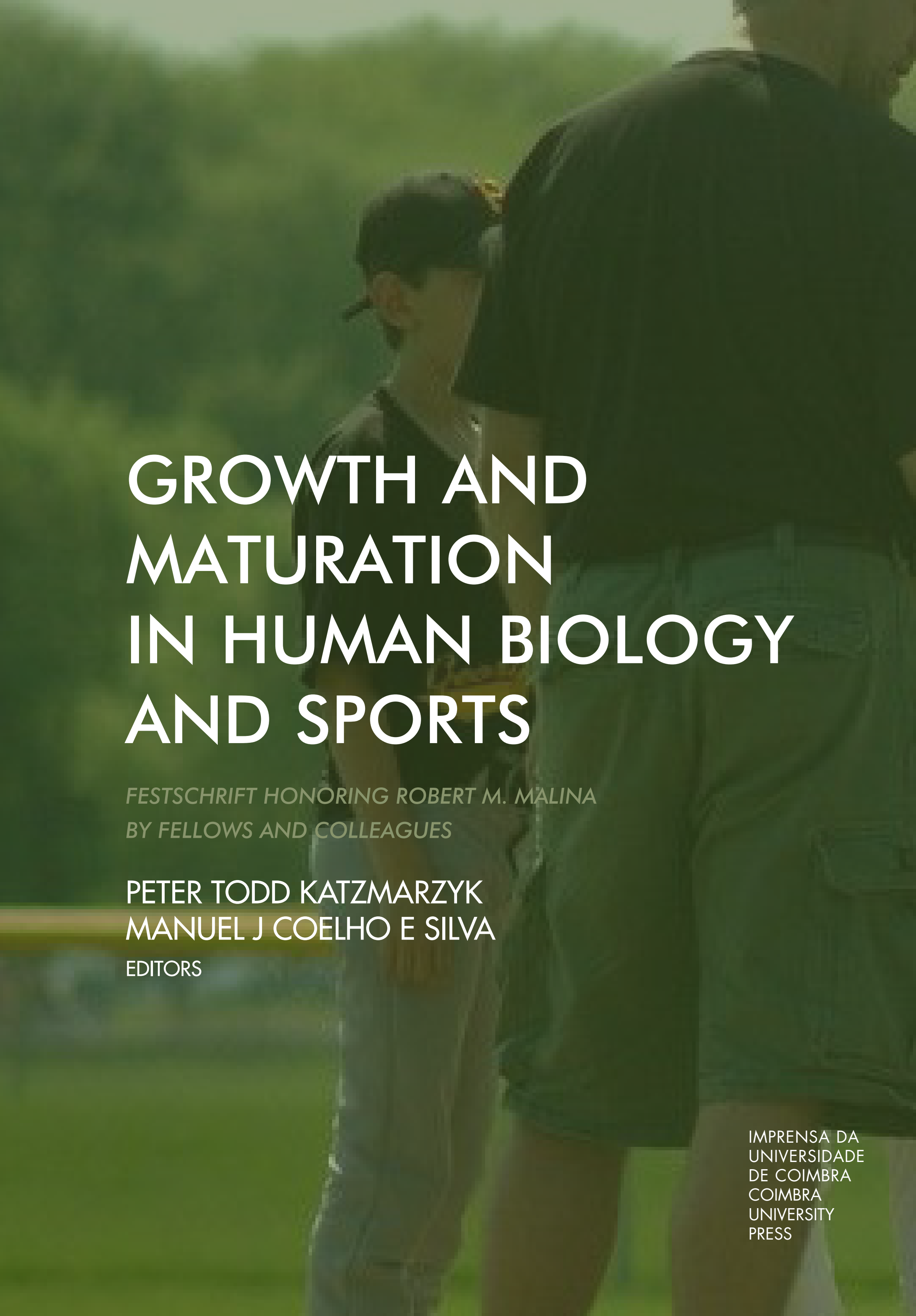

GROWTH AND MATURATION IN HUMAN BIOLOGY AND SPORTS

FESTSCHRIFT HONORING ROBERT M. MALINA BY FELLOWS AND COLLEAGUES

PETER TODD KATZMARZYK
MANUEL J COELHO E SILVA
EDITORS

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THE HONOREE: ROBERT MARION MALINA

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This collection of articles in the fields of physical anthropology and exercise science is presented by the authors to Robert Marion Malina in celebration of his on-going support of colleagues in this academic field as well as his on-going contributions to the field. Perhaps better known as "Bob" to many colleagues and friends, he merits a vote of gratitude for his voluminous work and the inspiration it has provided to many who have benefitted from his advice and encouragement.

Bob was born on September 19, 1937, to Mary and Joseph Malina, Sr., in Brooklyn, N.Y., the third of nine children. His early formal education began at Our Lady Of Consolation Parish School, in the Williamsburgh section of Brooklyn and Padua Franciscan High School, Watkins Glen, N.Y. Throughout his childhood and early adolescence, he matched his older siblings in academic success and in great dedication to sports – from the lots, streets and stoops of Williamsburgh to the soccer and baseball fields of secondary schools. His early and continued interest in sports moved him to pursue an undergraduate degree in Physical Education (now called Exercise Science) in Manhattan College, Riverdale, N.Y. (BS degree granted 1959).

This foundation led to graduate study in Physical Education at the University of Wisconsin (MS granted 1960 and PhD granted in 1963 with his dissertation: "Performance changes in speed-accuracy task as a function of practice under different conditions of information feedback," directed by Prof. G. Lawrence Rarick). His post-graduate interests led him to the department of Anthropology at the University of Pennsylvania, and another PhD granted in 1968. His dissertation was entitled: "Growth, maturation, and performance of Philadelphia Negro and White elementary school children," directed by Prof. Wilton M. Krogman.

Bob's academic career began at the University of Texas in the department of Anthropology (1967-1989) and subsequently in the department of Kinesiology and Health Education (1989-1995). His next appointment was at Michigan State University in the department of Kinesiology (1995-2002). At present he is adjunct research professor in the department of Kinesiology, Tarleton State University, Stephensville, Texas. This skeletal summary of his university positions tells little of what his ninety-five page curriculum vitae attests to.

Over the years he has taught many students who have signed up for his undergraduate courses in physical anthropology, while directing a number of master theses. His career has likewise included directing some fifty doctoral theses as well as entertaining a number of foreign scholars who came to study his research methods.

Throughout this period, Bob has served on the editorial boards of numerous international scholarly periodicals. Perhaps most significantly, he served as editor of the Yearbook of Physical Anthropology (1980-1986) as well as editor of the American Journal of Human Biology (1990-2002). His continued research with a number of populations, both at home and abroad, has led to friendships with an international network of colleagues. This research has led to the publication of over seven-hundred scholarly articles.

Given this admirable academic career, it is no surprise that Bob Malina has been awarded a number of academic honors. Among these perhaps it is noteworthy to mention four honorary doctoral degrees (Catholic University of Leuven, Faculty of Biomedical Sciences, Leuven, Belgium 1989; University of Kraków, Bronis³aw Czech College of Physical Education, Kraków, Poland 2001; University of Wroc³aw, College of Physical Education, Wroc³aw, Poland 2006; University of Coimbra, Faculty of Sport Sciences and Physical Education, Coimbra, Portugal 2008).

It is my pleasure to introduce this volume of articles in those fields to which my brother has dedicated himself, and which have provided him with decades of experience, study and global recognition.

ROBERT M. MALINA: A RENAISSANCE MAN AND BIG PICTURE HUMAN BIOLOGIST

Claude Bouchard

INTRODUCTION

It is an honor for me to be given the opportunity to contribute to this Festschrift recognizing the many accomplishments and the global legacy of Professor Robert M. Malina. I met Professor Malina for the first time in 1972 in Saskatoon, Canada, at a meeting focused on ongoing growth studies in Canada. It was a defining moment for me as it marked the beginning of a successful working relationship and a long-term friendship. Over the last 40 years, I have had the privilege of being able to observe from a front-row seat the numerous contributions made or spearheaded by Professor Malina (RMM), and this commentary is inspired by sustained contacts with him over these decades.

RMM is a true scholar as evidenced by hundreds of publications, oral presentations and invited lectures delivered around the world. His influence has been felt well beyond the United States. RMM has developed a large network of collaborations that have translated into numerous research projects and publications and the training of graduate students. Having often been a witness to the evolution of such relationships, I can testify that they were always approached by RMM with respect for the others and an unlimited listening capacity. Professor Malina is a devoted family man, supportive of his wife, Dr. Eva Malina, and three grown-up children, just as he was so strongly supported and motivated by them. Professor Malina's interest in history, old books, sculptures, paintings, religious arts, languages and good food and wine sets him apart from most of his peer scientists. His whole integrated bio-cultural approach to science questions and his personal life philosophy represent some of the typical traits of what is often referred to as a renaissance man, and this is undoubtedly among the reasons why we have all been fascinated by him over the years.

This commentary will highlight Professor Malina's research productivity and contributions to the training of the next generation of academics and scientists. It will conclude with some personal notes arising from our longstanding relationship.

RESEARCH PRODUCTIVITY

Anyone who has reviewed the curriculum vitae of RMM realizes that his research interests extend from human biology in the broad sense to exercise science, with a particular focus on growth and a variety of pediatric issues. His contribution to science spans a period of

50 years. He published his first research paper in 1962 in the *Journal of Bone and Joint Surgery* (Rarick *et al.,* 1962). Since then, he has contributed to the advancement of knowledge in areas as diverse as the morphological growth of children; motor development and motor skills across the growing years; maturation, including age at menarche; skeletal age; growth and sports performance; the risk factor profile for common chronic diseases in children; and the role of social, cultural and economic circumstances as seen in developed and developing countries on growth and maturation.

RMM has published almost 400 peer-reviewed research papers and about 300 book chapters, technical papers, book reviews and other reports. He has also written several monographs and books, including being the lead author on the first and second editions of *Growth, Maturation, and Physical Activity* (Malina & Bouchard, 1991; Malina, Bouchard & Bar-Or, 2004). His publications have been cited more than 7,600 times in the world literature.

I have chosen to highlight three aspects of his scholarly contributions. First, Professor Malina has been considered for decades as one of the premier experts on anthropometry, particularly as applied to pediatric populations. One example should suffice to illustrate the latter. RMM served for about a decade as the anthropometric consultant for the United States Health Examination Survey (HES) and Health and Nutrition Examination Survey (HANES). Second, RMM has had a longstanding interest in motor development and skill acquisition in children and adolescents. This was recognized in a comprehensive review of this research area by Professor Jerry Thomas presented at a meeting of the American Academy of Kinesiology and Physical Education and published in *Quest* in 2006. Thomas (2006) concluded that RMM was "the most highly cited motor development scholar," as well as the scientist who had published the most extensively in the area. Third, RMM is also widely perceived as the most prominent scholar on the topic of the "young athlete." He has published extensively and consulted with several national and international bodies on talent detection and growth and development of young athletes, including issues such as maturation, bone development and social integration in youth exposed to the demanding regimens of training for sports performance.

TRAINING GRADUATE STUDENTS

RMM has contributed substantially to the training of the next generation of scientists in his field. He has supervised 70 graduate students during his career, including 43 who were doctoral candidates. Several of them are actually contributing to this volume. A trademark of Professor Malina's approach to mentoring graduate students was his continuous effort to involve them in publication activities. This strategy allowed him to teach students to be accurate in their writing, to learn how to present their data in a clear manner, and most importantly to learn the art and science of interpreting their results in light of the existing literature. I suspect that it was also a tool for him to identify the best students who had a chance at succeeding at the doctoral and postdoctoral levels so that he could encourage them to consider a career in academia and science.

A hallmark of Professor Malina's contributions to training is his dedication to engaging colleagues from other countries and cultures. This is reflected in his portfolio of participation in graduate courses, research seminars and graduate thesis committees, especially in Europe and Latin American countries. Over the years, RMM has established strong collaborative research and graduate training partnerships with several institutions and colleagues, particularly from Belgium, Canada, Mexico, Poland and Portugal. His work in Oaxaca, Mexico, exemplifies this collaborative spirit; over the last 40 years, he has carried out growth and health assessments on samples of the indigenous community. One of his former doctoral students from Mexico is closely involved in this study and in the planned 45-year follow-up. RMM has always been very generous of his time, often working long hours helping non-English-speaking faculty or students with their manuscripts destined for publication in English language journals. Without his input and word-smithing, many of these manuscripts would not have been considered favorably by journal reviewers and editors.

Another indicator of the contributions of RMM can be seen in the performance of his former trainees. For instance, many of his former doctoral students have been asked to write papers for this Festschrift. For the sake of illustration, I will mention two of them. RMM's first PhD graduate was Dr. John H. Himes who completed his degree in 1975 (Himes, 1975). Over the last few decades, John has been a productive scientist at the University of Minnesota. He has been involved in about 147 peer-reviewed publications, which have been cited about 4,600 times to date, an average of 31 citations per paper. More than 20 years later, in 1997, Dr. Peter T. Katzmarzyk was the 30th graduate student completing a doctoral degree with RMM as his major professor (Katzmarzyk, 1997). Since then, Peter has risen to a high-profile research position and has been a highly productive scientist with more than 200 peer-reviewed papers averaging 28 citations each. Although several others have had distinguished careers following their training with RMM, these two cases illustrate the main point, which is that Professor Malina has made substantive contributions to the training of graduate students and to the emergence of the next generation of academics and human biologists.

PERSONAL NOTES

I feel that personal souvenirs and remarks are warranted at this stage. As I said above, I met RMM for the first time in Saskatoon in 1972. I enjoyed his presentation, but I had also read earlier his chapter on "an anthropological perspective of man in action" (Malina, 1969), published in a book edited by Cratty and Brown on the topic of "new perspectives on man in action." This chapter had a major influence on the direction that my career was about to take. I was looking for an institution where I could study human biology and human genetics with a focus on normal human variation. Behavior genetics programs were almost the only ones asking the kind of questions I was interested in, but my interest was more on biological and physiological traits. There were really no programs with this particular focus. To make a long story short, I enrolled at the University of Texas at Austin in the physical anthropology program with RMM as my major professor. He became like an orchestra conductor guiding me among the many courses in anthropology, molecular genetics, biochemical genetics, human genetics, statistical genetics, population genetics, etc, that were offered on the campus. It was a superb experience—and I became a Longhorns fan in the process!

To date, RMM and I have collaborated on about 50 publications, which have been cited about 2,000 times, for a very respectable average of 40 citations per paper. Incidentally, some of these papers were published with Dr. Arto Demirjian from the Human Growth Center at the University of Montreal. Our relationship with Arto was delightful and productive. Seventeen of these joint publications are based on the data of the Quebec Family Study, which RMM became familiar with when he spent a sabbatical year (1986-1987) with us in the Physical Activity Sciences Laboratory at Laval University in Quebec City. During this sabbatical, we wrote a substantial portion of the first edition of the book *Growth, Maturation, and Physical Activity* (Malina & Bouchard, 1991), which was finally published by Human Kinetics in 1991. In 1999, we began planning for the second edition of the book (Malina, Bouchard & Bar-Or, 2004), which was ultimately published in 2004. The late Professor Oded Bar-Or joined us for this new version, and it was a wonderful experience to work on this project with RMM and Oded. Both editions of the book have been well received around the world.

RMM and I have shared many passions over the years. His enthusiasm for human biology and human variation research had a great influence on me and broadened my thinking, which had been focused on genetic differences. His love for New York has been contagious, and I am proud to say that it is now a passion that I share with him and Eva. Needless to say, we both enjoy traveling and experiencing other cultures outside of North America, which we have done frequently. Finally, one other passion that we have shared for more than 35 years is for good food and great wines. This one is not likely to be attenuated as we get older.

So, on the wonderful occasion of this well-deserved Festschrift, from your many colleagues and friends around the world, Longue Vie et Bonne Santé, Robert Malina.

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SECTION I:
GROWTH, MATURATION AND PHYSICAL ANTHOPOLOGY

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THE FELS METHOD OF SKELETAL MATURITY

William Cameron Chumlea
Ramzi W. Nahhas
Richard J. Sherwood
Dana L. Duren

INTRODUCTION

Skeletal maturation, quantified as skeletal age, is the level of maturity expressed in years and months assigned to a bone or skeletal area irrespective of a child's chronological age (Roche *et al.,* 1988). Skeletal age helps to account for maturational variance among children in clinical and epidemiological studies of growth, body composition, physical status and performance (Beunen *et al.,* 1992; Malina *et al.,* 1999; Claessens *et al.,* 2006). The assessment of skeletal maturation is based upon the appearance, recognition and grading of maturity indicators. These are three dimensional features of a bone that appear two-dimensionally on a radiograph. For example, an indicator can be the initial ossification of a bone or an epiphysis, the shape of a bone, a radio-opaque line or zone that represents the edge of a bone or increased ossification in the metaphysis and/or epiphysis with fusion. A maturity indicator must occur during the maturation of every child in order to be useful in determining skeletal age (Pyle & Hoerr, 1969), and its progression of radiographic changes must appear in a regular sequential order as the bone matures to adult status (Roche, 1980). Skeletal age reflects the combined skeletal mechanisms occurring at different stages of growth and development based on the assumption of a universal progression of changes in the ossification, shape, joint formation, and epiphyseal fusion of bone(s) in the selected area of the skeleton in normal healthy children. During early childhood, skeletal age is primarily a measure of ossification onset; in mid-childhood it is a measure of changes in bone shape, individually and with respect to joint formation; and near the end of growth it measures the rate of epiphyseal fusion. Skeletal maturity is a system-wide phenomenon, but the assessment of skeletal maturation is typically done via hand-wrist radiographs. The hand-wrist is the most accepted site for skeletal maturity assessment due to its easy accessibility, the large number of bones in a very small area exposed to a small amount of radiation, and its history of numerous assessment methods (Roche, 1980; Cox, 1997).

THE FELS METHOD

The FELS method for assessing skeletal maturity independently grades sex- and age-specific maturity indicators for the twenty bones in the hand-wrist, the distal radius and ulna, the carpals and the first, third and fifth metacarpals and their corresponding phalanges. It was developed using 13,823 serial radiographs of the left hand-wrist from 355 boys and 322 girls in the Fels Longitudinal Study that were taken between 1932 and

1977 (Chumlea, *et al.,* 1989; Roche *et al.,* 1988, 1992). Five criteria were used to select the maturity indicators: 1) discrimination, the ability of an indicator to distinguish between children at the same chronological age, 2) universality, the grades for an indicator occur during the maturation of each child, 3) high reliability, with both inter- and intra-observer differences in the prevalence of grades of an indicator of 8% or less, 4) validity, the prevalence of grades change systematically with age until the most mature grade for an indicator is universal, and 5) completeness, the extent an indicator clarifies and restricts the age ranges at which the final indicator grades are applicable. The FELS method provides a detailed description of indicators and the morphological differences between grades and presents radiographic pictures for the indicator grades of the bones to be scored. Some examples are the ossification and shape of the triquetral, the development of the hook of the hamate, the appearance of the styloid process of the radius, and epiphyseal fusion.

There are ninety-eight maturity indicators in the FELS method, but only subsets of indicators are used for assessment at any given chronological age. The non-selected indicators are those that do not vary between children at that selected age, and thus do not provide any maturational information. The number of indicators assessed ranges from a minimum of 21 for boys and 9 for girls at age 18 years (when adult status has occurred) to a maximum of 61 for boys and 64 for girls at 10 years of age which is a time of rapid skeletal maturation involving a number of ossification and epiphyseal changes. The assessed indicator grades are entered into a computer where the FELS software (Roche *et al.,* 1988), a maximum likelihood based analysis of the maturity indicators, calculates a skeletal age and standard error. The FELS Method is the only skeletal age assessment method that provides a standard error or confidence limit for the calculated skeletal age. The median standard error for the FELS method is about 0.3 years from chronological age 6 months to 14 years in both boys and girls, and then increases to about 0.6 years in boys and 0.5 years in girls by age 18 years.

Statistical Basis of the FELS Method

The FELS Method utilizes a maximum likelihood technique to estimate a child's skeletal age using three classes of skeletal maturity indicators: binary indicators such as ossification, multiple grade indicators such as fusion and continuous indicators such as the ratio of epiphyseal to metaphyseal widths. The probabilistic behavior as a function of chronological age is modeled for each of these types of indicators. For example, the prevalence of children in the calibration sample who are immature for a given binary indicator is modeled as a logistic function of age, allowing estimation of the probability of maturity for that indicator at any given age. The calibration sample was used to estimate the parameters of each indicator's probability distribution as a function of age. The FELS method skeletal age for a child is the chronological age at which that child's indicator values are most likely in the calibration sample; that is, in the calibration sample, the chronological age at which one is most likely to find a child with similar values of the assessed indicators. This age, along with its standard error, is estimated using maximum likelihood.

This technique can be demonstrated with a two-indicator example in Figure 1. In this example, both indicators are binary with grade 1 indicating immature and grade 2 indicating mature. As seen in Figure 1 for the first indicator, the probability of a mature score (grade 2) up to age 4 is zero. The probability of being scored as mature (grade 2) begins (becomes positive) at approximately five years of age, and increases with age so that by age 10 years the probability of a mature score is 0.5. By age 14, the probability of a mature score for this indicator is 1.0. For the second indicator, the probability of an immature score (grade 1) at age 4 is 1.0, at age 10, it is 0.8, and by age 15 years the probability of an immature score is zero (i.e., no one at age 15 should be immature for this indicator). The joint likelihood for both these indicators is shown at the bottom of Figure 1 as the product of the two probability curves, where the likelihood of observing both a grade 2 for the first indicator and a grade 1 for the second indicator at less than age 7 or greater than age 13 years is minimal. The likelihood of the score {2,1} is greatest at age 10.6 years. In this simple example, the skeletal age of a child with a score {2,1} for just these two indicators would be 10.6 years (Roche *et al.,* 1988).

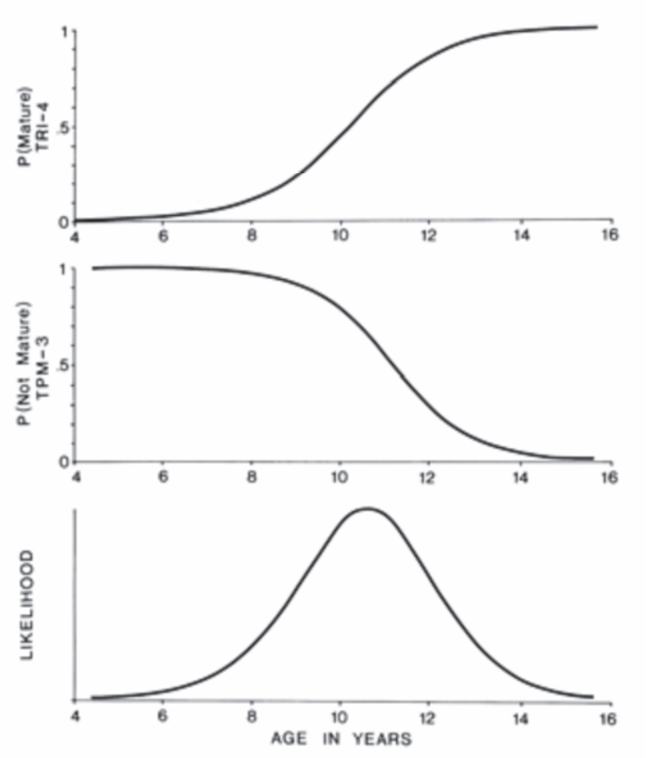


Figure 1. Probability curves for two indicators and their joint likelihood in the FELS Method.

Incorporating additional maturity indicators into the model follows the same pattern as described above with probability curves initially identified for each indicator followed by the construction of the joint likelihood model from those curves. When all indicators required at a chronological age are considered together, an estimate of skeletal age is determined. This skeletal age is based on multiple maturity indicators of various types from different bones, and the estimated skeletal age maximizes the information from the maturity indicators.

COMPARISONS AMONG THE HAND-WRIST METHODS

The Greulich-Pyle atlas method (Greulich & Pyle, 1950) is generally used as a set of flash cards to locate subjectively the single atlas radiograph that most closely resembles the whole hand-wrist radiograph in question. This incorrect, overly simplified use of this assessment technique has resulted in limited reliability (Greulich & Pyle, 1950; Tanner *et al.,et al.,* 1975; Roche *et al.,et al.,* 1988). In the early 1970's, it was recognized that this method did not reflect the skeletal age of normal healthy U.S. children accurately, and this was especially true for black children (Garn *et al.,et al.,* 1967; Anderson, 1968). These findings have been reinforced repeatedly over the past several decades both in the U.S. for white, black, Hispanic- and Asian-American children (Loder *et al.,* 1993; Ontell *et al.,* 1996; Russell *et al.,* 2001; Mora *et al.,* 2001; Stanitski, 2006) and around the world (Shaikh *et al.,* 1998; Bull *et al.,* 1999; Koc *et al.,* 2001; Haiter-Neto *et al.,* 2006). The Tanner-Whitehouse method (now in its third edition, TW3) (Tanner and Whitehouse, 1959, Tanner et al., 1962, 1997, 1975, 2001) is a more sophisticated assessment method than the Greulich-Pyle method that is based on scoring 20 bones in the hand-wrist to produce a skeletal maturity score (SMS) that measures skeletal maturity on an absolute (population invariant) scale. The SMS score can then be calibrated to any population of interest to produce a bone age. The TW3 bone age is calibrated to European and European-American populations. The population invariant nature of the SMS score, however, depends on the assumption that there are no population differences in the relative tempo of maturation among the bones of the hand-wrist. There is, in fact, some evidence that such differences exist, namely that there are secular trends of differing direction and magnitude in the timing of maturation of the bones of the hand-wrist (Duren *et al.,* 2010). Such secular differences within a single population imply that there are very likely to be between-population differences in the relative tempo of maturation of the bones of the hand-wrist. Thus, despite the calibration of TW3 to European-American children, it is not clear whether the underlying SMS scores are applicable to other than the European population used to derive them.

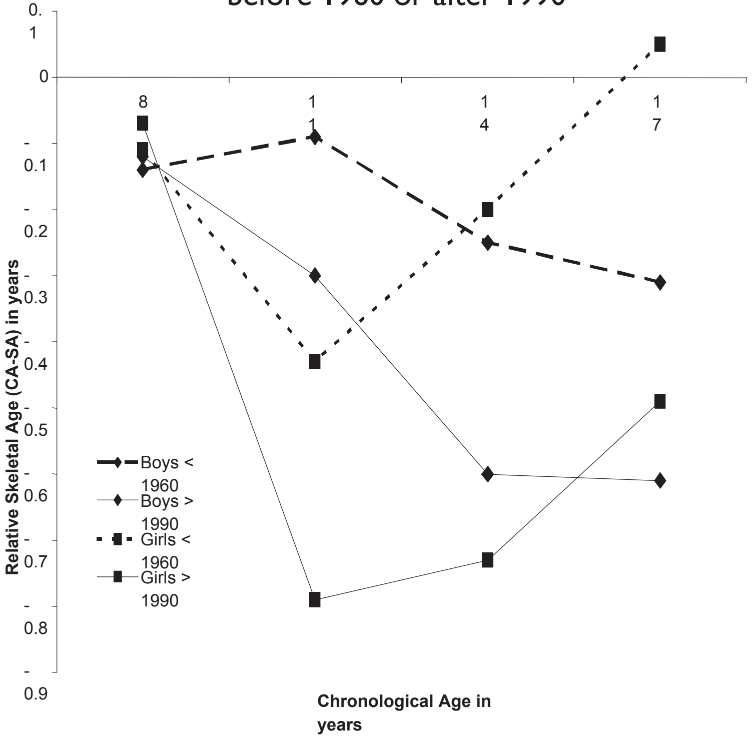
The FELS method provides accurate and reliable estimates of the skeletal ages of U.S. children (Roche *et al.,* 1988). As part of the validity testing for this method, a sample of 500 radiographs from white and black children in the first National Health and Nutrition Examination Survey were assessed. The mean skeletal ages for these US children were similar to their mean chronological ages at the assessed ages of the radiographs. There was no systematic trend in the differences between the chronological and FELS skeletal ages for each sex. These findings indicated that the FELS method was appropriate for the U.S. pediatric population of white and black children at that time (Chumlea *et al.,* 1989). The Greulich-Pyle and Tanner-Whitehouse methods lack accuracy, and have limited validity, and/or their levels of skeletal maturity do not reflect the skeletal age and maturity of normal U.S. children today. It is not possible to calculate confidence intervals for the estimated skeletal ages when using the Greulich-Pyle or Tanner-Whitehouse methods which are important in the proper interpretation of a skeletal age (Roche *et al.,* 1988). These differences reflect both the underlying samples from which the methods were developed and the statistical methodology used to derive a skeletal age.

SECULAR TREND IN SKELETAL MATURITY AS A RELEVANT HYPOTHESIS FOR ADDITIONAL RESEARCH

Recent reports signal a world-wide secular trend in maturation (Karlberj, 2002) including skeletal maturity. Children today are more advanced in their skeletal maturity at least by age 10 years as compared to the children of just a few decades ago (Ranjitkar *et al.,* 2006; Lin *et al.,* 2006; Savaridas *et al.,* 2007). Data from our own study sample, the Fels Longitudinal Study, indicate a trend for accelerated skeletal maturity in children born since 1960, compared to those born in the 30 years prior. We conducted a small pilot analysis to determine if a shift in the relative skeletal ages (chronological age less skeletal age) of Fels Longitudinal Study children has occurred. We randomly selected a small group of children (N = 39 to 69 depending on the age group) who had a hand-wrist radiograph at ages 8, 11, 14 and 17 years before 1960 (one visit per child) and a random selection of unrelated Fels children (N = 24 to 46 depending on the age group) with corresponding age radiographs after 1990. Relative skeletal ages at the corresponding chronological ages are plotted in Figure 2.

The skeletal ages of the children with a radiograph before 1960 were used in the development of the FELS Method which explains the small values of their relative skeletal ages (in absolute value), which are similar to those reported in the details of the method (Roche *et al.,* 1988). In comparison, contemporary Fels children have relative skeletal ages that are considerably larger (in absolute value), approaching a -0.8 year difference. These preliminary findings indicate that the FELS method is potentially underestimating the skeletal ages of these healthy children during the critical period of pubescence by half a year or more. Moreover, an investigation of the various types of maturity indicators contained in the FELS method has revealed differences in the tempo (and, in some cases, direction) of the secular trend in skeletal maturity, with indicators such as fusion of the epiphyses exhibiting the most extreme trends towards earlier maturation (Duren *et al.,* 2010).

Figure 2. Relative Skeletal Ages of Fels Children with Visits before 1960 or after 1990



The accelerated maturation has implications for a variety of aspects of child growth, development, obesity and physical performance. This includes the potential age alterations in the timing of the magnitude of peak height velocity, bone mineral accrual, predicted adult stature, menarche and secondary sex characteristics and physical performance. Accelerated skeletal maturation as reflected in skeletal age can alter established uses of skeletal age in the interpretation of attained maturity at a chronological age affecting participation in youth sports (Malina *et al.,* 2010). In order to assess reliably the associations, timings and onset among these maturational processes with skeletal age, it is imperative that skeletal age methods reflect the maturity status of contemporary children. To this end, the FELS Method is undergoing a revision that should be available shortly.

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THE TIMING AND SEQUENCE OF GROWTH SPURTS IN DIFFERENT BODY DIMENSIONS DURING ADOLESCENCE

Christina A. Geithner

INTRODUCTION

The adolescent spurt is a hallmark of somatic growth and maturation. Longitudinal research designs are required in order to understand the biological changes that occur during adolescence and to identify the parameters of the growth spurt (Malina, 1978; Shuttleworth, 1937; Tanner, 1962). The primary indicators of the adolescent growth spurt are age at peak height velocity (PHV), or the timing of the maximum rate of growth in stature, and the magnitude of the spurt, or PHV (cm/yr). This spurt is universally present in normally developing males and females; however, the timing and magnitude vary considerably among individuals and between sexes. Females attain PHV near age 12.0, approximately two years before males (Tanner, 1971), but the spurt is of greater magnitude in males. Age at PHV is used as a reference point for comparisons of size attained and rate of growth in other dimensions rather than chronological age (Beunen *et al*, 1988; Malina *et al*., 1988; Malina *et al*. 2004; Shuttleworth, 1937). Age at peak weight velocity (PWV) generally occurs approximately 0.3-0.9 years after PHV in females and 0.2-0.4 years after PHV in males (Beunen and Malina, 1988).

Many longitudinal analyses of adolescent growth and maturation are limited to the timing and magnitude of the growth spurts in stature and weight. Most body dimensions also exhibit growth spurts within about a two-year period. The timing and the magnitude of the spurts differ (Shuttleworth, 1937; Beunen *et al*, 1988; Malina *et al*., 2004; Satake *et al*., 1993, 1994), and there is considerable interindividual variability in the sequence in which the spurts in different dimensions occur (Stolz and Stolz, 1951; Satake *et al*., 1994). Studies of the sequence of spurts in several body dimensions are relatively few (Stolz and Stolz, 1951; Bielicki and Welon, 1973; Roche, 1974; Lindgren, 1978; Welon and Bielicki, 1979; Cameron *et al*., 1982; Satake et al., 1994), as are studies that have included aerobic capacity, particularly submaximal aerobic capacity or power output. Physical work capacity (PWC), or workload, at a heart rate of 170 bpm, or PWC_{170} is a common marker of submaximal aerobic capacity (Nudel, 1989), and is highly correlated with VO_2max ($r=0.85$ for adolescent males, mean age 14.2±0.9 years, Franz *et al*., 1984). Most of the limited, longitudinal data on submaximal work capacity have been treated in a cross-sectional manner, and there are fewer data available in females than in males (Armstrong and Welsman, 1994; Cunningham *et al*., 1984; Vanden Eynde *et al*., 1984).

The purpose of this study was to describe the timing and tempo of somatic growth and maturation, and PWC_{170} of Polish adolescents followed longitudinally from approximately 11 to 18 years of age. Objectives were: 1) to mathematically fit curves to individual data for anthropometric dimensions and PWC_{170} in order to estimate ages at PV and PVs for each dimension by sex; and 2) to examine mean and modal sequences among peak velocities by sex.

METHODS

Description of Subjects and Data Collection

The data are collected in a longitudinal study of Polish school children, organized in part by Dr. Robert M. Malina. Dr. Barbara Woynarowska, the attending physician at the schools and the director of school medicine of the National Institute of Mother and Child, Warsaw, Poland, collected the data along with Pawel Gorinsky between 1974 and 1982, and made the data available to Dr. Malina. Subjects were recruited and informed consent was completed following the procedures of the National Institute of Mother and Child.

Subjects

The 105 subjects (53 males and 52 females) were of Polish ancestry from Warsaw and all were healthy. On average, the subjects were 11.2±0.4 years of age at the time which data collection began (range=10.5 to 12.7 years at first measurement), and 18.2±1.6 years at the last data collection (range=14.0 to 20.1 years at last measurement).

Data Collection

Subjects were measured at three-month intervals from approximately age 10 or 11 to age 15 and annually thereafter until age 17 or 19. Complete data were not available for every subject and some attrition occurred during the course of the study (Table 1). The total sample size at 18+ years was 73 (37 males, 36 females) or 69.5% of the initial sample).

Weight, stature, four skeletal lengths (estimated arm length: estimated leg length: stature - symphyseal height, estimated sitting height: stature – symphyseal height, trunk length: suprasternal height – sympyhyseal height), three skeletal breadths (biacromial, bicristal, and chest breadths), chest depth, and six circumferences (chest, relaxed arm, estimated arm muscle, forearm, thigh, and calf circumferences) were assessed. Anthropometry was done according to the procedures of Martin (1956). Similar instrumentation and methods of measurement have been used in other European longitudinal studies of growth and maturation during adolescence.

Age at menarche was obtained prospectively for females as a measure of sexual maturity status. Submaximal power output, or PWC_{170}, was measured at approximately six-month intervals or yearly as part of the school health and fitness program. An average of 10 measurements of PWC_{170} (range=7-12) were taken on each subject. PWC_{170} was calculated from measurements of heart rate (ECG) and workload during a three-stage, graded submaximal test on a Monark bicycle ergometer, with workload increased with each stage in order for the subject to achieve a heart rate of ≥170 bpm (HR_{170}). Heart rate (by ECG) and revolutions per minute (rpm) were recorded at the end of each minute of cycling, and values for power output were plotted against heart rate on a graph, with power output at HR_{170} estimated by linear interpolation (Woynarowska and Kaminska, 1988) and recorded in kpm. The data were converted to Watts and expressed per unit body weight (Watts/kg) for the purposes of analysis.

Analyses

The data as recorded on the original data sheets were screened for completeness, recording errors, and outliers, variable by variable for each individual by Robert M. Malina and the author. Some missing values were interpolated over short intervals. Data were entered and analyzed via SAS. Individual data for stature, weight, and selected body dimensions and for several derived measures were mathematically fitted with curves using a kernel regression program (adapted from Guo, 1989). The program fitted distance curves to individual longitudinal data for various dimensions, and then calculated the first derivative of the distance curve, yielding velocity curves and estimates of age at PV and PV. Based on these criteria, visual comparisons of the fits of the curves to stature for several individuals of both sexes produced by the kernel regression to the actual data, and recommendations of researchers who had previously utilized kernel regression with growth data (Gasser *et al*., 1984; Guo, 1989; Guo *et al*., 1992), a 5th degree polynomial, a bandwidth of 3.0 years, and an interval of 8 (8 estimates/yr) were chosen for the curve-fitting of all variables. RMSEs for stature in this sample were 0.55 for males and 0.48 for females, and were deemed acceptable based on the criterion of Guo *et al.* (1992) of an RMSE<1.5 for stature data fit with kernel regression. Data for each individual and each of 16 body dimensions and PWC_{170} were submitted to kernel regression analysis in order to obtain ages at PV and PVs for each dimension and submaximal power output for each subject. RMSEs for body dimensions other than stature were more variable: RMSEs ranged from 0.22 to 1.22 for males and from 0.22 to 1.12 for females, except for PWC_{170} in Watts, RMSE=7.85 for males and 5.57 for females. RMSEs were higher for PWC_{170} than growth measures due to greater variability in the performance data compared to growth data and to six-monthly measurements of PWC_{170} compared to quarterly measurements of body dimensions (i.e., fewer PWC_{170} data points available for curve fitting).

In addition to individual estimates for age at PV and PV for each body dimension and PWC_{170}, mean ages at PV and mean PVs were calculated for each dimension and PWC_{170} by sex. The prevailing order of occurrence of PVs was also examined relative to PHV and PWV (i.e., prior to, coincident with, or following PHV and PWV, respectively) after Beunen *et al*. (1988) Coincident was defined as a difference of <0.25 years (or ±0.125 years) between ages at PV.

Sequence of growth spurts

The sequence of growth spurts in various body dimensions was determined for each sex in two ways: by comparing the mean ages at PV calculated from kernel estimates (mean sequence of spurts), and by determining the modal sequence of spurts in selected body dimensions (stature, weight, sitting height, biacromial and bicristal breadths, plus estimated arm length and chest circumference or symphyseal height and thigh circumference) for comparison with the literature. The modal sequence of spurts was determined by documenting the sequence of spurts for each individual (after Satake *et al*., 1994; Stolz and Stolz, 1951), and determining the frequencies with which the spurt in each dimension occurred at a given position within the sequence of growth spurts and the cumulative frequencies (of occurrence) at each position within the sequence. The dimension with the greatest cumulative frequency in first position within the sequence was considered first in the modal sequence; of the remaining dimensions, the dimension with the greatest cumulative frequency in the second position within the sequence was considered second in the modal sequence, and so on. This is an equivalent approach to spurt sequence determination to that used by Stolz and Stolz (1951). Mean and modal sequences were then compared to each other and to the literature (Stolz and Stolz, 1951; Marubini *et al*., 1972; Tanner *et al*., 1976; Welon and Bielicki, 1979; Beunen *et al*., 1988; Buckler, 1990; Gasser *et al*., 1991; Satake *et al*., 1994).

RESULTS

Representativeness of the sample with regard to body size

Means and standard deviations for various body dimensions were calculated by sex for the age groups and compared to reference data for Warsaw youth (collected from 1976-1980 on 1460 adolescents, 772 M, 688 F), ages 10-18 years (Kurniewicz-Witczakowa *et al*., 1983). The sample in this study was generally representative of the greater population of Warsaw adolescents (i.e., within ±1 SD of the reference means).

Timing and tempo of the growth spurts

Mean ages at PV, PVs, and RMSEs for all dimensions to which curves were fit are shown by sex in Table 1. Mean ages at PHV and PHVs were 13.5±1.1 years and 9.1±1.3 cm/yr in males and 11.9±0.7 years and 7.5±1.6 cm/yr in females. PHV occurred, on average, 1.5 years earlier in females than in males, and females had a lower PV than males by 1.5 cm/yr. In addition to age at PV and PV in stature, sex differences were apparent in the timing and tempo of all dimensions, measured or derived. Mean ages at PV for various body dimensions ranged from 12.6 to 14.4 years in males and from 11.7 to 13.2 years in females. Females' ages at PV were, on average, earlier than males' ages at PV in every body dimension. However, males exhibited an earlier mean age at PV in absolute PWC_{170}. The intensity of the growth spurt in PWC_{170} and all body dimensions was greater in males than in females, with the exception of estimated trunk and arm lengths, bicristal breadth, arm circumference, and estimated arm muscle circumference.

The spurt in absolute PWC$_{170}$ occurred, on average, at 13.2±1.0 years in males, slightly earlier than PHV (13.5±1.1 years) and more than one-half year earlier than PWV (13.8±1.5 years). The spurt in absolute PWC$_{170}$ occurred at 13.2±0.8 years in females, the last in the sequence of ages at PV, 1.1 years after PHV (11.9±0.7 years) and 0.72 years after PWV (12.5±1.4 years). There was no sex difference in the timing of the spurt in PWC$_{170}$.

Table 1. Means (M) and standard deviations (SD) for age at peak velocity (Age at PV, yr) and peak velocity (PV, units/yr) by sex for various body dimensions. EAMC=estimated arm muscle circumference.

		Males				Females			
		Age at PHV		PV		Age at PHV		PV	
		M	SD	M	SD	M	SD	M	SD
Stature	cm	13.47	1.14	9.05	1.29	11.95	0.69	7.51	1.58
Weight	kg	13.83	1.51	9.14	3.62	12.52	1.36	7.55	2.18
Symphyseal ht	cm	13.04	1.16	5.59	1.14	11.92	0.90	5.12	2.60
Est. trunk length	cm	12.79	2.00	4.81	2.13	11.86	0.97	5.16	3.40
Est. sitting ht.	cm	13.22	1.76	5.27	1.62	12.10	0.97	5.03	2.07
Est. arm length	cm	12.84	1.47	5.23	1.74	11.73	0.69	5.28	2.42
Biacromial breadth	cm	13.39	1.36	2.44	0.53	12.05	0.78	2.08	0.65
Bicristal breadth	cm	13.23	1.53	1.82	0.55	12.73	1.08	2.22	0.86
Chest breadth	cm	12.85	1.22	2.17	0.96	12.42	1.41	1.70	0.83
Chest depth	cm	12.59	1.09	1.78	1.54	12.28	1.15	1.48	1.03
Chest circumference	cm	14.36	2.16	8.75	4.68	12.79	1.81	5.83	3.25
Arm circumference	cm	12.65	1.29	2.11	1.00	12.05	1.21	2.43	1.35
Forearm circumference	cm	13.56	1.87	2.20	0.86	13.15	2.02	1.52	1.48
Thigh circumference	cm	13.24	2.02	5.08	2.58	12.70	1.76	4.87	2.40
Calf circumference	cm	12.74	1.74	2.76	1.40	12.38	1.08	2.52	2.02
EAMC	cm	12.95	1.24	2.15	0.93	11.96	1.11	2.17	1.41
Absolute PWC$_{170}$	Watts	13.18	0.98	42.4	15.78	13.24	0.82	25.46	11.93

Timing of growth spurts relative to PHV and PWV

The prevailing order of occurrence of PVs relative to PHV and PWV (i.e., prior to, coincident with, or following PHV and PWV, respectively) is shown in Table 2. Growth spurts in nine dimensions preceded PHV in males, while those in weight, several upper body lengths and breadths, and chest and forearm circumferences follow PHV, and approximately equal numbers of individuals (i.e., within one case) exhibited spurts in thigh circumference before and after PHV. All body dimensions and PWC$_{170}$ exhibited spurts before PWV in males, with the exception of chest circumference, which followed PWV. In females, the majority of body dimensions exhibited spurts after PHV and before PWV.

The exceptions were symphyseal height and estimated trunk and arm lengths, which attained PV coincident with PHV, and estimated sitting height and biacromial breadth, which had spurts which were evenly distributed (i.e., within one case each) before and after PHV. In addition, PVs in chest depth were evenly distributed before and after PWV, chest circumference spurts occurred coincidentally and after PWV (i.e., evenly distributed within one case), and PVs in bicristal breadth, forearm and calf circumferences and PWC170 occurred following PWV in females.

The PV in PWC$_{170}$ tended to occur on either side of (i.e., both before and after) PHV in males (Table 2). It preceded PHV in 43.4%, was coincident with PHV in 22.6%, and followed PHV in 34.0%. In contrast, PV in PWC$_{170}$ followed PHV in 86.5% of females, preceded PHV in 5.8% and was coincident with PHV in 7.7% (Table 2). Based on mean ages at PV, the spurt in absolute PWC$_{170}$ occurred before PWV in males (64.2% before, 11.3% coincident, 24.5% following), and after PWV in females (17.3% both before and coincident, 65.4% following).

Table 2. Timing of growth spurts in various body dimensions and PWC$_{170}$ relative to PHV and PWV based on the modal occurrence by sex from data for individuals (X=males, O=females), after Beunen *et al.* (1988). P=Prior to, C=Coincident with (PV within ±0.12 years), and F=Following; --=approximately equal numbers of cases (within one case). EAMC=estimated arm muscle circumference.

		PHH			PWV	
	P	C	F	P	C	F
Stature				XO		
Weight			XO			
Symphyseal height	X	O		XO		
Estimated sitting height		O - -	XO	XO		
Estimated trunk length	X	O		XO		
Estimated arm length	X	O		XO		
Biacromial breadth		O - -	XO	X		O
Bicristal breadth			XO	XO		
Chest breadth	X		O	XO - -		- - O
Chest depth	X		O		O - -	XO
Chest circumference			XO	XO		
Arm circumference	X		O	X		O
Forearm circumference			XO	XO		
Thigh circumference	X - -		- - XO	X		O
Calf circumference	X		O	XO		
EAMC	X		O	X		O
PWC$_{170}$	X		O			

THE SEQUENCE OF GROWTH SPURTS IN DIFFERENT BODY DIMENSIONS AND PWC$_{170}$

Mean sequence of PVs by sex

Based on mean ages at PV (Table 3), the spurts in estimated trunk length and symphyseal height preceded the spurts in stature and weight, and that the spurts in weight, forearm circumference, and chest circumference followed the spurt in stature in the sequence in both sexes. Also, PHV and PWV occurred earlier in the sequence of spurts in females than in males. PHV occurred relatively early in the sequence of PVs in females (4th out of 17 variables), whereas it occurred relatively late in the sequence of PVs in males (14th out of 17 variables).

Table 3. Mean sequence of growth spurts in 16 dimensions and PWC$_{170}$ by sex (EAMC=estimated arm muscle circumference).

Position	Males		Females	
	Variable	Mean Age at PV (yr)	Variable	Mean Age at PV (yr)
1	Chest depth	12.59	Arm length	11.73
2	Arm circumference	12.65	Trunk length	11.86
3	Calf circumference	12.74	Symphyseal height	11.92
4	Trunk length	12.79	Stature	11.95
5	Arm length	12.84	EAMC	11.96
6	Chest breadth	12.85	Arm circumference	12.05
7	EAMC	12.95	Biacromial breadth	12.05
8	Symphyseal height	13.04	Sitting height	12.10
9	PWC$_{170}$, Watts	13.18	Chest depth	12.28
10	Sitting height	13.22	Calf circumference	12.38
11	Bicristal breadth	13.23	Chest breadth	12.42
12	Thigh circumference	13.24	Weight	12.53
13	Biacromial breadth	13.39	Thigh circumference	12.70
14	Stature	13.47	Bicristal breadth	12.73
15	Forearm circumference	13.56	Chest circumference	12.79
16	Weight	13.83	Forearm circumference	13.15
17	Chest circumference	14.36	PWC$_{170}$, Watts	13.24

Modal sequence of PVs by sex

The modal order (the most frequently observed sequence in individuals) of PVs was determined for a set of selected body dimensions (Table 4) for comparison with the results of Stolz and Stolz (1951). PHV occurs later in the mean sequence than in the modal sequences in males, and earlier in the mean sequence than in the modal sequences in females. Ten males exhibited complete asynchrony of PVs in these dimensions and none showed complete synchrony. Two females exhibited complete asynchrony in PVs and no one individual was completely synchronous; however, females showed a greater tendency toward synchronicity in PVs than males.

Table 4. Modal sequence of ages at growth spurts in selected body dimensions by sex.

Position	Males	Females
1	Thigh circumference	Symphyseal height
2	Symphyseal height	Stature
3	Stature	Thigh circumference
4	Bicristal breadth	Biacromial breadth
5	Biacromial breadth	Sitting height
6	Weight	Weight
7	Sitting height	Bicristal breadth

DISCUSSION

Timing and tempo of the growth spurts in stature and weight

Although the timing of the growth spurt, or estimated age at peak height velocity (PHV), varies among studies, there is relatively little variation in the sex-specific estimates of age at PHV given the variety of analytical procedures used and populations studied. In this sample of Polish adolescents, age at PHV estimated by kernel regression was 13.5±1.1 years in males with a PV of 9.1±1.3 cm/yr, and age at PHV in females was 11.9±0.7 years with a PV of 7.5±1.6 cm/yr. Females in this sample experienced their adolescent growth spurt in stature 1.6 years earlier than males in this sample, but males had a greater tempo or maximum rate of growth than females by 1.5 cm/yr.

The mean age at PHV for males in this study was somewhat early compared to all but one non-parametric analysis (Satake *et al*., 1993) and several of the parametric analyses (Deming, 1957; Thissen *et al*., 1966; Bock *et al*., 1973; Johnston *et al*., 1973; Shohi and Sasaki, 1987; Berkey *et al*., 1994). The mean age at PHV for boys in the present study was also early compared to that for boys in the Wroclaw Growth Study, 14.0±1.2 years (Malina and Bielicki, 1992). The results suggest that this group of males might have been early maturers compared to those in other samples (range=12.6-14.7 years). In contrast, the mean PHV for males in this study was comparable to mean PVs estimated for other samples of males (range=6.9-11.9 cm/yr).

Mean age at PHV and mean PHV for females in this study compared closely with results of other studies (range for age at PHV=11.0-12.6 years, range for PHV=6.4-11.0 cm/yr). The results thus suggested that the girls in this study were average in their maturity status, which is consistent with their mean age at menarche, 13.1±0.8 years (range=10.9-15.0 years). The mean age at menarche for this sample is consistent with those reported for Polish girls (Koniarek, 1971: 13.0±0.9 years; Bielicki, 1975,1976: 13.1±1.0 years; Bielicki *et al*., 1977: 13.0±1.1 years; Welon and Bielicki, 1979: 13.1±0.9 years; Laska- Mierzejewska *et al*., 1982, Warsaw: 12.7±1.1 years, rural: 13.4 years) and those reported for other European populations (range=12.1 to 13.5 years).

The PWV for this sample of Polish males occurred at an earlier mean age (13.8±1.5 years) than those reported by the majority of studies by approximately one-half year, which range from 13.6 years (Johnston *et al*., 1973; Satake *et al*., 1993) to 14.6 years (Beunen *et al*., 1988). On the other hand, females in this study exhibited a growth spurt in weight that was consistent with the literature in timing and magnitude, and consistent with their average maturity status as indicated by mean ages at PHV and menarche. In both sexes, PWV occurred approximately 0.5 year after PHV, within the range of 0.1 year to approximately 1.0 year between mean ages at PHV and PWV reported in other studies.

Differences among studies in ages at PHV, PWV, and menarche may be due, in part, to population differences, as populations of southern European ancestry tend to mature earlier than those of northwestern or central European ancestry (Eveleth and Tanner, 1990). Differences in ages at PHV and PWV may also be due to different frequencies of measurement and the use of different analytical procedures. For example, the mean ages at PHV and PWV for the Polish sample in this study are closest to those for Japanese adolescents reported by Satake *et al*. (1993), who derived estimates from spline functions, a curve-fitting procedure similar to kernel regression.

Mean ages at PV for various body dimensions

Ages at PV ranged from 12.6 to 14.4 years (1.8 years) in males and from 11.7 to 13.2 years (1.5 years) in females (Table 5). The range of ages at PVs for this sample (time from earliest PV to latest PV) is consistent with ranges previously reported in other studies (Stolz and Stolz, 1951: 0.5-2.0 years; Bielicki and Welon, 1978: 1.9 years; Satake *et al*., 1993, 1994: 1.2-1.6 years). Sex differences were apparent in the timing (age at PV) and tempo (PV) of growth in all body dimensions, measured or estimated. On average, females had earlier mean ages at PV than males in every dimension; however, the intensity of the growth spurt was greater in males than in females in the majority of body dimensions. These findings are consistent with the literature, except for a couple of reports, which noted a greater PV in bicristal breadth in females than in males (Takai and Shinoda, 1991; Tanner *et al*., 1976).

Ages at PV and PVs of different body dimensions have been estimated by a number of methods (graphic, logistic, Gompertz logistic, splines, and kernel regression) for various samples studied longitudinally. Similar to comparisons of ages at PHV and PWV, the ages at PV for symphyseal height (estimated leg length), sitting height, trunk length, and biacromial and bicristal breadths for males in the present study were earlier relative to most of the comparative data, while mean PVs were generally greater than or equal to those reported in the literature. In females, both mean ages at PV and mean PVs for these dimensions were consistent with the literature.

Timing of growth spurts relative to PHV and PWV

Growth spurts in nine dimensions preceded PHV in males, while those in weight, upper body lengths and breadths, and chest and forearm circumferences followed PHV (Table 2). The timing of PVs in body dimensions for males relative to PHV was consistent with that in Belgian males (Beunen *et al*., 1988); however, relative to PWV, males in the Polish sample exhibited growth spurts in every body dimension prior to PWV except for chest circumference, while in Belgian males, PVs in biacromial and chest breadths and thigh and flexed arm circumferences were coincident with PWV. Comparisons of the timing of PVs in body dimensions to PHV and PWV have not been made for females.

Sequences of growth spurts in various body dimensions

In the present study, the mean sequence of spurts was determined from PVs derived from kernel estimates and the modal sequence of spurts was determined for two sets of selected body dimensions for comparison with the results of Stolz and Stolz (1951) and Satake *et al*. (1994).

Mean sequence of growth spurts

Differences between mean ages at PV for body dimensions and PWC_{170} were quite small, on the order of hundredths of a year in adjacent ages at PV in some cases, and smaller than those previously reported between ages at PV in selected dimensions. For example, several studies have reported a difference of approximately 1.0 year between mean ages at PV in estimated leg length and trunk length (Shuttleworth, 1937; Tanner, 1962; Bielicki and Welon, 1973). In the present study, spurts in estimated leg and trunk lengths occurred 0.25 years apart in males and 0.18 years apart in females. Differences between the results of this study and those of other studies may be due to different ways in which leg and trunk lengths and other skeletal lengths yield variable estimates for ages at PV. Population variability may be an additional factor.

In the majority of individuals of both sexes, spurts in two or more dimensions were synchronous, i.e., they occurred simultaneously (ages at PV were <0.25 years apart). However, spurts in body dimensions tended to be asynchronous, on average (Marshall and Tanner, 1986), i.e., different parts of the body achieved their maximum rates of growth at different times. The frequency of synchronous PVs in the present study may be related to the large number of dimensions (16 body dimensions and PWC_{170}) for which ages at PV were estimated.

The timing of the spurt (age at PV), and intensity of the spurt (PV), in each dimension were variable among individuals, which is consistent with other studies (Roche, 1974; Marshall, 1974; Cameron *et al*., 1982; Satake *et al*., 1994). Sequences of mean ages at PV also differ among longitudinal studies (Table 5), and present some problems in making comparisons, since different dimensions are included in the studies. Differences in sequences of mean ages at PV among studies may be due, in part, to individual variability in maturation rate and sequence of PVs, to the different analytical curve-fitting procedures or models used to estimate parameters of the spurt, to different measurement frequencies and study durations, and to sampling variation.

Based on mean ages at PV, the sequences of spurts occurred in males and females exhibited several commonalities: the spurts in estimated trunk length and symphyseal height (estimated leg length) preceded the spurts in stature and weight, and the spurts in weight and forearm and chest circumferences followed the spurt in stature in both sexes. Also, the PVs in chest dimensions occurred in the same order relative to each other in both sexes (chest depth, first; chest breadth, second; and chest circumference, third). Sex differences in the sequence of PVs, however, outnumbered the similarities, which is generally consistent with the literature, which indicates that the sequence of growth spurts in various dimensions generally varies by sex. For example, PV in bicristal breadth precedes that in biacromial breadth in males (Stolz and Stolz, 1951; Tanner *et al*., 1976; Welon and Bielicki, 1979; Buckler, 1990), while the opposite occurs in females (Tanner *et al*., 1976; Buckler, 1990; Satake *et al*., 1993). Other examples of reversed order include the timing of PVs in trunk and arm lengths (trunk before arm in males, arm before trunk in females), and PVs in bicristal and biacromial breadths and calf and thigh circumferences precede PHV in males and follow PHV in females. PHV also occurred earlier in the sequence of spurts in females than in males, as did PWV.

The sex difference in sequence of PVs found in this study is not uncommon, although only one study has tested the statistical significance of the similarity of the sequences between sexes. Satake *et al*. (1994) calculated Kendall's rank order correlations among average and individual sequences to determine whether or not there was significant agreement among growth gradients. The order of mean ages at PV in seven body dimensions was statistically similar in both sexes (Kendall's $r=0.62$, $p<0.05$). The sequence of mean ages at PV in this sample of Polish adolescents was not subjected to this type of statistical analysis; however, this might be considered in follow-up analyses.

Modal sequence of growth spurts

Modal sequences have been reported in only one other study (Stolz and Stolz, 1951). Of the 16 body dimensions in the present study, 7 were selected for modal sequence determination and for comparison with Stolz and Stolz (1951). Modal sequences in the present study differed by sex (Table 5); however, leg growth (symphyseal height and/or thigh circumference) exhibited a spurt prior to stature, followed by spurts in breadths, sitting height, and weight, not necessarily in that order. Similarities exist between the modal sequence of the present study and mean sequences of other studies (Table 5): the spurt in leg length generally precedes that in stature, spurts in sitting height and breadths follow the spurt in stature, and the spurt in weight tends to occur late in the sequence of spurts. Aside from these similarities, the modal sequence in the present study differs from the sequence of mean ages at PV in this and other studies. Besides the obvious difference between the methods used to determine the mean and modal sequences, differences between the modal and mean sequences in the present study are probably due to a number of factors already mentioned, including differences among analytical procedures and population variability.

The modal sequence for males in this study (thigh circumference, symphyseal height or estimated leg length, stature, bicristal breadth, biacromial breadth, weight, and sitting height) was reasonably similar to that described by Stolz and Stolz (1951) (leg length; thigh circumference; stem length or sitting height and stature, coincident with one another; bicristal breadth; biacromial breadth; and weight. The sequence was quite variable in the majority of individuals, both in the present study and in that by Stolz and Stolz (1951). In contrast to the findings of Stolz and Stolz (1951), however, no individual exhibited completely synchronous PVs in this set of 7 body dimensions, while 10 individuals exhibited complete asynchrony in the present study. In the study of Stolz and Stolz (1951), PVs were completely synchronous in two individuals and completely asynchronous in two individuals.

The modal sequence of PVs in Polish females in the present study was: symphyseal height (estimated leg length), stature, thigh circumference, biacromial breadth, sitting height, weight, and bicristal breadth. Two individuals exhibited complete asynchrony in PVs and none exhibited complete synchrony; however, females showed a greater tendency toward synchronicity in PVs than males. Finally, the modal sequence of spurts in the present study does not mirror any of the sequences of mean ages at PV from other studies. This is, perhaps, due to the fact that the beginning age at data collection in females was closer to the age at PHV in females than in males. There are no corresponding data for California adolescents; Stolz and Stolz (1951) studied only males. However, this modal sequence for females in the present study is consistent with that reported by Satake *et al*. (1994).

It seems that the fewer the number of body dimensions measured and the longer the duration of the study, the more likely that PVs for different dimensions will be asynchronous, i.e., that they will show distinct and different ages at PV. In this study, there were a relatively large number of dimensions (17, including PWC_{170}, compared to 4-8 in most studies) to which curves were fit to estimate ages at PV and PVs; thus, there may have been a greater tendency towards synchronicity in PVs in this study than in others. These conditions may also underlie the small differences between ages at PV for different dimensions as reported by Satake *et al*. (1994), and smaller differences between ages at

PV for selected dimensions found in this study compared to those reported in other studies.

Table 5. Mean sequences of growth spurts by sex. Variables for which ages at PV were estimated in this study that are the same as variables included in other studies of sequence are shown in **bold** font.

Study, Method	Males	Females
NON-PARAMETRIC ANALYSES		
This study	chest depth	**arm length**
Kernel regression	arm circumference	**trunk length**
mean ages at PV	calf circumference	**leg length**
53 M, 52 F	**trunk length**	**stature**
	arm length	**EAMC**
	chest breadth	arm circumference
	EAMC	biacromial breadth
	leg length	**sitting height**
	sitting height	chest depth
	bicristal breadth	calf circumference
	thigh circumference	chest breadth
	biacromial breadth	**weight**
	stature	**thigh circumference**
	forearm circumference	**bicristal breadth**
	weight	**chest circumference**
	chest circumference	forearm circumference
Beunen *et al*. (1988)	leg length	
Non-smoothed polynomials	stature	
mean ages at PV	sitting height	
Leuven Growth Study	weight	
432 M	chest circumference	
	arm pull	
Satake *et al*. (1993)	stature	stature
Splines	biacromial breadth	arm span
mean ages at PV	arm span, bicristal breadth	sitting height, biacristal breadth
Kanagawa, Japan	sitting height	weight
16 M, 21 F	weight	bicristal breadth
	chest circumference	chest circumference

(to be continued)

(continuation of Table 5)

Study, Method	Males	Females
Gasser *et al.* (1991)	leg length (supine)	leg length
Kernel - structural average curves	leg height (stature.-sitting height)	leg height
mean ages at PV	arm length	arm length
Zurich Longitudinal Growth Study	supine length, stature	supine length, stature
120 M, 112 F	sitting height, crown-rump length	sitting height, crown-rump length
PARAMETRIC ANALYSES		
Stolz and Stolz (1951)	leg length	
Graphic	thigh circumference	
California Adolescent Study	stem length, stature	
67 M	bicristal breadth	
	biacromial breadth	weight
Marubini et al. (1972)	leg length	leg length
Gompertz and Logistic	stature	stature
Harpenden Growth Study	sitting height	sitting height
23 M, 15 F	biacromial breadth	biacromial breadth
Tanner et al. (1976)	stature	stature
Logistic	bicristal breadth	sitting height
Harpenden Growth Study	biacromial breadth	biacromial breadth
55 M, 35 F	sitting height	bicristal breadth
Welon and Bielicki (1979)	leg length	leg length
Graphic	biiliac breadth	biiliac breadth
Wroclaw Growth Study	biacromial breadth, weight	biacromial breadth
192 M, 250 F	stature, trunk length	stature
	trunk length	Weight

DISCUSSION

The specific aims of this study of somatic growth and maturation in 105 Polish adolescents were to mathematically fit curves to individual data for anthropometric dimensions and PWC_{170} in order to derive estimates of ages at PV and PVs for each dimension by sex; and, in addition, to examine the mean and modal sequences among peak velocities by sex.

The males in this study may have been advanced in maturity status relative to other samples based on a mean age at PHV that was somewhat early compared to other estimates; although mean PHV was comparable to values for other samples of males. The females in this study appeared to be average in maturity status because the mean age at PHV and mean PHV were consistent with estimates from other studies.

The PVs in body dimensions other than stature occurred within a relatively narrow time period (1.51 years in females to 1.77 years in males), and the ranges of PVs were consistent with ranges previously reported (0.5-2.0 years).

Sex differences were apparent in ages at PV and PVs. On average, females had earlier ages at PV in somatic dimensions than males, with the exception of PWC_{170}. The intensity of the growth spurt in PWC_{170} was greater in males than in females, and the same was true for the 12 of the 16 body dimensions (including stature) for which parameters were estimated, consistent with the literature.

When the timing of spurts in various body dimensions was compared to ages at PHV and PWV, the prevailing order of PVs showed that growth spurts in weight and upper body lengths and breadths followed PHV in males, while almost all body dimensions exhibited spurts after PHV in females and before PWV in both sexes. In the majority of the sample, a number of dimensions were synchronous in estimated age at PV, perhaps because ages at PV were estimated for more body dimensions than in any other study previously.

In both sexes, the growth spurt or PV in PWC_{170} occurred near both PHV and PWV; however, it occurred closer to PHV in males than in females, and PV in PWC_{170} tended to occur on either side of PHV and before PWV in males, while it tended to occur after both PHV and PWV in females.

There was a reasonably well-defined sequence of mean ages at PV in body dimensions as well as a reasonably clear modal sequence of spurts, and both mean and modal sequences differed by sex. There is some consistency with mean sequences reported in other studies; however, the modal sequence of PVs differed from that based on mean ages at PV and from sequences previously reported.

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PHYSICAL GROWTH AND HEALTH STATUS OF MEXICAN AMERICAN YOUTH: overview of past research by Robert M. Malina and fellows

Antonio N. Zavaleta

INTRODUCTION

Professor Robert M. Malina has dedicated his career to the study of human growth, development and physical performance. As such, he has always been keenly interested in the growth and development of children and the role that ethnic variation, migration and nutrition play in their ultimate adult stature, weight and associated dimensions and performance (Malina et al. 1970).

Professor Malina's career as an active physical anthropologist resulted in the incorporation of both field studies and students in his life's work. Beginning with United States-based population (Johnston et al. 1971), opportunity and professional inquiry led him to study the unique physical characteristics of the Zapotec native to Oaxaca in Mexico in the late 1960s (Malina et al.1972). From the indigenous Zapotec of Latin America he investigated the mixed race or Mestizo/Ladino populations of Guatemalan Ladino children (Malina et al. 1974).

During the course of his career, professor Malina and his students returned to these field venues on several occasions, extending their original studies to significant longitudinal ones. In the case of the Zapotec, Malina's study continues to this day. His pattern of continuous study flows throughout his career and has proved significant in providing doctoral opportunities for several generations of students (1970-2010). Additionally, this pattern of collegial mentorship, combined with his research interests, has produced a cadre of graduates who continue to collaborate with Malina well into their careers. This pattern has suited all.

In the early 1970s, Professor Malina had recently arrived at University of Texas at Austin, having completed doctoral degrees in Kinesiology and Anthropology. As such, he enjoyed departmental appointments in both of the departments representing his disciplines.

MEXICAN AMERICANS

The University of Texas, while serving as the flagship university of a State with a significant Mexican American population, in fact, admitted very few African and Mexican Americans as undergraduates. Mexican American graduate students at University of Texas were even scarcer.

In 1971, Anthony N. Zavaleta, a Brownsville, Texas native took a course in human growth and development with Dr. Malina and that experience led him to a lifetime of collaboration and friendship. Malina's anthropology course changed Zavaleta's perspective on career and allowed him to fulfill a lifelong dream of studying the anthropology of the U.S.-Mexico border. Zavaleta completed the undergraduate degree in anthropology with honors and subsequently applied to the graduate program.

Zavaleta was admitted, conditionally, to the masters degree program, told by the graduate advisor that UT, "did not have a place for him and could not take a chance on him." Meaning, the message sent was that they could not take a chance on a Mexican American from the Lower Rio Grande Valley of Texas lowering their national standing. At that time, the UT anthropology doctoral program was ranked in the top ten in the country and readily admitted only top candidates nationally. "Admitting a Mexican American from the Rio Grande Valley of Texas was too much of a risk for the program to take," he was told by the graduate advisor.

Confident, and at the same time bolstered by the confidence and support of professor Malina, Zavaleta began his course work in physical anthropology, human growth and development, skeletal biology and human adaptation. Additionally in his studies he included a cultural focus on Latin America, Mexican Americans and the U.S.-Mexico border.

The combination of the courses, biological and cultural, led to his lifelong interests in the cultural aspects of health status and health care, which would some years later evolve into the sub-discipline today known as medical anthropology.

Zavaleta once encountered renowned medical anthropologist Arthur J. Rubel at a conference. Rubel and colleague, Madsen were among the first anthropologists to study Mexican American health status in the Lower Rio Grande Valley of Texas (Rubel 1966) (Madsen 1973). Armed with a Hogg Foundation for Mental Health grant in the early 1960s, the two pioneered a connection between physical and cultural anthropology; known today as alternative and complementary medicine. Professor Malina was always supportive of Zavaleta's interest in cultural and medical anthropology which they discussed often.

Through the work of Rubel and Madsen in south Texas, several next generation, native anthropologists were trained, including Joseph Spielberg-Benítez who retired from Michigan State University.

Dr. Rubel pioneered the early development of the medical anthropology field, and when asked "how does one become a medical anthropologist?" Dr. Rubel replied to Zavaleta, "call yourself one."

In the middle 1970s, professor Malina was able to expand his work on the diversity of Latin American populations to Mexican Americans on the border. Serving as a mentor for Zavaleta, the initial interest and studies in the growth and development and health status of Mexican American children began with a master's thesis. (Zavaleta 1973).

By developing the confidence of school administrators at the Brownsville Independent School District in 1972, Zavaleta and Malina were able to conduct the first anthropometric study of Mexican American youth in a border town.

Completing his master's degree, and by proving himself to the anthropology faculty, Zavaleta was admitted to the doctoral program (Malina and Zavaleta 1976).

The close association of Malina and Zavaleta and their shared interest in the growth and development of Mexican American children, led to the study of their body composition and the completion of a doctoral dissertation (Zavaleta 1976).

The laboratory work on body composition was performed using the recently-completed underwater-weighing tank; constructed with the direction of Dr. Hugh Bonner. With the support and direction of professor Malina, the kinesiology department at UT was expanding into modern exercise physiology and Zavaleta's dissertation was the first to be completed using the now old method of complete body submersion for the determination of body composition.

This study performed by Zavaleta under the direction of Malina would further their interest in the nutritional and health status of Mexican Americans and its influence on growth and development in general (Malina 1987 a; Malina 1987 b; Malina 1987 c).

Malina mentored and guided a wide array of studies examining many topics and including many different graduate students from the initial Zavaleta study onward for more than 25 years. These studies examined both Mexican-American and Mexican children, including Mexican immigrants living in the United States (Hughes 1982).

Various studies on and about Mexican Americans began appearing in the literature in the 1920s, and Malina examined the historical literature with the publication of growth status of Mexican American children and youths: Historical and contemporary issues. While the initial anthropometric studies were conducted in the early part of the 20th century, it was not until the work of Malina and Zavaleta that true growth studies were conducted on Mexican American children and connecting their status to health and nutritional status (Malina et al. 1986). Studies containing anthropometric data on Mexicans and Mexican Americans were sustained from 1920 through the 1990s. Through the work of Malina and Zavaleta they ultimately led to dramatic improvements in child-health status along the lower Texas-Mexico border (Malina and Zavaleta 1980) (Zavaleta and Malina 1980).

An historical overview of Mexican and Mexican American growth studies was published in homage to Mexican physical anthropologist Santiago Genovés for his 33 years of service to Mexican anthropology (Tapia 1990). In their contribution, Kobyliansky and Goldstein summarized the study of two generations of Mexican and Mexican American youth including the work of Malina and Zavaleta and compared the growth of children of Mexican parents in Mexico and in the United States as well as changes in physical traits with age of adults, the parents of the children (Kobyliansky and Goldstein 1990). In the same volume, Malina and Little examined body composition of young boys from rural Zapotec-speaking villages in Oaxaca, Mexico (Malina and Little 1990).

Credit must be given to the pioneers in physical anthropology who showed legitimate interest in Mexican American children beginning with Paschal and Sullivan in 1925 who studied the relationship between intelligence and growth; H. T. Manuel in 1934 who was principally interested in the education of Mexican Americans; Whitacre in 1939 took a more traditional approach while in 1943 Goldstein examined Mexican immigrant children and in 1952 Meridith and Goldstein examined growth and socioeconomic status of Mexican American Children (Malina and Zavaleta 1980).

In the period from the earliest Malina-Zavaleta studies, to the latest in the 1990s, and others have outlined the importance of establishing Mexican American baselines for determining health status (Mendoza 1991) (Zavaleta 2000). The Hispanic Health and Nutrition Survey in the 1980s played a role but little work has been completed to link Mexican American health to growth status (Troiano et al. 1995).

Meanwhile, Malina expanded his interests to include topics such as secular trends, age at menarche, growth spurts, nutritional status, human performance, immigrant status and intergenerational advances etc. Throughout the 1990s, Malina continued his work on Latin American populations expanding to Brazilians while further exploring opportunities with diverse European populations especially eastern European (Malina 1990). Malina continues his study of many and diverse aspects of the growth and development of Zapotec children. In the last 20 years, Malina's work as an active researcher, author and speaker is marked by its increasing universality in worldwide studies of human populations.

WHAT HAPPENED NEXT?

Zavaleta completed his doctoral degree at Texas in 1976 and returned to the Lower Rio Grande Valley. Zavaleta counts his years with Malina as the most significant in his life as they cemented the foundation for his professional career (Zavaleta 1989). While Malina and Zavaleta were not able to continue their studies of the growth and development of Mexican American children, Zavaleta utilized what he had learned from Malina and for the following quarter of a century made a positive impact upon the Mexican Americans of south Texas. Often, this took place in consultation with professor Malina (Zavaleta 2002).

Soon after returning to south Texas, and based upon the work of Malina and Zavaleta, a Health Needs Assessment Survey of Brownsville, Texas was performed (Zavaleta 1985). This study was the first-ever in south Texas and served as the basis for tens of millions of dollars in state and federal funds applied directly to improve the health status of the local population.

Another Malina student, William H. Muller at the University of Texas Health Science Center at Houston asked Zavaleta to join its South Texas Diabetes Research Project, which led to our early understanding of obesity and diabetes in Mexican American children (Muller et al. 1984) (Muller et al. 1984).

In his work with Malina, it became obvious that maternal and neonatal mortality rates in Cameron County, Texas were the highest in Texas. Further examination of this problem led to the creation of a Texas law regulating the practice of lay midwifery and ultimately saving hundreds of lives. This fact led to Zavaleta joining the board of directors of Su Clinica Familiar, a federally funded community and migrant-farmworker clinic in south Texas. Zavaleta served 20 years on the board and developed the clinic into a highly regarded system for the delivery of primary care as well as a birthing center for the indigent of south Texas.

Working with the University of Texas Medical Branch's Department of Pediatrics, a major multiple-year grant was awarded by the State of Texas for the development of a community oriented primary care facilities around the state. These projects were intended to deliver primary health care to poor Mexican Americans and other poor living in the colonias in and around Brownsville, Texas. The project treated many thousands and lasted 18 years until legislation changed directions (Zavaleta, et al. 1992).

In the 1990s Zavaleta began work with health-education professor Nell Gottlieb whom he had met through Malina, and the pair received a grant from the Texas Higher Education Coordinating Board to develop health-education material for the prevention of breast and cervical cancer among maquiladora (cross border factory) workers in Matamoros, Mexico (Gottlieb et al. 1996). Two Latina doctoral students were supported and trained through this project.

By the late 1990s, the COPRIMA project at UTMB had collected sufficient data under the supervision of professor Malina to conduct several studies which examined the relationship of Zinc to Mexican American growth status (Egger et al. 1999; Penland et al. 1999; Sandstead et al. 2000; Sandstead et al. 2008).

SUMMARY

It is clear that any examination of Robert Malina finds a career full of diversity of investigation as well as support of students. This overview must also focus on the tangible projects that developed along our southern border during the last 35 years and to place those projects as points of light in Malina's list of accomplishments. It is with great respect and honor that I am able to point out these unparalleled accomplishments for the record of this great man's life. Professor Malina had total faith in what a Mexican American student from Brownsville, Texas could and would accomplish. Zavaleta's career varied somewhat from his colleagues (Zavaleta and Salinas 2009). However, through the work and vision of Malina, the lives of Mexican American children have and continue to be changed through the delivery of health care. Malina and Zavaleta set out to examine the health status of Mexican American youth through their growth status and those studies eventually led to the creation of tangible projects which operate today.

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BIOLOGICAL AND HEALTH CONSEQUENCES OF HUMAN MOBILITY

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INTRODUCTION

Social mobility may be of two kinds. Vertical mobility occurs in socially stratified societies and involves a shift of a person's position (up or down) on a scale of attained education or wealth or power or prestige; such scales are often, though not necessarily, interrelated. Vertical mobility may occur between generations, when the shift is measured relative to the position of the subject's parents, or within a single generation, when the subject moves up or down the scale during his/her adult lifetime. Horizontal mobility, in contrast, involves movement either to a different place of residence (e.g. rural-urban, different geographical region, or ethnic group) or to a new marital category. Horizontal mobility does not have to cause a shift in the person's position on any vertical social scale. It is widely recognized that social mobility in one of the factors having a significant indirect impact on a society's biological well-being and health status (Heller et al. 2002).

In Poland an abrupt transition from a socialist command economy to a free-market system has occurred during the early 1990s. It had a profound impact on virtually all aspects of the society's occupational, educational and demographic structure. More specifically, it has been hypothesized that the recently observed increasing incidence of cardiovascular diseases among younger people in Poland may in part be due to the new patterns of social mobility generated by the country's systemic transformation.

INFLUENCE OF HEIGHT ON ATTAINED LEVEL OF EDUCATION

The fact that children and adults from upper social strata tend to be taller than their age-mates from lower strata is usually regarded as a phenotypic manifestation of social disparities in living standards (Malina & Bouchard, 1991). However, the possibility has also been contemplated that in modern industrial societies upward social mobility may be selective with regard to body height, in which case statural differences between social classes might also have a genetic component, even in an ethnically homogenous society. More precisely, the hypothesis postulates that taller individuals are for some reason more likely to move up the scale of educational and/or occupational status than are their shorter peers coming from the same social background.

Evidence consonant with the above conjecture has been presented and discussed in a number of studies, e.g., Bielicki & Szklarska (2000) and Szklarska *et al*. (2007). In these reports an interesting attempt is made to look at this problem. Statures of young adults equated as strictly as possible for social background but differing sharply in educational status achieved by the age of 19 years were compared. Out of a total of 57000 19-year-old conscripts (27,000 in the 1986 and 30,000 in the 1995 cohort), 23 non-overlapping groups were chosen. The 23 groups represent the maximum degree of social homogeneity attainable in the material. Each group was formed of subjects equated for six criteria of social background: education and occupation of parents, number of the subject's siblings and the degree of urbanization. Within each group, men who at the age of 19 years were either secondary-school or college students are, on average, taller than age-mates who come from a very similar social background, but who have never moved beyond the basic trade school. The results demonstrate that among young males equated for social background a significant positive association exists between the subject's stature at the age of 19 years and the educational level attained by him by that age.

NEGATIVE CONSEQUENCES OF DOWNWARD INTRAGENERATIONAL SOCIAL MOBILITY

Many studies have shown that unemployment has a negative impact on health (Bartley & Owen, 1996). The loss of one's job not only means a financial loss but also can lead to several secondary difficulties, both physical and psychological: the loss of a structured, fulfilling daily life, of a certain social status, and thereby of a variety of supportive social relationships (Rasky *et al*., 1996). Martikainen & Valkonen (1996) showed that unemployment significantly increased the mortality rate among Finnish men from 1981 to 1985. After having controlled for all background variables, they found that relative total mortality among the unemployed was 93% higher and the relative death rate from circulatory diseases was 54% higher than it was among men who were employed. Furthermore, unemployment can cause psychological disturbances (Morrell *et al*., 1994), hypertension and cardiovascular diseases (Cook *et al*., 1982).

In 2006 the Institute of Anthropology Polish Academy of Sciences took part in a screening program, the Program for the Prevention of Cardiovascular Disease, carried out by the municipal health department of Wroclaw. 452 men and 572 women underwent a medical examination and completed a questionnaire regarding educational level, professional career and life-style elements. All participants were divided into three groups: professionals, skilled and unskilled workers, and currently unemployed individuals. The unemployment status was a recent event, and emerged at most five years before examination, so the third group was recognized as a group experiencing downward social mobility. The Framingham Risk Score (FRS) was used to determine the cardiovascular consequences of employment status. The FRS, derived from the Framingham Heart Study cohort, was designed to predict the risk over a 10-year period of an individual's experiencing one or more of several major adverse coronary events, including mortality due to coronary artery disease and non-fatal myocardial infarction (Kozieł *et al.,* 2010).

Regression analyses indicate that occupational status is associated significantly with increased risk of cardiovascular diseases (CVD). This association remains with the inclusion of education level, BMI and/or waistline in the regression, implying that occupation relates to CVD independently. For both sexes FRS mean values regularly increased across the range of occupational groups, with the highest values among unemployed participants (Kozieł *et al.*, 2010).

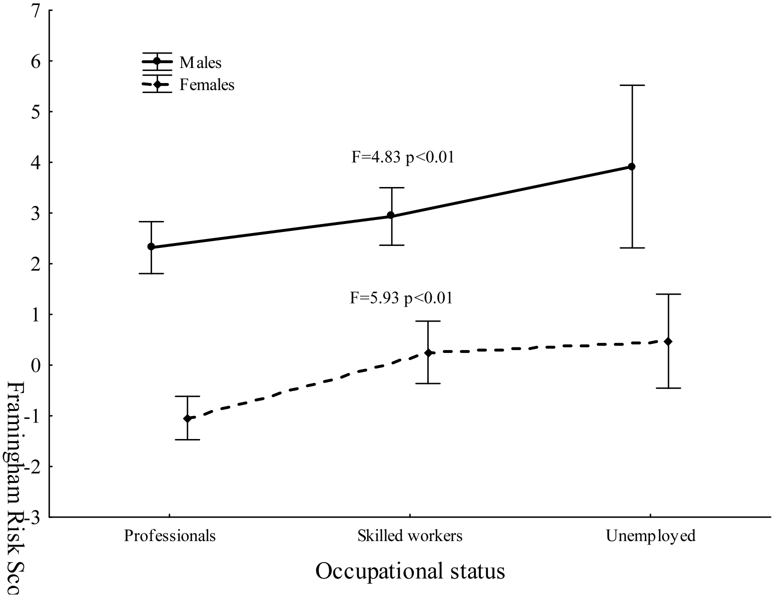


Figure 1. Means and standard errors of Framingham Risk Score (FRS) by sex and occupational status. [Source: Kozieł et al., 2010, Economics and Human Biology; reproduced with permission, Elsevier, license number 3150111129121].

This study indicates that downward intragenerational social mobility, here analyzed by unemployment status, is associated with an elevated risk of CVD.

MOBILITY BY MARRIAGE

An example of 'vertical' mobility is change of social position as a result of marriage to a spouse with a discrepant level of education. In general, when the husband is better educated than his wife, she is described as upwardly mobile; when the wife is better educated than her husband, she is described as downwardly mobile. Significant differences in body build, physical fitness and certain health parameters were found between persons moving up and those moving down the social scale through marriage (Lipowicz & Szklarska, 2011). Taller women tended to marry men of higher social class, while downwardly mobile men and women were fatter than individuals who 'marry up' (Garn *et al.* 1989). Women with lesser educated husbands also had a more abdominal fat distribution than comparable women with better educated spouses (Lipowicz, 2003).

Also social mobility by marriage significantly affects health status among married Polish men and women. Downwardly mobile women were characterized by higher risk of CVD while upwardly mobile women had a lower risk of CVD compared with individuals in homogamous marriages. The relationship remained significant, when level of education of the individual and lifestyle behaviors were controlled. A similar pattern was observed in men, but the differences were not significant. Poorly educated men who married a better educated wife were an exception; their upwardly mobile marriage did not affect risk of CVD.

Several hypotheses have been proposed for the observed relationship between social mobility and biological condition and health status. Selective social mobility might partly explain the relationship. Among men/women at a constant educational level, slim, taller or healthier persons with better biological condition and healthier lifestyles have more chances of finding better-educated wives/husbands, whereas individuals with health problems or risky behaviours have rather less-educated spouses.

Assortative mating is an additional consideration (Silventoinen *et al*., 2003). People tend to choose partners with characteristics that resemble their own socioeconomic group. Given the strong inverse social gradient of health status observed in Poland, it can be hypothesized that men/women who marry up or marry down select spouses with health status and lifestyle behaviors similar to their own. Spousal correlations in fatness and indicators of lifestyle such as diet, drinking and smoking behaviors and frequency of physical activity are significant but vary in magnitude (Macken *et al*., 2000). It is possible that sharing a common household environment and assimilation of lifestyle in the spouse's social class may influence CVD risk. In Poland, parity changed in the direction of the spouses' socioeconomic environment, leading women to 'imitate' the reproduction model of less-educated women (Lipowicz, 2003). Thus, downwardly mobile Polish women had more children compared with upwardly mobile women. An upwardly mobile husband may experience more favorable lifestyle behaviors related, for example, to diet, alcohol consumption and/or utilization of medical and social services associated with a better educated wife. On the other hand, less educated women may pay inadequate attention to potentially risky behaviors of their husbands. The prevalence of smoking, for example, was higher among men whose wives had only primary school education (Bosma *et al*., 1995). For women, upward social mobility may have a positive influence on their biological condition and health status through better material conditions of the household.

A better educated wife seems to be "a problem" for poorly educated men. Our results showed that upward social mobility did not affect their health status. It is suggested that better educated wife provokes marital dissatisfaction and disagreements resulting from role conflict or dual roles of wives, what in a consequence impairs their biological condition and health status.

INTER-GENERATION SOCIAL MOBILITY MODIFIES CHD RISK IN MIDDLE-AGED MEN AND WOMEN

An important type of inter-generation vertical social mobility is the difference between parents and their adult offspring in the attained level of education. From the point of view of human biologists, and also of students of public health, such mobility is interesting because of the well-known significant effect the individual's position on the educational scale on his/her health status (Lipowicz et al. 2007; Jankowska et al. 2008).

The impact of such inter-generation mobility on health status was recently examined in the course of the Program for Prevention of Cardiovascular Disease conducted by Health Department in Municipal Council in Wroclaw in cooperation with Institute of Anthropology, Polish Academy of Sciences. Because education as a single predictor of social class is more strongly associated with disease than are other indicators (Liberatos *et al.*, 1988), level of father's education was chosen as measure of social position of the individual in childhood.—The detailed effects of inter-generation change in educational status in subgroups of men and women, varying of their father's education level were analyzed.

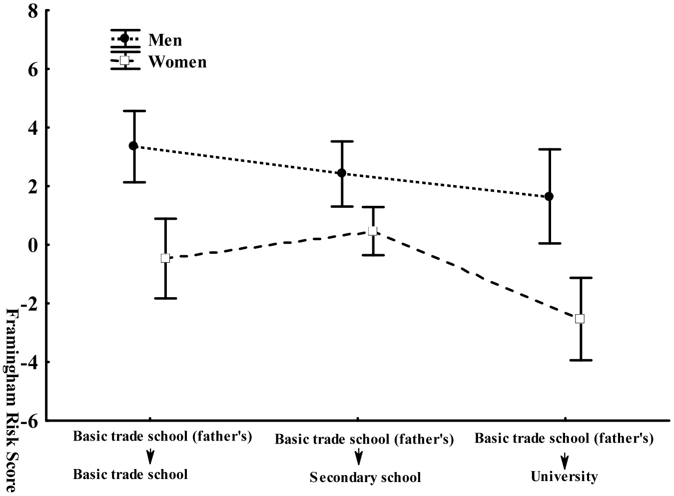


Figure 2. Framingham Risk Scores in Polish men and women according to inter-generational change in educational level (means±95%CI). [Source: Jankowska et al. 2008, J Biosoc Sci, 40(3):401-12; permission not required]

Among adult males inter-generation social mobility was shown to be an independent factor affecting the CHD risk as measured by the FRS: irrespective of the level of paternal education, men better educated than their fathers tended to have lower risk scores than those who did not change their position on the educational scale. No such tendency was noted among females. For example, an improvement in educational level among those men whose father had finished basic trade school was followed by a significant decrease of CHD risk (F=3.25, *P*=0.04); (see Fig. 2).

It was also found that social mobility influences several traditional risk factors for cardiovascular disease, which in fact are internal elements of FRS (systolic and diastolic blood pressure, HDL-cholesterol).

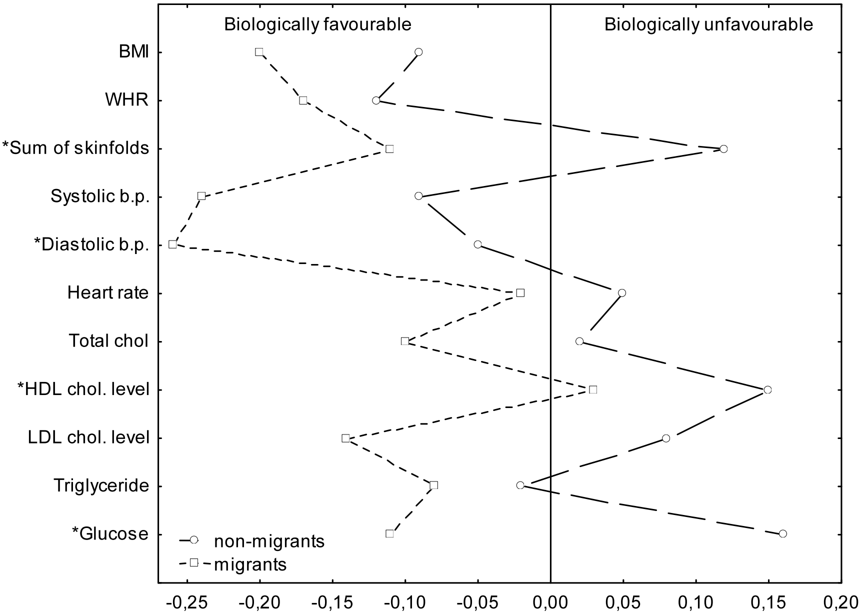
A somewhat controversial explanation of the relationship between inter-generation vertical social mobility and health status is the hypothesis of selection. It postulates that persons endowed with higher biological fitness have a better chance to move up on the educational scale relative to their parents; in other words the subject's current health status is an effect of his/her individual chances for social advancement (Cardano *et al.* 2004). Attention has also been drawn to the possible gradual accumulation of risk factors to which the individual is exposed during his/her lifetime ever since childhood - the phase when living standards are strongly dependent on the parents' education and social position. The lack of relationship between the CVD risk and inter-generation mobility among females is, however, not fully understood. Perhaps some role is played by the fact that in females, health status is more strongly dependent on the social position attained by marriage than upon her own educational attainment (Lipowicz 2003). Moreover, in women the subjective feeling of belonging to a specific social class exerts a stronger influence on the person's health status than does her real position on the social ladder either in childhood or in adult life (Adler *et al.*, 2000). Accumulation of risk throughout the life course has been proposed as an alternative hypothesis. It suggests that exposures or insults gradually accumulate to increase the risk of chronic disease and mortality and that cumulative differential lifetime exposure is the main explanation for the observed socioeconomic differences in risk of disease (Hallqvist *et al*., 2004). On the other hand, using longitudinal follow-up data, Power *et al*. (1991) found that health-related mobility did occur but did not explain the health inequalities and pointed out that it was rather lifetime social circumstances that were responsible. Beneficial effects are particularly seen in those men who improved their social position as compared with their fathers.

MIGRATION AS A KIND OF VERTICAL MOBILITY

Human migration is the movement from place to place of individuals or groups of individuals for the purpose of taking up permanent or temporary residence, usually across a political boundary. Migration occurs at a variety of scales: intercontinental (between continents), intracontinental (between countries on a given continent), and interregional (within countries). People migrate for a variety of reasons. We can recognize a "push" or a "pull" factors. Pull factors - reasons for immigrating (moving into a place) because of something desirable such as a better educational and occupational conditions, freedom, improving living condition, a better food supply access to medical services etc. Push factors - reasons for emigrating (leaving a place) because of a difficulty such as a food shortage, war, discrimination, political or religion persecution, etc. Current migration trends affect living conditions, violence and armed conflicts, environmental problems, a lack of economic perspectives and the growing gap between rich and poor countries (National Geographic Society, 2005).

One of the most significant migration patterns has been rural to urban migration—the movement of people from the countryside to cities in search of opportunities. The extent of rural-urban migration in today's world is enormous.

Anthropology studies are concerned with the biological consequences of urban-rural migration, especially growth and development and morbidity and mortality (Bogin, 1988). Most empirical studies of rural-to-urban migration find that the health of migrants is better, mortality is lower, and fertility is low compared to rural residents, and their children grow taller (Zielinska, 1991; Klinthäll & Lindström, 2011). The social and economic literature notes that migrants are generally better-educated, higher in socioeconomic status, and younger than rural residents (Butterworth & Chance, 1981).



* $p < 0.05$; significant level

Figure 3. Comparison of men with university education by migrational status. [Source: Szklarska et al. 2008, Am J Hum Biol 20:139-145; reproduced with permission, Wiley & Sons, license number 3144740169983.]

Szklarska and coauthors (2008) compared and analyzed differences in health-related biological variables in relation to migration status among inhabitants of the city of Wrocław. In this study, differences in health status between migrant (those who had come to Wrocław at the age of 16 years) and nonmigrant (those who had lived in Wrocław since birth or had come with their parents) inhabitants of Wrocław, Poland were estimated. Comparisons were made based on Borkan's and Norris's profiles (Borkan & Norris, 1980, Fig. 3).

Male migrants were significantly taller than their peers born in Wrocław. In females, migrants had significantly lower blood pressure and heart rate than nonmigrants. In interpreting the results two possible, not mutually exclusive, mechanisms are proposed: selective spatial mobility, and changes toward healthier life style as an adaptation to new urban environment.

Study of second generation migrants provides an opportunity to examine the long effects of migration on a variety of characteristics, including attained young adult height. On the basis of the study of 19-year-old Polish conscripts born in 1976 and examined in 1995, the impact of parental origin (urban or rural) on the attained height of 19 year old males resident in urban centers in Poland was evaluated. Within each of the selected social groups, conscripts whose parents were of rural origin were, on the average, taller than age peers from the same social background but whose parents were of urban origin. These results suggest that region of parent origin has a strong effect on stature of 19 year old males. Corresponding analyses based on only maternal or paternal origin and level of education shown that "post-rural" conscripts tend to be, on average, taller than "urban" conscripts when either maternal or paternal level of education and origin were considered separately. Within each social group with one or two children in the family and with three or more children in the family, there is a trend for mean heights of conscripts born to "post-rural" and "urban" parents to decline from higher to lower levels of parental education. The trend is slightly greater in conscripts from one or two child families (Kołodziej *et al*., 2001). The trend may be interpreted within two contexts. First, the differences may reflect selective migration with respect to height. Second, migrants may have a greater variety of adaptive strategies to conditions of urban living because of their combined rural and urban experiences and continued access to rural resources (nutritional resources in particular) during the transition to urban living.

The general trends showed that selective migration with respect to body size is not a factor; rather, improved environmental conditions - better hygienic standards of households, quality of diet, regularity of meals and accessibility of health care - are responsible for the growth differences between migrants and non-migrants. It appears likely that the observed differences in height may result from greater adaptability of migrants and/or from the influences of better living conditions.

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DEVELOPMENT OF STRENGTH PARAMETERS DURING CHILDOOD AND YOUTH: A LONGITUDINAL STUDY FROM CARIRI, BRAZIL

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INTRODUCTION

Longitudinal studies of motor performance, particularly pertaining to strength parameters, describing children and adolescents development are limited in the pediatric exercise science literature. For example, a review of changes in motor performance from a variety of tasks in boys and girls, followed for several years, was reported by Malina et al. (2004). However, many of the studies reviewed were conducted some 10-20 years prior to publication. In addition, no formal modeling or hypothesis testing were produced to interpret performance changes presented in the review. Within the European mainstream, the best approach to describe repeated information concerning motor performance was performed by Beunen et al. (1988). They provided distance and velocity charts for several motor tests (flamingo balance, plate tapping, sit and reach, vertical jump, standing long jump, arm pull, leg lifts, sit ups, shuttle run 50m, and shuttle run 480m) for Belgian boys followed over 6 years from 12 to 18 years of age.

Seminal work about static strength changes during youth was reported by Carron and Bailey (1974). They followed 99 Canadian boys from 10 to 16 years of age, using seven static strength tests. They found that maximum strength increments occurred 1 year after peak height velocity and peak weight velocity. Early maturers had significantly greater strength than late maturers. However, when strength was divided by body height, the results remained unchanged. Furthermore, when the effects of weight were factored out, no differences remained among groups of different maturational levels. In Belgian boys, Beunen et al. (1988) showed that static strength (arm pull test) increased fairly linearly with chronological age from early childhood to approximately 12 or 13 years of age. On the other hand explosive strength performance (standing long jump test) , and on average, increased linearly with age in both sexes until 12 years in girls, and 13 years in boys. In contrast to girls, in boys, a clear growth spurt in explosive strength was seen to occur, 6 months after age at peak height velocity and coincided with peak weight velocity. In both sexes, size, body composition and biological maturation were associated with strength characteristics, although the magnitude of correlations varied with sex, age and the strength component (Malina, Bouchard & Bar-Or, 2004).

An adequate understanding of the dynamics of changes in performance necessarily implies the use of longitudinal and/or mixed-longitudinal designs; and the use of flexible statistical models. This is because the effects of maturation may mask of be greater than the effects of growth per say. The description and interpretation of the dynamics of change, its patterns, as well as the use of relevant covariates that can explain the magnitude and direction of change is mostly lacking (Baxter-Jones, Sherar & Eisenmann, 2005; Beunen et al., 1988; Maia et al., 2005). Fortunately, developments in the statistical theory of hierarchical linear models (HLMs) enables the integration of the study of the complexities of individual growth, group description and investigation of correlates of status and change (Bryk & Raudenbush, 1987; Hox, 2010).

To our knowledge no recent longitudinal studies have attempted to describe or interpret changes in strength development or identify what variables predicts theses changes. This study aims to describe strength development obtained from a variety of motor performance tasks observed in Brazilian children and youth to: (1) model changes in strength performance of children and youth of four cohorts followed longitudinally from 8 to 16 years; (2) verify the presence of gender, and differential effects of biological maturity in their normative trajectories; and (3) describe the effects of time varying covariates; namely physical activity level and fatness

SUBJECTS AND METHODS

The sample comes from the 'Growth and Health Cariri Study', a mixed-longitudinal research about growth, sexual maturation and motor performance dynamics of children and adolescentes. Three main cities from Cariri Region, Ceará state, northeast region of Brazil were selected: Juazeiro do Norte, Crato and Barbalha. All participants were from public and private schools, and the sample consisted of four age cohorts: 8, 10, 12, and 14 years at study entry. These cohorts were followed for three consecutive years with measurements taken at six-month intervals during the period 2006 – 2009. Due to the overlapping nature of the cohorts it was possible to develop developmental patterns from 8 to 16 years of age during a three year time period. The original sample comprised 796 children and youth (368 girls and 428 boys) (Table 1). Student's socioeconomic status (SES) was defined according to family's average income and school attendance: private (high level) and public (low level). Sex and age specific sample sizes are given in Table 1. The "Healthy Growth in Cariri Study" was approved by the Ethics Research Committee of the Medical School of Juazeiro do Norte and informed consent was obtained from parents and directors of all schools.

Table 1. Sample size by age, cohorts and sex.

Cohort	Ages	Girls	Boys	Total
C 1	08 – 10	117	148	265
C 2	10 – 12	96	87	183
C 3	12 – 14	111	124	235
C 4	14 – 16	44	69	113
	Total	368	428	796

Measurements and tests

Skinfolds were measured by highly trained staff according to the procedures described by Claessens et al. (2008) at the following anatomical sides: triceps, subscapular, biceps, iliac, and calf. Due to skewed distributions, all were log transformed and summed in each subject at all measurement occasions. This sum is used as an indicator of fatness.

Strength was assessed with two tests taken from the American Alliance for Health, Physical Educations, Recreation and Dance (AAHPERD, 1980) test battery. The tests reflected two important components: static (hand grip) and power (standing long jump).

Bone age was estimated using the Tanner–Whitehouse method (TW3) (Tanner et al., 2001). Radiographs were taken at the Radiology Department of the public hospital of Juazeiro do Norte. A radiograph of the left hand and wrist of each child was taken on a yearly basis over the three consecutive years. The difference between biological and chronological ages was calculated for each child at study entry. The classification scheme described by Malina et al. (2004) was used to divide children and youth into late maturers (difference greater than -1 year), average maturers (difference between -1 and 1 year), and early maturers (difference greater than +1 year).

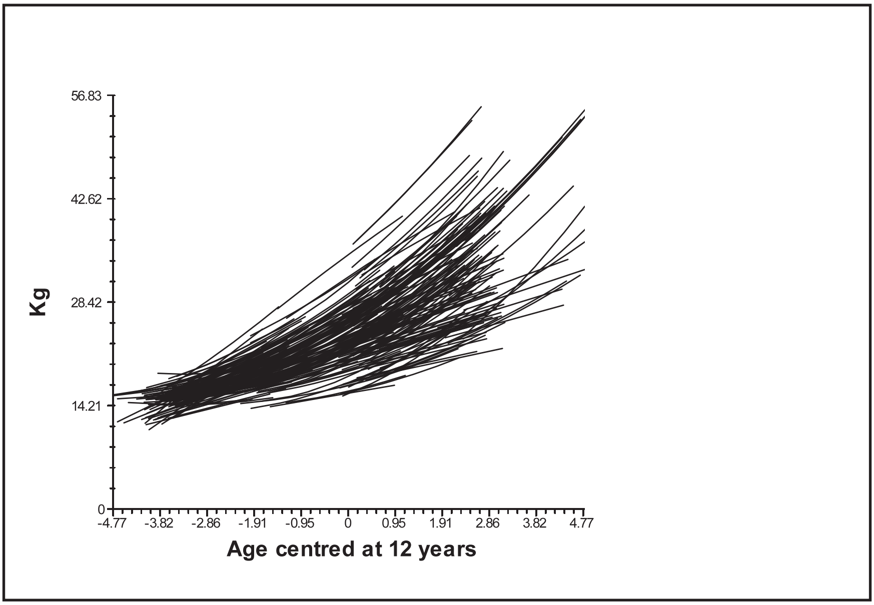
Children's physical activity (PA) was estimated by direct interview (one-to-one) using the Baecke questionnaire (Baecke, Burema & Frijters, 1982), which is considered a valid and reliable instrument (Philippaerts & Lefevre, 1998). This questionnaire consists of questions that call for Likert-type response (1–5) and are designed to assess different categories of the concept of PA (work/school, sports and leisure-time). Sport index was scored, in part, from the two most frequently played sports (divided into three levels: low level for sports that average energy expenditure is 0.76 MJ/h; middle level: 1.26 MJ/h; and high level: 1.76 MJ/h), for which the number of hours per week, month per year, and estimated frequency of sweating, and a subjective comparison of participation in exercise relative to others of the same age. Leisure time index was based on the frequency of television viewing, cycling, and time spent walking daily. In this study we used the sum of the sport index and the leisure time index to summarize the total physical activity level.

Data quality control was performed in two steps. In the first step a pilot study was implemented and all team members were trained and applied all testing procedures on a sample of 26 children, under the supervision of JM, AC and GB. Secondly, an in-field reliability procedure was implemented during data collection. Each day, a random sample of five children was retested. Intraclass correlation coefficients (R) were high for the two strength tests: 0.95 (hand grip), and 0.96 (stand long jump). The Baecke questionnaire was also re-assessed in a random sample of 105 children and youth from both genders and all cohorts. The intraclass correlation for total physical activity was 0.82 (sport score R=0.81 and leisure time R=0.78). Technical error measurement for skinfolds varied from 0.4 to 0.7 mm. The first author (SS) rated all radiographs. Training and quality control procedures were described in detail elsewhere (Silva et al., 2010). In brief, we randomly re-assessed a total of 110 radiographs (intra-observer reliability). Agreements/disagreements in assigning bone stages for each of the 13 bones were verified. Agreements varied from 74.6% (for distal phalanx I) to 90.9% (proximal phalanx III). Overall agreement was 84.9%.

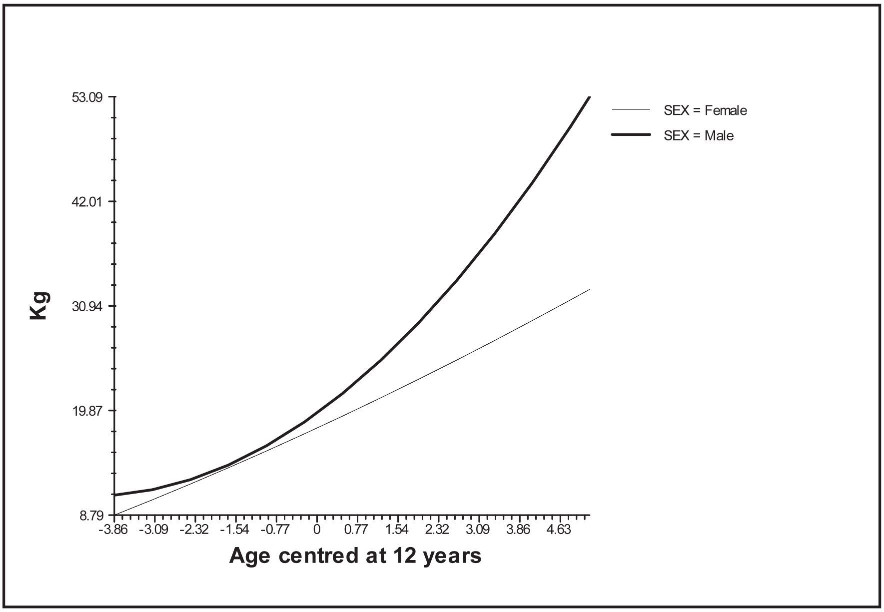
Descriptive statistics were computed in SPSS version 18.0. Modeling changes in strength performance were performed with HLM 6.0 software within the framework of the multilevel approach (Bryk & Raudenbush, 1987). Maximum likelihood estimation procedures were used to assess intra-individual changes as well as average motor performance. In HLM analysis, the number and spacing of measurement observations may vary across persons. It can also easily accommodate data from mixed-longitudinal designs with missing data under the assumption that missing is at random (Hox, 2010). To best describe individual longitudinal trajectories, average trajectories and respective predictors, a stepwise procedure was adopted. We first defined the level-1 model using up to a 3rd degree polynomial of age. To facilitate the interpretation of model parameters describing change, age was centered at 12 years which is, on average, the age at peak height velocity in girls and the age at onset of the growth spurt in boys (Malina, Bouchard & Bar-Or, 2004). A series of hierarchically nested level-1 models were fitted with increasing patterns of change (linear, quadratic, cubic). Deviance statistic, as a measure of model quality, was compared in such models, and the one with lower Deviance was retained showing the best fit based on the evidence that the Chi-square value related to this decrease was statistically significant. The next step was to include time varying covariates: total physical activity and sum of skinfolds (fatness) each available at every six points of data collection. Only statistically significant predictors were allowed to enter the model. Finally, time invariant predictors (level-2) were included in the best fitting model describing change: sex, and a dummy coding (D1 and D2) of biological maturation (late, on time, early) assessed at the first measurement occasion.

RESULTS

Intraindividual trajectories in hand grip were best described by a 2nd degree polynomial (see Figure 1 panel a). The average curves for boys and girls are presented in Figure 1 panel b.



[panel a]



[panel b]

Figure 1. Intraindividual trajectories of all subjects for hand grip (panel a) and average curve by sex (panel b).

Results of the best fitting models are displayed in Table 2. Average hand grip strength of 12 year-old girls was 18.26 (±0.49) kg. Boys were, on average, 1.58 (±0.57) kg stronger. At 12 years, late maturers are less strong (-2.40 ±0.65 kg) than advanced ones (3.56±1.00 kg). Per year, girls increase their strength at the rate of 2.51 kg/year (±0.15), but boys did so at a higher rate (3.98 kg/year: 2.51+1.47).

Late maturers had a linear rate of growth similar to that of average maturers, but early maturing subjects handgrip performance increased at a higher rate (3.44 kg/year= 2.55+0.93). While in girls the quadratic component was not significant (-0.003±0.06), in boys such an upward trend in strength development was evident (0.41±0.08). Maturity advanced youths (Figure 2) showed greater strength gains, while for late maturers (Figure 3) the strength trajectories were similar to average maturers.

Table 2. Fixed and random-effects estimates for the best fitting growth curve model of hand grip.

Fixed-effects estimates	Coefficient	Standard error	T-ratio	P-value
Intercept (12 years)	18,26	0.49	37.45	< 0.001
Sex	1.58	0.57	2.76	0.007
Late maturers (D1)	-2.40	0.65	-3.67	< 0.001
Early maturers (D2)	3.56	1.00	3.56	0.001
Linear Slope	2.51	0.15	16.70	< 0.001
Sex	1.47	0.20	7.25	< 0.001
Late maturers (D1)	-0.09	0.23	-0.41	0.684
Early maturers (D2)	0.93	0.42	2.21	0.028
Quadratic Slope	-0.003	0.06	-0.06	0.953
Sex	0.41	0.08	5.32	< 0.001
Late maturers (D1)	0.26	0.09	2.87	0.005
Early maturers (D2)	-0.13	0.13	-0.99	0.322
Fatness	0.99	0.22	4.50	< 0.001
Total Physical Activity	–			
Random-effects estimates	Variance component		Chi –square	P-value
Intercept	13.26		734.448	< 0.001
Linear Slope	0.48		338.726	0.001
Residual	8.18			
Correlation (Intercept/LinearSlope)	0.98			
Deviance	5286.88			
Parameters	17			

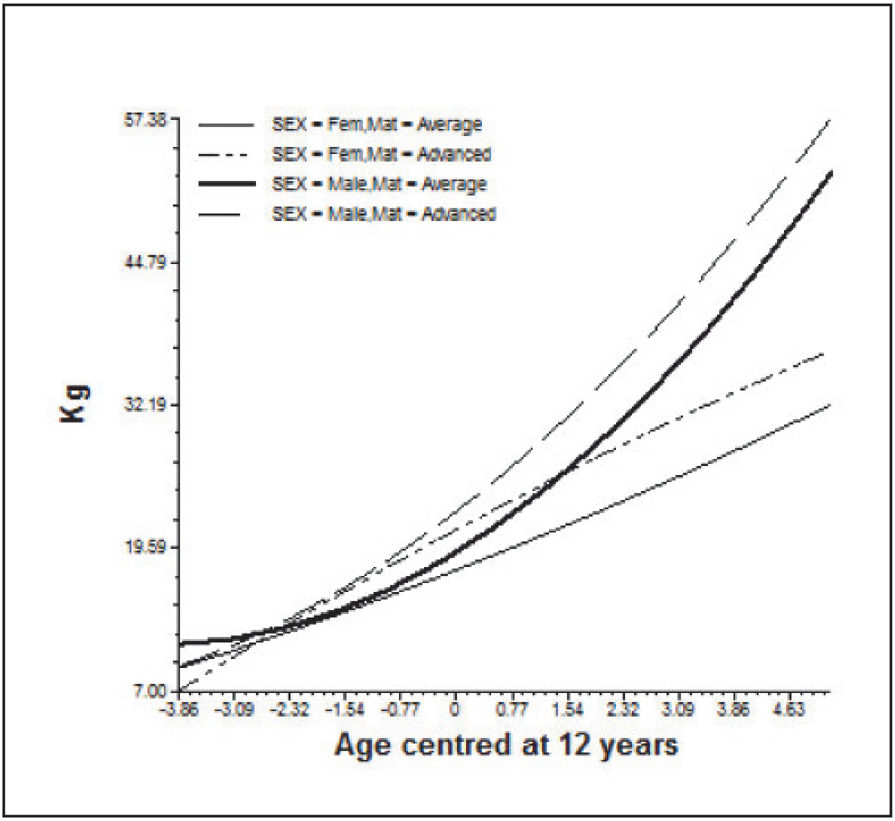


Figure 2. Strength (handgrip) trajectories of boys and girls of contrasting maturity status: average maturers versus early maturers.

Total physical activity did not show any longitudinal association with static strength development, whereas total body fat had a significant positive association (0.99±0.22). Statistically significant interindividual differences were present at 12 years (13.26); the same occurred for the linear rates of change (0.48) in force production. No such trend was present in the curvilinear part of the trajectories.

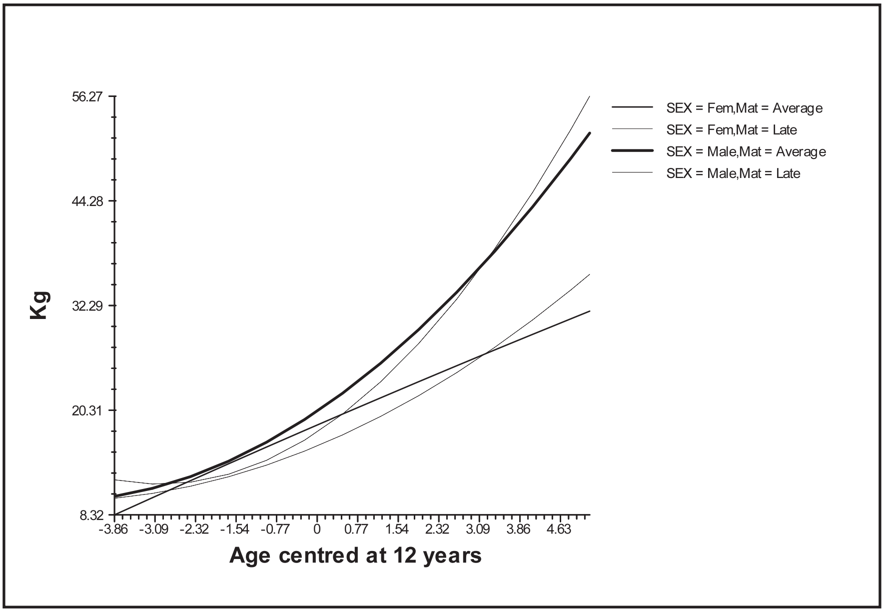


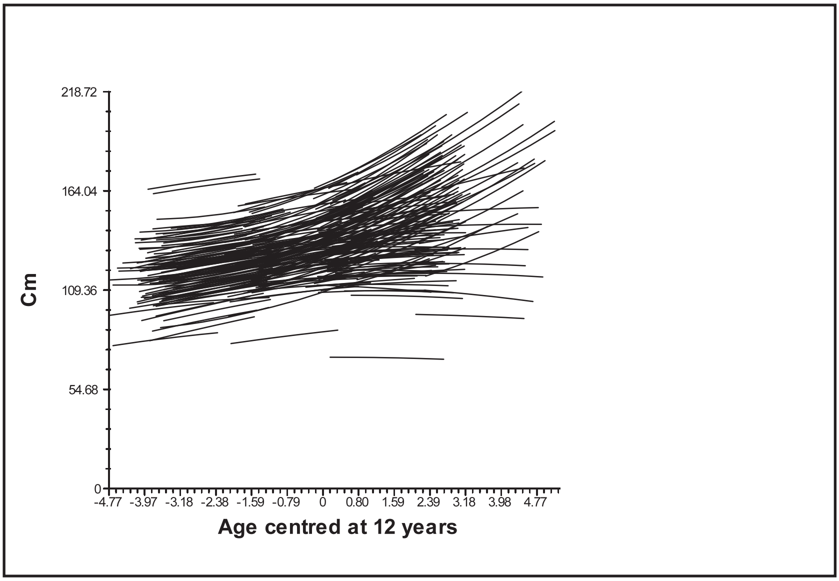
Figure 3. Strength (handgrip) trajectories of boys and girls of contrasting maturity status: (average maturers versus late maturers).

Figure 4 (panel a) shows the intraindividual changes in standing long jump (SLJ), and panel b, presents average curves for boys and girls. A general 2^{nd} degree polynomial of time was the best descriptor of changes.

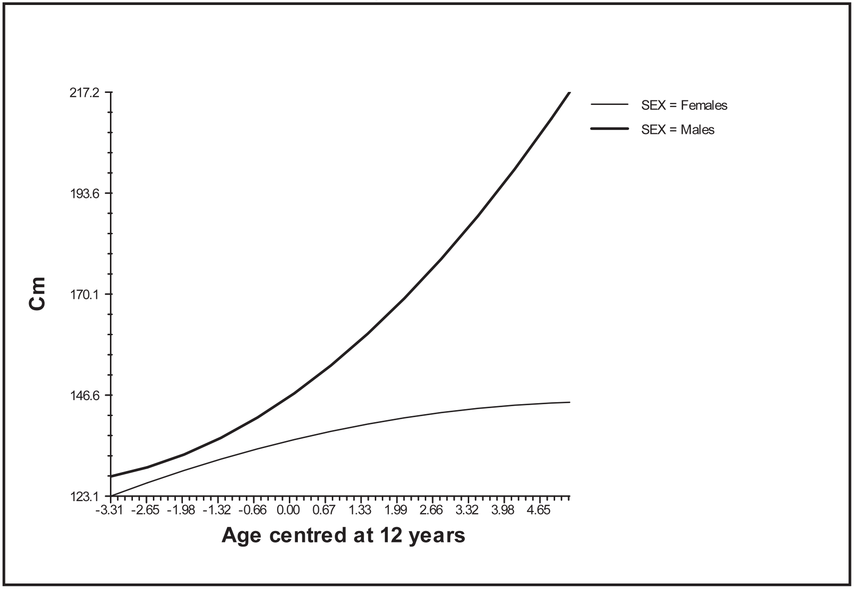
Table 3 and Figure 4 summarize information from the best fitting model with time varying and time invariant covariates. On average, a girl of 12 years jumped 137.52 (±0.85) cm. Boys performed 10.23 (±2.17) cm better. At 12 years of age, late and early maturers had a lower (-4.19 cm) performance compared to average maturers although this difference was not statistically significant. Per year, the rate of change in explosive strength in girls was 2.56 (0.86) cm/year, but in boys it was (2.56+5.68=8.24 cm). Late and early maturers did not have significant differences in the linear rate of change in SLJ. While an upward trend (quadratic effect) was not evident in girls, in boys such trend was evident (1.20±0.33 cm). No specific maturational effect were presented in the non-linear effect of SLJ changes. Subjects with higher body fat had, in longitudinal terms, a negative association (-3.41±0.69 cm) with SLJ performance, whereas total physical activity had a positive association (1.76±0.59 cm). At baseline (12 years of age), a statistically significant interindividual difference was found among subjects, and the same occurred for the linear part of power changes. At 12 years, those who performed better had also the greater rates of linear change in SLJ (r=0.25).

Table 3. Fixed and random-effects estimates for growth curve models of standing long jump..

Fixed-effects estimates	Coefficient	Standard error	T-ratio	P-value
Intercept (12 years)	137.62	1.85	74.24	< 0.001
Sex	10.23	2.27	4.51	< 0.001
Late maturers (D1)	-4.19	2.41	-1.74	0.082
Early maturers (D2)	-4.19	3.63	-1.16	0.249
Linear Slope	2.56	0.86	2.97	0.004
Sex	5.68	1.01	5.60	< 0.001
Late maturers (D1)	1.14	1.08	1.05	0.294
Early maturers (D2)	1.85	1.34	1.38	0.170
Quadratic Slope	-0.30	0.25	-1.21	0.229
Sex	1.20	0.33	3.66	< 0.001
Late maturers (D1)	0.12	0.41	0.28	0.779
Early maturers (D2)	0.12	0.48	0.25	0.807
Fatness	-3.41	0.69	-4.95	< 0.001
Total Physical Activity	1.76	0.59	2.97	0.004
Random-effects estimates	Variance component		Chi –square	P-value
Intercept	252.34		996.977	< 0.001
Linear Slope	9.02		392.046	< 0.001
Residual	113.99			
Correlation (Intercept/LinearSlope)	0.25			
Deviance	9108.67			
Parameters	18			



[panel a]



[panel b]

Figure 4. Intraindividual trajectories of all subjects for standing long jump (panel a) and average curve by sex (panel b).

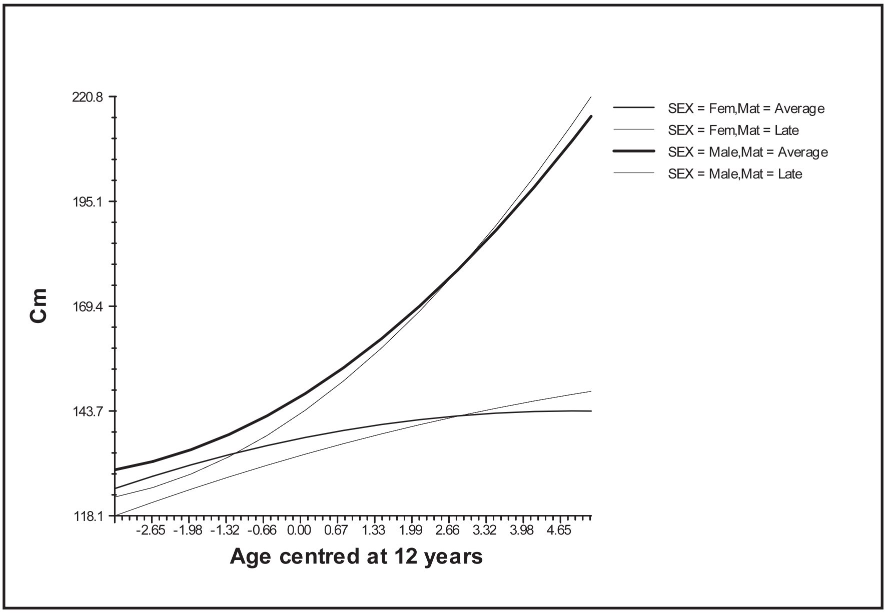


Figure 5. Srength (standing long jump) trajectories of boys and girls of contrasting maturity status: average maturers versus late maturers

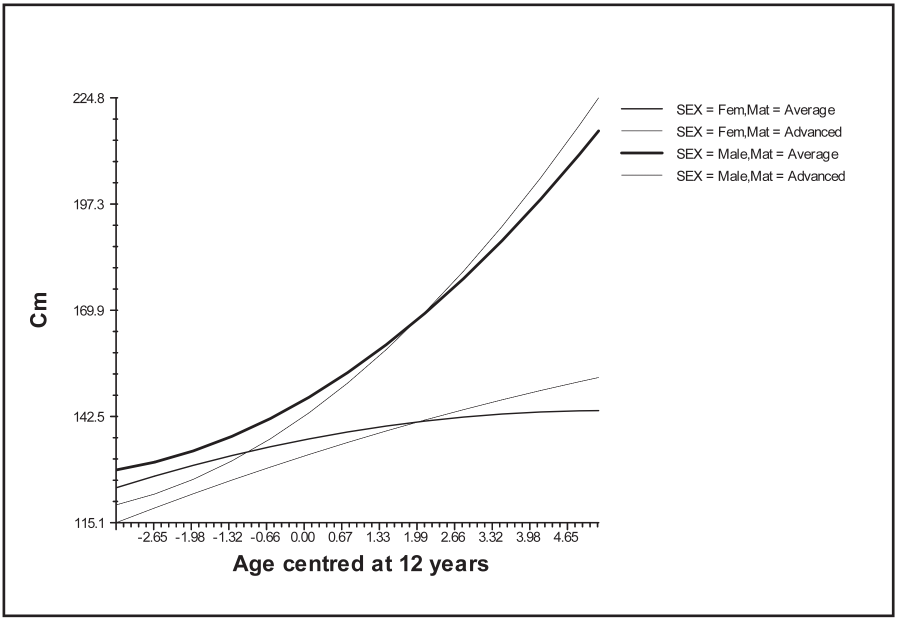


Figure 6. Srength (standing long jump) trajectories of boys and girls of contrasting maturity status: average maturers versus advanced maturers

DISCUSSION

The main aim of this study was to model longitudinal changes in strength development of children and youth from Cariri, Brazil. We also assessed the importance of physical activity levels and fatness on strength development. Furthermore, we also intended to verify the significant presence of gender, as well as, the differential effects of biological maturity in their strength trajectories.

Cariri boys were found to be stronger and jump further than girls. The growth trajectories were also different: boys had non-linear growth trajectories in static and explosive strength, while girls had linear trends. Variation at baseline, i.e., 12 years of age, is highly pronounced in standing long jump and hand grip strength, which is indicative of significant heterogeneity among subjects of both sexes in strength status; similar inter individual differences were noticed for their slopes, i.e., velocity in strength development. This variation, not only at 12 years of age, but also in strength changes may be explained by marked differences in timing and tempo of their growth spurts. Physical activity as a time-varying predictor was not independently associated with static strength, but it was associated with explosive strength (standing long jump). Fatness was a significant independent positive predictor of static strength, but it was negatively associated with explosive strength. Maturity was positively associated with static strength but not with explosive strength.

Although recent longitudinal data about strength performance in boys and girls followed from 8 to 16 years is lacking, our most important body of information relies on studies conducted some 20-30 years ago. At that time no novel statistical modeling strategies, fast algorithms and sophisticated software was available. However, highly relevant descriptions and interpretation emerged from distance and velocity curves, as well as from aligning data according to age at peak height and weight velocities. A great deal of this body of data comes primarily from USA (Branta, Haubenstricker & Seefeldt, 1984; Espenschade, 1940; Jones, 1949), Canada (Carron & Bailey, 1974) and Belgium (Beunen et al., 1988). No such longitudinal information is available in children and youth from South American countries, namely in Brazil, where socio-economic disparities are widely common (Ulijaszek, 2006; UNDP, 2009). The sex differences and growth trajectories of Brazilian youths studied herein follow closely the growth characteristics described earlier. Sex differences in strength between boys and girls become more pronounced at the beginning of the adolescent period. The marked acceleration of strength performance during the male adolescent growth spurt magnifies the sex difference which is somewhat linked to greater increases in muscle mass in males (Beunen & Malina, 1988). In the Cariri sample, average strength curves continue to increase more rapidly for boys than for girls, suggesting strength spurt in boys, but not in girls. A leveling off is to be expected earlier in girls than in boys, despite the fact that present data only cover the period till 16 years of age. Although in most growth studies data collection is usually terminated at 18 years of age, it has been shown that strength continues to increase until the third decade of life. This trend was empirically confirmed in a subsample of the longitudinal series of Belgium boys that were measured again at 30 years of age. Significant increases in strength occurred between 18 and 30 years (Lefevre et al., 1990). However, the differences among early-maturing, average-maturing and late-maturing boys in static strength vanished at 30 years. These findings emphasize the continued growth in strength of late-maturing boys and transient nature of maturity associated variation in performance during adolescence.

Physical activity as a time-varying predictor was not longitudinally associated with static strength, but was with explosive strength (standing long jump). Associations between physical fitness components in adolescent boys and girls and hours of physical activity, total daily energy expenditure, energy expenditure in moderate-to-vigorous physical activity and inactivity (television viewing time) are usually low. For example, a cross-sectional Canadian study (Katzmarzyk et al., 1998) involving 9 to 18 year-old boys and girls, provided some evidence of the relationship between several components of physical activity and physical fitness using a multivariate approach (canonical correlation). Results showed that 11% to 21% of the common variance space arise from health-related physical fitness (sit up's, static leg strength and power), physical activity and the sum of six skinfolds. However, the large amount of the variability, about 80% to 90% in health-related fitness, was not accounted for by physical activity or inactivity. Similarly, but using a different design, Belgian boys followed longitudinally for 6 years from 12 to 18 years and classified as active and inactive did not differ in static strength and power (Beunen et al., 1992). The same trend was observed in Dutch children (Verschuur, 1987) followed longitudinally from 13 to 16 years of age who were also divided in active and non active boys. No significant different trajectories among activity groups in static arm strength, sit-and-reach, vertical jump and speed of upper limb movement were identified. These result suggest that to a certain extent strength development in childhood and youth are related to normal growth and development and to a lesser degree exposure to PA.

Fatness was a significant positive predictor of static strength, but a negative predictor for explosive strength. It has been widely shown in cross sectional studies that fatness is negatively associated with the motor performance, although the magnitude of these correlation varies considerably (Malina, Bouchard & Bar-Or, 2004). It is easily understood that fat represents an inert mass that adversely affects those motor tasks that require jumping (as standing long jump), running (dashes) of lifting of the body (pull-ups).

Although differences in socio-economic status may act with a gradient spectrum in physical fitness in children and youth (Eiben & Mascie-Taylor, 2004; Sallis et al., 1996) no such trend was evident in the Cariri subjects despite the fact that this region may be best described as having a low socio-economic level when compared to others Brazilian regions or industrialized countries.

At 12 years, late maturing youngsters from Cariri are less strong (handgrip) than their advanced peers. However, in SLJ both late and early maturers did not differ significantly in the linear rate of change. These major trends in hand grip and SLJ are seen after adjustments for longitudinal association with physical activity and body fatness. It has been consistently shown that the associations (Beunen et al., 1992; Beunen et al., 1981; Malina, Bouchard & Bar-Or, 2004) between maturity and strength performance are positive during the adolescent period. In Canadian boys (Carron & Bailey, 1974), early maturers had significantly greater strength than late maturers of the same chronological age. When strength was divided by body height, results remained unchanged. However, when the effects of weight were factored out, differences disappeared. In the mixed-longitudinal sample of the Adolescent Growth Study in Oakland, California, early maturing boys were stronger at all ages than average and late maturers. In girls, early maturers tend to be slightly stronger only early in adolescence, but as adolescence continues, the differences among maturity groups are reduced (data reviewed by Malina et al, 2004). Similar results are found in Portuguese children participating in the 'Madeira Growth Study' (Freitas et al., 2002), in which 507 boys and girls were followed for three consecutive years. Boys from the early maturing group (classification based on skeletal maturity) had higher mean values in hand grip and standing long jump than either on time or late maturers. Early maturing girls showed the same trend as in boys in the hand grip, but not in the standing long jump.

Little et al. (1997) studied 61 Canadian girls aged 10 to 14 years who were followed for 3 years. Functional strength, explosive strength and static strength improved significantly with age and sexual maturation. Generally more mature girls tended to perform significantly better than the less mature for the same chronological age. The results from contrasting maturity groups have been confirmed by correlational analyses. More comprehensive analyses considering the interactions between chronological age, skeletal age, height, and weight indicate that variation in maturity status influences strength characteristics indirectly. Skeletal maturity influenced strength mainly through its interaction with body mass and height (Beunen & Malina, 2008).

Notwithstanding the data quality control, the careful design and sophisticated data analysis this study has limitations: (1) total physical activity was assessed using a self-reported questionnaire. It is possible that subjects do not recall their activities accurately. To minimize this possible bias the questionnaire was completed with the assistance of a trained interviewer. This allows a higher reliability than self-reported methods in children (Corder et al., 2008); (2) the difficulty of comparisons of present data with other state or national studies, due to the absence of longitudinal information about strength performance of schoolchildren in South America. Despite these limitations, the study was driven by important factors that we consider relevant: (1) the sample size and representativeness in terms of age groups and sex; (2) biological age was estimated by a trained observer and use of the latest version of TW3 Method; and (3) the statistical analysis technique to fit strength curves using time-varying and invariant covariates.

In summary, strength increases differently in boys (non linear) and in girls (linear). At 12 years, marked interindividual differences are observed in both sexes. Biological maturity is significantly different only in static strength. Physical activity is a significant predictor only in SLJ; fatness is significantly associated to static strength development, although is negatively linked to explosive strength.

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ROBERT M MALINA: CONTRIBUTIONS TO THE STUDY OF PHYSICAL GROWTH, DEVELOPMENT, AND PERFORMACE IN BRAZIL

Maria Beatriz Rocha Ferreira

INTRODUCTION

It is a great pleasure to contribute to this volume in honor of Professor Robert M. Malina. His knowledge, wisdom and teachings were significant in determining my own professional career. This tribute highlights his professional ethics, systematic thinking in research, organization and accuracy of information, and friendship. These are several of his numerous gifts and the legacy that he has given to his students.

I met Professor Malina in Brazil in 1978 during a sports medicine conference in São Paulo. He made a significant impression on me. After that, I entered the Masters program at the Faculty of Physical Education at the State University of São Paulo (USP) where I conducted research on nutritional status and physical fitness in preschool children under the supervision of Miguel Zucas.

When the opportunity presented itself to pursue doctoral studies overseas, there was no doubt about my choice to study in the Department of Anthropology at the University of Texas, Austin, under Malina's supervision. It was dream come true. I started the PhD in 1982. It was an exciting and challenging experience, and I was always able to count on the support and guidance of Professor Malina.

His courses on Human Physical Growth and Development, Human Adaptability, Introduction to Graduate Physical Anthropology, and Human Adaptation and Evolution were superb and unique. With earned Ph.D. degrees in Physical Education and Anthropology, he was able to combine both fields in his courses and teaching. The subjects were always well structured and extremely well presented. My vision of the world changed with the knowledge that I acquired in his classes and research projects associated with courses taught by other professors at the University of Texas, such as Social Anthropology, Linguistics, Archeology, and Health and Nutrition in Latin America. Upon completing of my Ph.D in 1987, I have had the privilege of remaining in touch with Professor Malina and discussing research projects together.

Professor Malina is a world reknowned scholar and researcher. He has many hallmarks. As a professor and research adviser, he taught his students how to focus research goals clearly, conduct critical and precise literature reviews, select the appropriate variables and measurements to address the question, study and clean the data after collection; select the appropriate statistics, present the data, interpret results in light of the available literature, and write accurately. I have never seen anyone with the same capability to pick out a mistake among thousands of numbers and to know the exact page number of a bibliographical reference. His ability to synthesize is outstanding.

The first experience participating in a research team with him and other students was in a study of menstrual synchrony: "Environmental influences cause menstrual synchrony, not pheromones" (Little et al., 1989). To assess this influence we conducted a longitudinal study of 127 university students living in several houses surrounding a central courtyard. The results suggested that common environmental influences play an important role in the overall pattern of menstrual cyclicity.

MALNUTRITON, PHYSICAL PERFORMANCE IN CHILDREN AND YOUTH

Professor Malina's knowledge and teachings on human biology and human variation touched me deeply. I have chosen to focus on a subject that Malina has written extensively about and that influenced my own professional life: the study of growth and development, motor development and performance, physical activity, and undernutrition in young children, in addition to socio-cultural and economic circumstances. Subsequently, the role of his research and thoughts in guiding studies and research under my supervision at the State University of Campinas (UNICAMP) is considered.

In the 1980s, protein energy malnutrition (PEM) and its relationships with low socioeconomic status was one of the main public health problems in underdeveloped areas of Brazil. This focus influenced my option to develop research in this area.

Perceptions of malnutrition vary according to cultural circumstances. In Western societies, it is a biomedical entity but with socioeconomic implications, while in the non-western world the focus is more often centered on cultural interpretations and to a lesser extent diet as a primary cause of the condition (Cassidy, 1982). Variability in the timing, severity and duration of dietary deficiencies, different methodologies and ambiguity in terminology, and general unfamiliarity with the etiology of malnutrition make it difficult at times to obtain a consensus among scholars on the specifics of PEM and its effects. However, Professor Malina´s ability to synthesize information enabled his students to compare and interpret the findings (Malina, 1986, Malina et al., 1985, 1987).

PEM can seriously damage health of the individual. The most common consequences are stunted physical growth, reduced muscle mass, delayed maturation of the nervous system and motor development, decreased physical performance, decreased maximal oxygen consumption, delayed or perhaps impaired learning ability, increased susceptibility to infectious diseases, and elevated mortality (Spurr, 1993, Malina, 1981, Malina et al., 1981, 1990).

His paper (Malina, 1990), "Growth of Latin American children: Socioeconomic, urban-rural and secular comparisons," showed that trends in the growth status of low-income children in Latin America were consistent with those observed in other areas of the world. Children from low socioeconomic classes tended to be shorter, weigh less, and have reduced estimated muscle mass.

The relationship between undernutrition and physical performance has been another topic of his studies. Body size and proportions, physique, and body composition are related to physical performance. In particular, height and weight, together with age and sex, have been used to classify children and adolescents in various kinds of physical capacities (Malina, 1983, 1984, 1985, 1986, Malina et al., 1985, 1991, 2011, Peña Reyes at al., 2003a).

Changes in body composition, especially reduced lean body mass and muscle mass, may significantly affect performance. Reduced muscle mass in an undernourished individual is probably related to reduction in static and dynamic muscle strength, which may subsequently influence performance of other motor tasks (Malina, 1984, Malina et al. 1985, 1991). However, data showing this phenomenon are inconsistent among samples. For example, the correlation between grip strength and estimated body composition was low in mild to moderately undernourished Zapotec children in rural Mexico (Malina and Little, 1984), but was higher in undernourshided Manus children in Pere village, Papua New Guinea (Malina, 1986, Malina et al 1987).

My doctoral thesis under his supervision, "Growth, Physical Performance and Psychological Characteristics of Eight Year Old Brazilian School Children from Lower and Upper Socioeconomic Background," was a significant contribution to the area due to the diverse set of variables (Rocha Ferreira, 1987). The results pointed to the same pattern identified in Malina's studies (1994, 1995), i.e., children from lower SES tend to be shorter and leaner, and to have poor physical performance and psychological characteristics. The exception of better results for the 9-minute-run can be explained by the lifestype of low socioenomic children. They walked to school and played in the street, and some of them lived on steep hills and therefore exerted greater physical effort to go to school, in contrast to the upper SES children, who tend to go everywhere by car (Rocha Ferreira, 1987, Rocha Ferreira, et al. 1991). Indeed, in his Oaxaca studies, stunted children did not differ from normal weight children in a distance run of either 8 or 12 minutes (Malina et al., 2011).

The logistics and structure of the research carried out under Malina's supervision laid the groundwork for my future field research in Brazil. I became a Professor in the Faculty of Physical Education at UNICAMP and created the Laboratory of Biocultural Anthropology (1988-2012).

In the 1980s, 1990s and 2000s, Malina visited Brazil on several occasions and had an unbelievable influence upon teaching and advising students. He presented short courses on Growth and Development at the Faculty of Physical Education and the Faculty of Medical Sciences of UNICAMP and also at the School of Physical Education and Sports of the State University of São Paulo (USP), and conferences at several international sports science symposia hosted by the Center for the Study of the Physical Fitness Research Laboratory of São Caetano do Sul (CELAFISCS). The logic of his thinking, knowledge, and interpretation of the research influenced students and faculty and subsequent theses, dissertations and other publications in Brazil. During one of his visits, the Department of Adapted Physical Education at UNICAMP asked him to make a contribution in the area of adapted physical education. Although this was not his major focus of study, he lectured on the subject, and his teachings and writings are still important references.

LABORATORY OF BIOCULTURAL ANTHROPOLOGY

Over the past twenty years, the Laboratory has conducted studies focusing on child growth and development from a biocultural view. The research developed in this Lab is associated with the Graduate Program of the Faculty of Physical Education and the Faculty of Medical Sciences – Child and Adolescent Health, at UNICAMP. Dr. Malina's influences can be observed in the projects, theses and dissertations developed in the Laboratory, several of which are subsequently summarized.

Malnutrition and growth

The research conducted with preschool children from 4 to 6 years of age in different regions followed the same research design and produced similar findings as studies referenced by Malina. Research conducted with low-income children aged 4 to 6 years old in the cities of São Paulo (Rocha Ferreira and Zucas, 1981), São José dos Campos (Rocha Ferreira and Rocha, 1993, 1988), Limeira (Kube, 1995), Holambra (Eilert, 1997), Itapira (Arruda, 1997), and Ilhabela – 1989-1995 (Prado, 2000). Similar methods were used in the studies: anthropometry, motor tests and parent interviews or questionnaires dealing with socioeconomic status of the family, physical activity and infant feeding. Overall, the findings indicated similarities in patterns of growth and motor performance in the context of local social structure.

Although the cities varied with respect to population and geographical location, the conditions of diet, health, lifestyle and socioeconomic class were similar. For the preschool children, anthropometric dimensions depended largely on family social and cultural circumstances of the family interacting with susceptibility to infectious diseases and malnutrition among others factors.

The results were similar among studies. Boys performed better in motor tests than girls. Lack of physical (movement) activity among girls partially explained the poorer motor performances. Low-to-moderate correlations suggested that motor performance was not highly dependent on body weight and stature. The low correlations and differences in direction were likely explained by the different backgrounds of the children (Rocha Ferreira et al, 1998). To better understand the relationship between body dimensions and performance, second order correlations, controlling for age and either stature or weight were used. Movements in which the body was projected (standing long jump and dashes) tended to have low negative correlations with body weight. Stature, when age and weight are controlled, had a positive correlation with jumping, agility, sit-ups, and speed. Stature as a proxy of overall body size and to some extent biological maturation suggests that the more mature children had better motor performances.

From the perspective of family structure, physical activity of children was associated with the habits of parents or other adults with whom they lived or interacted regularly. Lack of physical activity in and out of school, and sedentary lifestyle due to lack of opportunities and/or safe environments interfered with the full development of movement skills, i.e., coordination, agility, speed, strength, motor learning, and so on. The young child is essentially active and requires appropriate conditions of health and education to optimize growth and development (Rocha Ferreira and Rocha 1993, 1988).

In the academic year 1997-1998, I was Visiting Professor at the Catholic University of Leuven and had the good fortune to interact with Gaston Beunen and Roland Renson. Malina made a short visit to Leuven, and we exchanged various ideas about my research topics. One of the high points of my time at Leuven was the ceremony of Honoris Causa for Claude Bourchard, a former student of Professor Malina.

The interdisciplinary research of Professors Renson and Beunen over several years Belgium was extremely important for the continuity of my career and research pursuits. It was a turning point that encouraged me to develop reseach focusing on cultural studies with indigenous peoples relative to biological factors. This results in the development of another research sub-area in the Laboratory of Biocultural Antrhopology at UNICAMP.

In studies of indigenous children in Oaxaca, Malina, colleagues and former students (Malina et al., 1981, Malina and Little, 1984, Malina and Buschang, 1985, Peña Reyes et al., 2003a. 2003b, among others) made significant contributions in the development of the laboratory and were fundamental to the doctoral dissertation of Tagliari (2006), "Growth, Physical Activity, Performance and Food Intake in 8 and 9 year old School Children in Rural, Urban and Indigenous Land in Paraná." Moreover, the opportunity to exchange ideas with Malina during his stay in São Paulo was important to the analysis of the data. Children living in rural and urban areas were heavier, taller, and had greater bone diameters, circumferences and skinfolds than those living on indigenous lands. These data were similar to observations of Oaxaca children (Peña Reyes et al., 2003a, 2003b).

Physical activities, games and entertainment were similar among the urban, rural and indigenous groups, while work activities were more frequent among indigenous youth.

Indigenous children tend to have higher scores on accelerometer measurements of physical activity. Rural and urban children, on the other hand, had better scores on performance tests, except for the sit and reach flexibility test, even when controlling for age, weight and height (Tagliari, 2006).

Indigenous children were also grouped on the basis of stature related to age, group 1 (< - 2 z score) and group 2 (> - 2 z scores). Children in Group 1 were, as expected, shorter, but were also leaner and had lower performance results and physical activity levels than children in Group 2. Children of both sexes in Group 1 also tended to come from households with lower income and with mothers having fewer years of schooling compared with Group 2. The results showed a social gradient in the indigenous land and its impact on growth, motor performance and physical activity of children. The characteristics of the indigenous socio-cultural context studied appeared to be less favorable for children with a possible growth deficit, thus contributing to less favorable development compared to other children in the same indigenous area and in rural and urban areas. The possible influence of genetic factors to variation in growth status between indigenous and non-indigenous children should be noted.

Nutritional transition

The decrease in the prevalence of child stunting and wasting and the rapid increase in overweight and obesity is a current public health problem in the world. This nutritional transition, which is associated with the growing prevalence of chronic diseases in the adult population, is evident in different areas in Brazil, particularly among in the low-income population (Monteiro, 1995, Batista Filho and Rissin, 2003). Children are showing lower rates of physical activity, increasingly sedentary lifestyles, poor quality of diet, and increased prevalence of obesity, especially in urban centers.

Research conducted by Bracco (2001) and Bracco et al (2002) was influenced by discussions with Malina during another visit to São Paulo. The aim of the study was to compare the physical activity profile, energy expenditure from physical activity, and energy intake of children of both sexes in a low socioeconomic school population in the city of São Paulo. The results showed that even in a low socioeconomic population, obesity was more prevalent among children than stunting and wasting, pointing to the nutritional transition process. Higher energy expenditure from physical activity (reflecting their larger body sizes) but less time in physical activity was noted in obese children. Moreover, the obese also presented higher total energy intake and carbohydrate ingestion than non-obese children.

Longitudinal research by Figueira Junior (2009) compared physical activity level, physical fitness, and socio-cultural factors in adolescents in Santo André (metropolitan city) and São Bento do Sapucaí (rural town) in 1997 and 2007. The number of active adolescents increased in 2007 compared to 1997 in both regions and sexes. Muscular strength also increased for both groups between periods. The same trend was observed for agility and trunk strength. Walking as health-related locomotion, positively contributed to total physical activity. Barriers to physical activity were greater in Santo André than in Sao Bento do Sapucaí in both years (2007 and 1997). The most common barriers to the practice physical activity in both years were shame of feeling overweight, lack of parent stimulus and lack of appropriate space (Figueira Junior, 2000, 2009). Multivariate regression showed that participation in physical education classes and siblings walking or riding a bike to or from school were variables that may favor physical activity in both regions.

In summary, Malina's contributions to studies on growth, development, maturation and physical activity in children and adolescents were immense and influenced many others in the field. I was also impressed by his dedication to youth as a baseball and soccer coach for his children and their friends. After his work at the University of Texas, I often noticed him spending afternoons coaching. I had the opportunity to enjoy some of these moments with him and his family. Morever, I thank him, Eva, and the children for the Easter holiday gatherings, which I remember with great fondness.

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IMPACT OF ELEVATED BLOOD LEAD ON GROWTH, MATURATION AND PHYSICAL FITNESS: RESEARCH IN THE COPPER BASIN OF SOUTHWESTERN POLAND

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INTRODUCTION*:*
Lead and Child Growth, Development, and Maturation

Environmental pollutants and toxicants associated with industry and power generation and have potentially negative consequences for the growth, maturation and development of youth. Lead is one of a variety of toxicants with such potential effects. Lead and lead compounds are common in the earth's crust, ~70 ppm (Baselt, 2002) and are associated with power generation and several industrial processes. Lead and lead-compounds are well-known to be toxic to developing humans, causing growth retardation, delayed sexual maturation and neurobehavioral developmental deficits.

Lead and Growth. Elevated levels of blood lead adversely affect prenatal growth (Andrews et al., 1994; Dietrich et al., 1987), but this has not been noted in all studies (McMichael et al., 1986; Factor-Litvak et al., 1991). A frequent finding among children is reduced length/stature in association with increased blood lead levels. Age at exposure, duration, and nutritional status are related to the degree of growth stunting, with younger, chronically exposed, undernourished children at greatest risk (Ballew et al., 1999). The estimated stunting effect of blood lead level on linear growth appears to follow a dose-related pattern of reduction in height by ~1-3 cm for each 10.0 μg/dL increase in blood lead level (Table 1).

Lead and Maturation. Information on the influence of elevated blood lead levels on indicators of biological maturation commonly used in growth studies is limited largely to age at menarche and to a lesser extent stages of puberty (breast and pubic hair development in girls, genital and pubic hair development in boys).

Table 1. Estimated decrements in height per 10 μg/dL blood lead levels in children 3 months (mos) to 14 years (yrs).

Study	Age range	Stature decrement
Cincinnati Lead Study (Shukla et al., 1989)	3 - 5 mos	2.0 cm
Cincinnati Lead Study (Shukla et al., 1991)	33 mos	1.5 cm
Dallas Lead Project I (Little et al., 1990)	1 - 10 yrs	1.6 cm
Dallas Lead Project II (Little et al., 2009)	2 - 12 yrs	2.1 cm
Three Greek Cities (Kafourou et al., 1997)	6 - 9 yrs	0.9 cm
NHANES II (Schwartz et al., 1986)	1 - 7 yrs	1.2 cm
NHANES III (Ballew et al., 1999)	1 - 7 yrs	1.6 cm
Lower Silesia, Poland (Ignasiak et al., 2006)	7 - 14 yrs	3.1 cm
Unweighted Mean	3 mos - 14 yrs	2.5 cm

Blood lead levels > 3 μg/dL were associated with later estimated attainment of stages of breast and pubic hair maturation in American girls from the Third National Health and Nutrition Examination Survey, 1988-1994 (NHANES III). Later attainment of stages of puberty was most apparent in American Black girls and to a lesser extent in Mexican American girls with ≤ 3.0 μg/dL of blood lead compared to those with >3.0 μg/dL. Later pubertal maturation was noted in American White girls with 3.0 μg/dL of blood lead, but the effect was not significant (Selevan et al., 2003). Corresponding data for lead levels and sexual maturation of boys are limited to a prospective study of testicular volume and stages of pubic hair and genital maturation in Russian boys. Later onset of puberty was associated with blood lead levels ≥5.0 μg/dL compared to boys with <5.0 μg/dL (Hauser et al., 2008; Williams et al., 2011).

Data for age at menarche and blood lead level are limited to three investigations. Two analyses were of the same national data set for American girls from NHANES III (Selevan et al., 2003; Wu et al., 2003), and one of American Indian girls (Denham et al., 2005). The two analyses of NHANES III data showed delayed menarche with elevated blood lead levels in American girls. In one analysis, menarche was delayed by approximately 3.6 months for each 1.0 μg/dL increase in blood lead > 3.0 μg/dL (Wu et al., 2003). In the other analysis, menarcheal age was also delayed by 3.6 months with blood lead concentrations > 3.0 μg/dL in African American girls. However, blood lead and later menarche was not statistically significant in American White and Mexican American girls with lead concentrations > 3.0 μg/dL (Selevan et al., 2003). Menarche was delayed at blood lead levels >0.5 μg/dL (geometric mean) among American Indian (Akwesasne Mohawk) girls (Denham et al., 2005). This study was unique because the analysis controlled for other pollutants (*p,p'*-DDE, HCB, mirex and mercury) in addition to lead. In contrast to lead, four potentially estrogenic PCB congeners were associated with a higher probability of having attained menarche in this sample of American Indian girls (Denham et al., 2005), indicating earlier attainment of menarche with higher PCB levels. Importantly, the association of blood lead level with age at menarche is likely confounded by other toxicants in the blood.

Lead and Motor Proficiency. Elevated blood lead levels are associated with impaired performances on tests of fine motor coordination and visual integration in children. Specifically, movement tasks that involve movement precision and coordination are adversely affected by elevated blood lead levels. Among 6 year old children, for example, elevated blood lead levels had a negative effect visual-motor control, bilateral coordination, upper limb speed of movement, dexterity and fine motor coordination (Dietrich et al., 1993), and on finger tapping speed (Winneke et al., 1994). Visual-motor integration, eye-hand coordination and spatial relations performance was poorer among 8-10 year old children with increased blood lead levels (Azcuno-Cruz et al., 2000). Of interest, high lead levels in dentin of deciduous teeth (i.e., in early childhood) were also associated with long term deficits in finger tapping rate (slower), eye-hand coordination (poorer) and reaction time (slower) at 18 years of age (Needleman et al., 1990). Neurobehavioral deficits associated with elevated blood lead levels persist across age and are apparently irreversible.

With few exceptions, tasks requiring muscular strength and endurance, speed, power, balance and coordination in gross movement tasks have not been systematically evaluated in children and adolescents with elevated blood lead levels. Gross balance at 6 years of age (Dietrich et al., 1993) and performance on rail balance tests at 8-10 years of age (Azcuna-Cruz et al., 1970) were not influenced by blood lead levels. Elevated blood lead levels were negatively associated with teacher ratings of agility defined as "…the ability to execute motor activities such as running and jumping with precision and rapidity," in 7-9 year old children (Muñoz et al., 1993). Increased postural sway in children was associated with elevated blood lead levels (Battacharya et al., 1990, 1993), but the association between postural sway and balance was not analyzed. If postural sway is analyzed with respect to dynamic and static balance, these results may suggest a potential influence of early lead exposure on the vestibular system and/or proprioception. Elevated blood lead was also associated with hearing deficits in children (Osman et al., 1999). Apparently lead affects middle ear function (i.e., otolithic and vestibular complexes).

THE COPPER BASIN – RECENT WORK ON LEAD EFFECTS ON CHILDREN BY MALINA AND COLLEAGUES

The copper mine region in Lower Silesia, southwestern Poland, has major smelting and refinery facilities near Legnica and Głogów, the Copper Basin (Figure 1). Mines and smelting plants associated with the copper industry generate large amounts of industrial by-products and waste including heavy metals, including lead. Copper mining and smelting has been a primary industrial activity for about two generations or more in Lower Silesia.

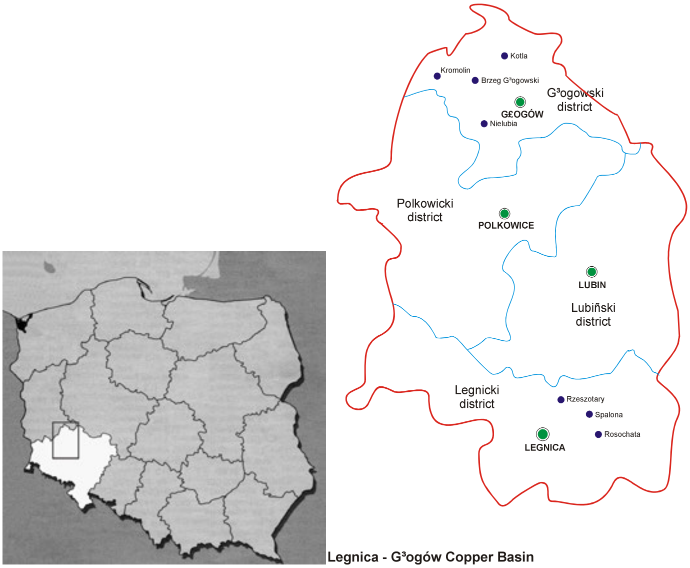

Figure 1. Map of Poland showing (a) the region and (b) the location of the study communities. (Adapted from Ignasiak et al., 2006; License 3156030919163, content publisher: Informa Healthcare, content publication: Annals of Human Biology)

Recent intensive environmental interventions by the Polish government have reduced emissions of harmful substances in areas with potential health hazards (Ignasiak et al., 2011). Interventions were targeted to maximize health-related benefits return on investment for the population resident in or close to the industrial zones (Bachowski et al., 2004). Observations from studies of the influence of elevated blood lead levels associated with industrial pollution in the Copper Basin on the growth, maturation and physical fitness of school children in the region have been conducted by Malina and colleagues (Ignasiak, Sławińska, Little).

The growth status, physical fitness and blood lead levels of school children, 7-15 years of age were surveyed in 1995 and 2007. Menarcheal status of girls was obtained by interview in both years. The children resided in seven communities (officially labeled villages) in the vicinity of major copper smelting and refinery facilities in the Legnica and Głogów districts. With two exceptions, schools in the same communities were surveyed in both years. Population sizes of the communities ranged from 337 to 1424 in 1995 and 266 to 1400 in 2007. All children were born and raised in the area. They were from families of mine and factory workers in the copper industry and farmers in the communities. The latter were largely part-time farmers with <10 hectares of land; most worked in the copper industry and only tended the farms after work and on weekends.

Relationships between blood lead levels and growth status are limited to the 1995 data (Ignasiak et al., 2006, 2007). Analyses of the 2007 data for growth status and physical fitness in the context of short-term secular change are currently under way. Changes in blood lead levels and ages at menarche between 1995 and 2007 have been analyzed (Ignasiak et al., 2011; Sławińska et al., 2012).

Growth Status

Reduced height was associated with elevated blood lead levels in school children of the Copper Basin observed in 1995 (Ignaziak et al., 2006). The negative effects of elevated blood lead were more apparent in growth of the extremities (arms, estimated leg length) than in growth of the trunk. Greater reductions in linear growth were observed at higher blood lead levels. The observations were consistent with experimental data suggesting a major influence of lead on linear bone growth, specifically proliferation of chondrocytes, hypertrophy and matrix calcification at the growth plates of long bones (Hicks et al., 1996). Other potential targets for lead are reduced osteoblast activity and bone remodeling (Puzas et al., 1992). It was deduced from these analyses that the effect of lead was on long bone growth than upon round bones (Ignasiak et al., 2006).

Physical Fitness

Relationships between blood lead levels and measures of physical fitness in the school were evaluated in the context of two research questions (Ignasiak et al., 2007). Are indicators of physical fitness directly related to blood lead levels? Alternatively, is physical fitness indirectly affected through reduced body size given the influence of elevated lead on linear growth? Smaller body size is generally associated with poorer performances on a variety of physical fitness tests in youth (Malina et al., 2004).

School children of both sexes from the Copper Basin in 1995 were on, average, shorter than Polish youth in a 1999 national physical fitness survey (Przewęda et al., 2005). Children from the Copper Basin also tended to weigh slightly less than the national sample between 7 and 11 years, while differences were negligible at older ages.

Several indicators of physical fitness were measured using the EUROFIT battery (Council of Europe, 1988): right and left grip (static strength), sit-ups in 30 seconds (abdominal muscular strength and endurance), flexed arm hang (upper body functional strength), plate tapping (speed of upper limb movement), shuttle run (running speed and agility), standing long jump (explosive power of the lower extremities) and medicine ball throw (explosive power of the upper extremities). Simple reaction time was measured in a subsample.

Standing long jump performances of boys and girls from the Copper Basin were, on average, slightly lower than those of the national sample from 7-13 years, while differences at 14-15 years were negligible. A similar age-related pattern was apparent for speed of upper limb movement (plate tapping). Performances in an agility shuttle run did not differ, on average, between children of both sexes in the Copper Basin and the national sample. In contrast, the number of sit-ups completed in 30 seconds was consistently lower in Copper Basin children of both sexes across the age range 7-15 years. Grip strength was, on average, greater in boys and girls from the Copper Basin than in the national sample. However, this comparison must be tempered because it was not clear what type of dynamometer was used in the national survey.

Results of regression and path analyses indicated that blood lead level did not directly affect the physical fitness of the school youth from the Copper Basin (Ignasiak et al., 2007). The effects of blood lead on indicators of physical fitness were indirect through a negative influence of high blood lead on growth in body size. Blood lead level was also not related with reaction time in the subsample of children. However, diet and family circumstances (except for maternal education) and level of habitual physical activity were not considered. Nutritional status and familial factors can independently influence both growth and physical fitness, while physical activity is an important correlate of fitness (Malina et al., 2004).

Age at Menarche

Age at menarche and blood lead levels were considered in the two surveys of school girls separated by 12 years, 1995 and 2007 (Slawinska et al., 2012). Blood lead level and age at menarche (estimated with probit analysis) declined, on average, over this interval (Table 2). Logistic regression analyses were done for each year with menstrual status (0 = no, 1 = yes) as the dependent variable and with age, height (linear growth), BMI (weight-for-height), and lead group (binary variable, $0 = Pb \leq 5.00$ and $1 = Pb \geq 5.10$ μg/dL) as the independent variables. The odds ratio for 1995 was not significant ($p<0.48$) indicating that lead group did not affect the odds of a girl attaining menarche. However, the odds ratio for 2007 approached significance ($p=0.057$). This indicates that increased blood lead was associated with later menarche (decreased odds of attaining menarche) in 2007.

Table 2. Blood lead levels and ages at menarche in school girls resident in the Copper Basin of Lower Silesia, Poland in 1995 and 2007.[1]

		Blood Lead Level, μg/dL		Age at menarche	
Year	N	Mean	SE	Median	SD
1995	436	6.57	0.13	14.36	1.16
2007	346	4.24	0.14	12.73	1.22

[1] Adapted from Sławińska et al. (2012)

The major difference in the specific logistic regression analyses of the two time periods (1995 vs. 2005) was in the contributions of the covariate BMI and the main effect (blood lead group) to the probability of attaining menarche. The BMI was less important to attaining menarche in 2007 (OR = 1.18, 95% CI: 1.03-1.35) than in 1995 (OR = 1.51, 95% CI: 1.26-1.82). The opposite was true for lead, which had a smaller effect in 1995 (OR = 0.70, 95% CI: 0.27-1.85) than in 2007 (OR = 0.31, 95% CI: 0.09-1.06). It may be possible that the influence of blood lead on menarche in 1995 was through its effect on weight-for-height (BMI). The decline in age at menarche between 1995 and 2007 may thus reflect attenuation of multiple environmental stressors (chronic malnutrition, iron and calcium intake deficiencies) in addition to blood lead level. It may be possible that somewhat marginal nutritional and health conditions associated with unstable political, social and economic circumstances in Poland from the late 1970s through the 1980s (girls in the 1995 sample were born during this period) confounding the influence of lead on the process of sexual maturation in the 1995 sample such that a significant effect of lead on age at menarche was masked or diminished to statistically non-significant.

Observations for girls in the Copper Basin in 1995 beg the following question. Given the elevated blood lead levels in the sample, why was an association between lead levels and age at menarche not observed in 1995? The broad range of blood lead values (2.0-33.9 μg/dL) contributed to unusually wide 95% confidence intervals and in turn a non-significant association. A much larger sample size was likely needed to sufficiently power the 1995 analyses to detect the influence of lead level on menarcheal status to reach statistical significance.

However, comparisons of estimated ages at menarche in subsamples of girls with high (≥5.1 μg/dL) and low (≤5.0 μg/dL) blood lead levels in each year provide some insights. The difference between estimated median ages at menarche (probit analysis) for girls with high and low blood lead levels in 1995 was 0.35 years, while that between estimated medians ages in 2007 was 0.69 years, an effective doubling of the difference in the latter time period. The difference between estimates of menarcheal age in 1995 was slightly greater than that noted in rural girls with inadequate vs. adequate nutrition in the 1970s, 0.2 years (Charzewska et al., 1976). The secular decline between 1995 and 2007 was due in large part to a reduction in age at menarche in girls with low blood lead group in 2007 compared to girls with low blood lead in 1995 (0.49 years), while the difference in ages at menarche in girls with high lead in both years was small (0.15 years). This implies that other environmental conditions (i.e., nutritional) among girls with low blood lead levels (≤ 5μg/dL), improved more than among girls in the high blood lead level group. As suggested earlier, the effect of blood lead level seems confounded by socioeconomic variation, which apparently exerts a strong effect on age at menarche in the sample of Polish school girls who grew up before and after the fall of communism, 1995 and 2007 cohorts, respectively.

CONDITIONS IN POLAND

Synthesis of these data indicate that environmental and economic conditions of the 1980s (birth years of boys and girls in the 1995 survey) may be quite strong confounders in the relationship between blood lead level and sexual maturation and growth status. The decade between 1978 and 1988 in Poland was characterized by political turmoil and eventual changes (i.e., decline of communism) which had major economic and social consequences. National and regional surveys of the growth and maturation of Polish children and adolescents suggested unstable health and nutritional conditions in the 1970s and 1980s, i.e., prior to and during the turmoil associated with the fall of communism (Bielicki and Hulanicka, 1998). Inadequate nutrition indexed by regularity of meals, estimated intakes of specific nutrients and clinical symptoms of nutritional deficits were often noted in Poland during the 1970s, especially among children from rural areas and children of semiskilled manual workers (Konieczna, 1977).

Specific information on dietary calcium and iron (both of which are chemically similar to lead) in the villages surveyed in the Copper Basin during the 1980s and early 1990s is not available. Limited data indicated comparatively lower dietary intakes of calcium and iron than recommended in rural vs. urban adolescent Polish girls (Charzewska et al., 2006). It is reasonable to assume that the trends apply to girls resident in the villages surveyed in the Copper Basin. Among adolescents and young adults 13-25 years in Glogów and Lubin in 1995, dietary calcium approximated only 45% and 62% of recommended daily intake, respectively. Similarly, intakes of females relative to the norms were lower than those of males of the same age (Charzewska et al., 2006). Iron intakes of school girls in Glogów and Lubin in 1995 were, respectively, 64% and 75% of the recommended level. In contrast, corresponding estimates for boys were higher than recommended. Estimated iron intakes for random samples of girls 11-15 years resident in villages throughout Poland were 79% of recommended in 1995, while for random samples of girls 11-18 years in several specific regions of Poland in the late 1990s varied between 62% and 67% of recommended values (Charzewska et al., 2006). A synergistic interaction between lead levels and marginal nutritional conditions may explain the large but statistically not significant effect of elevated blood lead on menarche noted in the 1995 survey.

Differential effects of lead on linear growth and sexual maturation have also been suggested (Wu et al., 2003). Height of the total sample of girls and boys in the 1995 survey significantly decreased with increasing blood lead levels (Ignasiak et al., 2006). As noted, some experimental data have suggested an influence of lead on the proliferation of chondrocytes, hypertrophy and matrix calcification at the growth plates of long bones and in turn on linear bone growth (Hicks et al., 1996). Data from the 1995 survey parallel these experimental data, and suggest a greater effect of lead on long bone growth compared to round bones. Notably, lead effects on bone growth are cumulative over time. Menarche, in contrast, is a single point in time and ages at menarche based on status quo surveys (as in the surveys in the Copper Basin) are sample estimates. Specific information dealing with the effects of elevated blood lead on neuroendocrine processes leading to delayed onset of menses is lacking, but available data suggest lead interrupts neuroendocrine functions. Marginal nutritional status and suboptimal calcium and iron intakes may be exacerbate factors that confound the influence of elevated lead on menarcheal status. These effects may operate through socioeconomic status, which is known to be highly correlated with blood lead levels (Ballew et al., 1999).

It is clear that improved health, nutritional and general living conditions, decreased environmental exposure to lead and better socioeconomic conditions in the Copper Basin between 1995 and 2007 contributed to a reduction in the age at menarche. It is difficult, however, to partition the secular decline in age at menarche associated with improved living conditions from the decline in blood lead levels between 1995 and 2007. As noted earlier, the analysis of secular change in growth status is currently in process.

An indicator of maturity status was not available for boys from the Copper Basin. It is reasonable to assume similar secular changes among males because blood lead levels also declined significantly in boys (Ignasiak et al., 2011). Importantly, percentages of youth with blood lead levels ≥ 6 μg/dL were higher in boys than girls in both years (1995, 77% vs 52%; 2007, 33% vs 17%). However, it is important to note that Poland instituted a requirement for catalytic converters on all cars produced since 1995, and this has contributed to the decrease in blood lead levels. But the magnitude of the contribution of this to decreased blood lead levels is unknown.

Unfortunately, data on uptake of lead and other toxicants by food crops grown in lead-tainted soil and perhaps on the nutrient quality of crops were not available. Moreover, other potential toxicants in the blood were not considered. In addition to lead, age at menarche was sensitive to several polychlorinated biphenyl (PCBs) congeners in a sample of Akwesasne Mohawk girls described earlier (Denham et al., 2005). On the whole, the results highlight the need to expand future studies to include simultaneous analysis of other toxicants that may influence the process of sexual maturation, growth, and development.

CONCLUSIONS

In 2012 the United States Centers for Disease Control and Prevention (CDC) lowered the blood lead level for medical intervention in children from10 μg/dL to 5 μg/dL (American Academy of Pediatrics, 2012). This was a welcome change as it is clear from human investigations that adverse effects on growth and sexual maturation are detectable at blood lead levels <10 μg/dL. Children in the Polish Copper Basin (Lower Silesia) have responded in an expected fashion to reduced environmental lead burden. The question remains, however, whether or not lead effects are a threshold effect or a dose-response effect. Most data suggest there may be no safe level for lead as there is no safe level for mercury for developing children. Minamata disease/syndrome was not documented until 1956 although mercury had been used by humans medicinally and cosmetically since at least 1500 B.C. Continued vigilance is prudent for known toxic elements such as lead.

It is extremely important for medical and policy professionals to fully appreciate the implications of environmental lead exposure. National and individual social and economic development cannot proceed at optimal levels when significant portions of the population suffer from lead-induced growth and neurodevelopmental impairments. Physical and mental impairments are associated with even low levels of lead (>5 μg/dL, American Academy of Pediatrics, 2012) which can potentially impede individual and national progress due in part to stunted physical growth and intellectual deficits. With environmental lead pollution, otherwise normal children are destined to suffer poor outcomes (growth stunting, delayed maturation) when environmental lead is not controlled through aggressive, effective abatement programs. In Poland, reduced smelter emissions of lead, transition to catalytic converters, and use of unleaded gasoline have had a significant biological benefit for growth and health of children. The national economic forecast is thus much more optimistic than in the past because the workforce has been improved physically and mentally through the improvement of childhood growth and maturation.

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SECTION II:
OBESITY, PHYSICAL ACTIVITY AND PUBLIC HEALTH

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STATURE–OBESITY RELATIONSHIPS AMONG 11,000 SCHOOL-AGED AMERICAN INDIAN CHILDREN

John H. Himes
Mary Story

Big children are most often tall as well as heavy. Stovitz and colleagues (2008) have demonstrated that the tallest U.S. children also have the highest current body mass index (BMI), and that they are more likely than their shorter peers to become overweight or obese as young adults (Stovitz *et al*., 2010). American Indian children are among the tallest children in the world (Haas & Campirano, 2006; Eveleth & Tanner, 1990), and they have among the highest prevalences of overweight and obesity compared with other children in the United States and elsewhere (Zephier *et al.,* 2006). Nevertheless, there is no information about the relationships between stature and obesity in American Indian children. Because of the elevated risks of obesity and its sequelae in childhood and adulthood, understanding the relationships between growth in stature and excess weight is important for evaluating the growth of American Indian children and for clinical management. Herein, we investigate relationships between stature, BMI and obesity for a large sample of American Indian children, 5-18 years of age, residing on 12 reservations in the Northern Plains of the United States.

MATERIALS AND METHODS

The sample children attended 55 schools where at least 50% of children enrolled were American Indians, and that were located on or adjacent to 12 reservations. The reservations comprise the Aberdeen Area of the Indian Health Service (IHS) and include tribes in the states of Iowa, South Dakota, North Dakota and Nebraska. A single well-trained measurement team of 7 individuals collected all data on gender, age, stature and weight during the 2002-2003 school year. For height and weight standardized measurement protocols and equipment were used (Lohman et al., 1988). Data are only reported for American Indian children.

Improbable values for stature and weight were excluded, as were data for children beyond the age cut-offs, leaving a sample of 11,099 children (5661 boys) 5.00-18.99 years of age with complete data. For some analyses children were grouped into whole-year age groups (*e.g.,* 5 yrs = 5.00-5.99 yr). BMI was calculated as weight (kg)/stature (m)^2. Exact percentiles and z-scores for stature, weight and BMI were calculated relative to the CDC 2000 Growth Charts (Kuczmarski *et al*., 2000). Z-scores or standard deviation scores express the measurements in terms of standard deviation units above or below the reference means for that gender and age, so that a z-score of zero corresponds to exactly the reference mean. Overweight was considered as BMI ≥ 85th percentile, and obesity BMI ≥ 95th percentile following national recommendations (Krebs *et al*., 2007). Unconditional logistic regression was used to estimate adjusted odds ratios (OR) of variables contributing to overweight and obesity status.

Informed parental consent was obtained according to individual school policies. In some schools, measurements were incorporated into regular health-screening activities. All procedures were approved by the appropriate institutional review boards for tribes and the IHS.

RESULTS

Table 1 presents previously unpublished mean stature and BMI for each gender in whole-year age groups. The means demonstrate the expected patterns of growth in stature and BMI across this age range.

Table 1. Means and standard deviations for stature and BMI of American Indian children

	Boys					Girls				
		Stature (cm)		BMI (kg/m^2)			Stature (cm)		BMI (kg/m^2)	
Age (y)	N	Mean	SD	Mean	SD	N	Mean	SD	Mean	SD
5	310	115.9	5.3	17.7	3.3	321	115.1	5.4	17.5	3.0
6	489	121.4	5.6	18.0	3.7	459	120.1	5.6	17.7	3.2
7	511	127.4	6.2	18.5	4.0	484	126.8	5.8	18.4	3.4
8	507	133.3	6.0	19.4	4.4	483	131.9	6.3	19.4	4.0
9	585	138.4	6.7	20.4	4.9	529	138.7	6.5	20.3	4.3
10	573	143.5	7.1	21.6	4.9	542	144.0	7.5	21.1	5.1
11	533	150.0	7.7	22.9	6.0	536	150.7	7.3	22.5	5.3
12	518	156.2	8.3	23.6	6.0	479	156.2	7.1	23.2	5.3
13	460	162.0	8.1	23.9	5.9	488	160.1	6.3	24.0	5.9
14	381	168.2	8.1	24.3	6.2	396	162.1	6.4	24.6	5.7
15	285	172.6	7.6	24.5	6.1	270	162.9	6.2	25.4	5.9
16	216	174.9	7.6	25.4	7.0	222	164.0	6.1	25.4	5.5
17	203	176.0	6.9	25.6	6.4	148	163.8	6.7	26.1	6.7
18	90	178.2	7.3	25.9	6.0	81	164.2	5.6	26.6	5.8

The age-related patterns of growth in stature and BMI can be better appreciated when presented as z-scores relative to US national data (**Figure 1**). These children clearly have elevated mean z-scores for stature and BMI at every age relative to national data, with mean BMI z-scores substantially higher than stature z-scores. For stature in both genders and for BMI in boys there is a general trend of decreasing mean z-scores across these ages. The short-term marked rises in mean stature z-scores at about 10 years in boys and 9 years in girls probably represent relatively advanced maturational timing of the events surrounding adolescence in these children relative to the national reference.

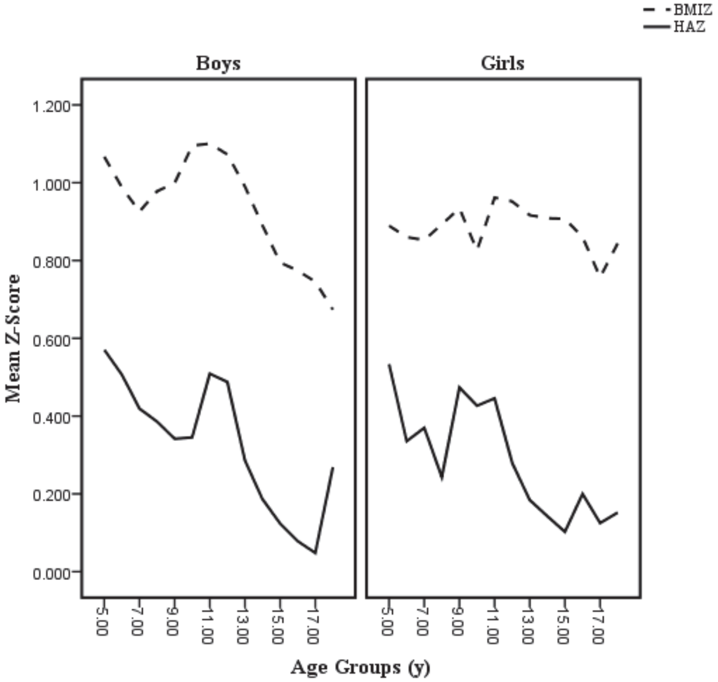

Figure 1: Mean z-scores for BMI and stature in boys and girls by whole-year age groups

The age-related patterns of prevalences of overweight and obesity are presented for boys and girls in Figure 2. Prevalences of overweight and obesity are very high in every age group. For boys prevalences peak at 11 years at 57.2% and 37.0% for overweight and obesity, respectively. In girls prevalence of overweight peaks at 51.8% at 12 years, and for obesity at 29.9% in the 11-year age group.

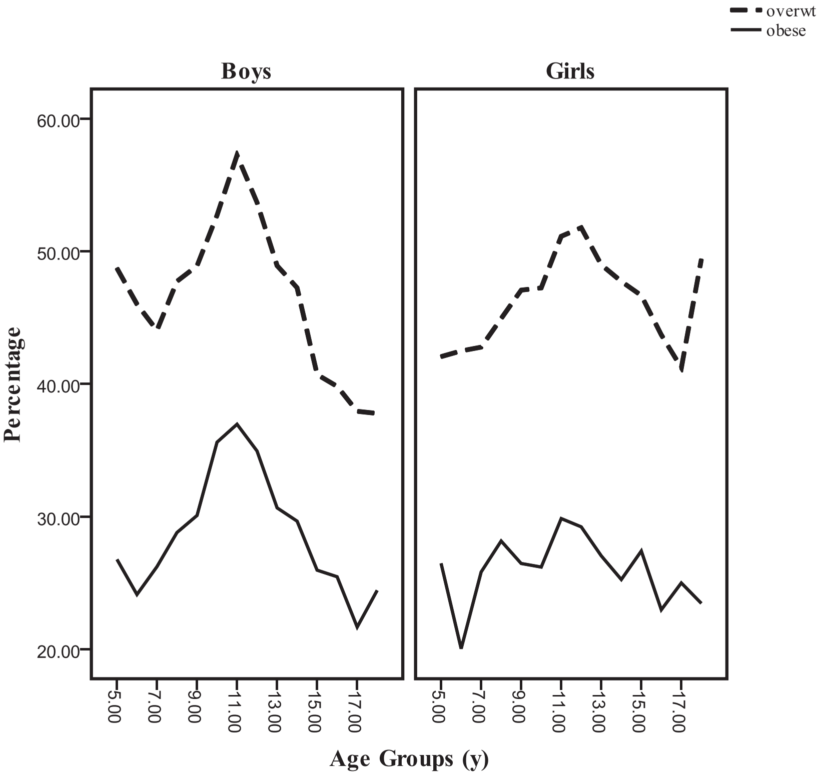

Figure 2: Prevalences of overweight and obesity by whole-year age groups

In these children correlations between stature z-scores and BMI z-scores are *r*=0.38 for boys and *r*=0.31 for girls. The corollary of this substantial positive relationship between stature and BMI can be seen in Figure 3 which presents median BMI z-scores, plotted for integer categories of stature z-scores. Clearly, taller children have greater BMI, and even for the shortest children, median BMI exceeds zero.

Finally, the results of logistic models investigating determinants of overweight and obesity status based on BMI are presented in Table 2. This analysis translates the associations between BMI and stature into adjusted odds ratios quantifying the risks of overweight and obesity according to categories of stature. Boys are about 15% more likely than girls to be obese (OR=1.16), controlling for stature and age, but a similar gender difference does not occur for overweight. There is an increase in adjusted prevalences of overweight and obesity of approximately 2% per year of age, controlling for gender and stature.

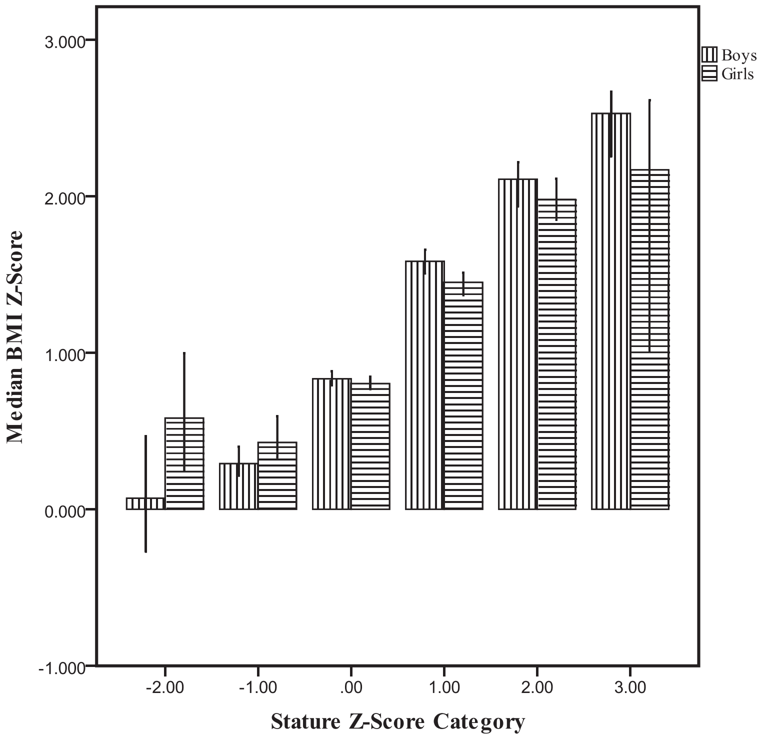

Figure 3: Median BMI Z-Scores (± 95% CI) by integer stature z-score categories

Integer categories of stature z-scores provide dramatic independent associations with prevalences of overweight and obesity. Compared with the shortest children, those whose stature is close to the median (z-score category '0') are still significantly more likely to be overweight (OR=1.68), and risks increase with each subsequently higher stature z-score category, such that children in the highest z-score category (+3.0) have more than 11 times the risk of being overweight. Consecutively higher odds ratios relative to shortest peers are observed for obesity status beginning at stature z-score categories of +1, +2, and +3, where adjusted odds ratios are 3.9, 9.4, and 15.5, respectively.

Table 2: Results from logistic models for overweight and obesity status

Variable	Overweight			Obesity		
	OR	95% CI	Sig.	OR	95% CI	Sig.
Gender (boys)	1.05	0.97, 1.13	0.266	1.16	1.06, 1.26	0.001
Age (yr)	1.02	1.00, 1.03	0.007	1.03	1.01, 1.04	<0.001
Stat -2 Z	Reference	-	-	Reference	-	-
Stat -1 Z	0.83	0.56, 1.23	0.355	0.57	0.35, 0.92	.022
Stat 0 Z	1.68	1.17, 2.41	0.005	1.37	0.89, 2.13	.154
Stat +1 Z	4.34	2.99, 6.29	<0.001	3.90	2.51, 6.07	<0.001
Stat +2 Z	8.77	5.74, 13.40	<0.001	9.43	5.87, 15.16	<0.001
Stat +3 Z	11.50	5.61, 23.59	<0.001	15.48	7.70, 31.12	<0.001

DISCUSSION

Our analyses showed that American Indian school children from the Northern Plains are clearly tall and have high BMI relative to national reference data. In a comparative study of children from around the world, including the current sample, Haas and Campirano (2006) found American Indian youth to be among the very tallest. Historically, American Indians of the Northern Plains were considered tall as children and adults (Wissler, 1911; Sullivan 1920). An implication of these earlier studies was that the tallness was due primarily to genetic factors. Clearly, nowadays the tallness is associated with overweight and obesity. This finding does not necessarily mean that the tall stature is unrelated to genetic factors, nor that the tallness necessarily results from large gains in BMI or from overweight or obesity status. Because the current data are cross-sectional no conclusions about causality or the direction of causality in the associations between stature and obesity can be made. For example, it may be that the same genes that favor tallness also favor weight gain in an obesogenic environment. Longitudinal study is required to help understand temporal associations between growth in stature and BMI.

The current data are consistent with results in other children indicating positive associations between stature and BMI, and stature and fatness during childhood (Himes and Roche, 1986; Freedman *et al*., 2004; Stovitz *et al*., 2008), although these associations do not persist in adults. Distinguishing between stature associations with BMI and stature associations with fatness is important because, although BMI is often used as a surrogate for body fatness and obesity status, BMI is really only a measure of body mass and not body fatness *per se*. Also, BMI includes stature in its denominator, and the squared term for stature may not be the exact exponential to best standardize weight at some ages in childhood, yielding residual associations with stature as an artifact of the formula used (Cole, 1991).

Some of the tallness of American Indian children in our sample is probably due to relatively advanced somatic maturation or growth tempo. As boys approach adolescence they accumulate weight and body fat about two years before they undergo the adolescent spurt in stature (Malina & Bouchard, 1991). The rises in z-scores for stature and BMI relative to the reference data at 9 and 10 years of age (Figure 1) almost certainly reflect entrance into these periadolescent events earlier than the national data so that the z-scores rise abruptly. The same pattern is seen for mean stature z-scores in girls. Most of the relative population stature advantage is lost in the oldest age groups, where the American Indian children are only slightly taller as young adults than the national norms. This is the expected pattern if the tallness were due to relatively advanced somatic maturation. Unfortunately, we are not aware of any contemporary data available for American Indians concerning the timing of adolescent events such as secondary sex characteristics or menarche that could conclusively confirm this finding.

It is tempting to view those children considered overweight and obese during the puberty-related increases in prevalences (Figure 2) as misclassified because they are simply early maturing children relative to national averages. Nevertheless, some recent analyses indicate that at the high levels of BMI cut-offs defining overweight and obesity the actual effects of the relative timing of somatic maturation on obesity misclassification is very small, probably clinically unimportant, and typically less than 1 BMI unit (Himes *et al*., 2009).

Although the biological etiology of the stature-BMI association may be unclear, it is clear that a strong positive association exists. Longitudinal analyses in other children indicate that such tallness-for-age in childhood is predictive of increased likelihood of being overweight or obese as young adults (Stovitz *et al*., 2010). The high prevalence of overweight and obesity in American Indian adults is well established, as are high burdens of obesity-related sequelae such as type 2 diabetes mellitus and cardiovascular disease (Story *et al*., 2003; Compher, 2006).

During the childhood years the BMI associations with stature are sufficient that even children approximately one standard deviation taller than the national average (≈ 85th percentile) have a four-fold risk of being overweight or obese compared to the shortest children. At the highest levels of stature-for-age the odds ratio for risk for overweight is 11.5 and 15.5 for obesity. These dramatic associations should alert health professionals of the current and future risks for tall American Indian children. The clinical notion held by some that tall children will outgrow their overweight or obesity is just not supported by the evidence.

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USING PAQ-C AMONG BRAZILIAN YOUTH

Rosane C Rosendo da Silva

In the past decades, the prevalence of chronic diseases increased among all age groups in the population, in most countries, regardless of their socioeconomic levels. There is a clear trend indicating that changes in both dietary and physical activity (PA) behaviors are at least partially responsible for these diseases, especially obesity and metabolic syndrome (Katzmarzyk et al., 2008). The health concerns among youth rely on the long exposure to risk factors and disease itself, which in turn, increase the chances of greater disease burden. Therefore, research on PA levels became mandatory in health behavior surveillance, allowing for the description of regular PA and also the factors affecting youth participation. After mapping active and sedentary lifestyles, interventions may be better tailored and are more likely to succeed (Tremblay et al., 2010).

PA levels can be assessed by objective and self-report methods. In epidemiological research, self-report is the assessment of choice, although it offers limitations during younger ages, mainly due to lower capability of recalling time spent on a specific type of activity. Objective measures of PA using electronic devices, such as accelerometers, offer information on both intensity and duration of PA throughout the day for several days. As technology evolves and becomes more affordable, this method will be wide-spread. Furthermore, there will be a clear distinction between sedentary behavior and low level of PA (Pate et al., 2008; Tremblay et al., 2010). Nevertheless, self-report of type and context of physical activity is still necessary to define active behavior (Biddle et al., 2011).

The physical activity questionnaire for older children (PAQ-C) was developed to assess levels of moderate-to-vigorous physical activity (MVPA) in children older than grade 4 who were participating in the Saskatchewan Pediatric Bone Mineral Accrual Study, Canada (Kowalski et al., 1997). A second instrument, PAQ-A, was developed to investigate PA levels among adolescents (Crocker et al., 1997). Both questionnaires were developed to provide low subject burden during the assessment, with an estimated completion time of 20 minutes. Two recent reviews on instruments for assessing PA among youth referred to PAQ-C as a promising tool (Biddle et al., 2011; Chinapaw et al., 2010). Biddle et al. (2011) identified three questionnaires for population surveillance based on their psychometric properties as well as support from expert researchers in the area, and the PAQ-C/PAQ-A was one of them.

A modified version of the PAQ, PAQ-AD, was developed to assess PA among adults, as individuals engaged in the longitudinal study grew up. In this way, PA level in adulthood can be observed and compared to the scores of childhood and adolescence (Copeland et al., 2005).

The PAQ-C is a seven-day recall self-administrated questionnaire that uses 12 items assessing (1) common sports, leisure time activities and games, and (2) activity during segmented day (in physical education classes, recess, lunch, after school, and in the weekends). Each of the items have a 5-point scale, the total score is a composite mean of 9 items (items 1 through 8 and 12). For the activity checklist, item 1, it is necessary to transform the score into a 5-point scale, by dividing the total number of points on the item by the number of activities in the checklist, including activities under the *other* category. A similar procedure is addressed to item 12, the activity on each day of the week, where the total points are divided by 7. Items 9 and 10 are related to peer comparison of PA level while item 11 asks if the subject was sick during the week which is being reported. Those three items are not included in the computation of the score. In two studies (Crocker et al., 1997; Kowalski et al., 1997), the scores of the PAQ-C were normally distributed. PAQ-C score represents a spectrum from the very inactive (1) to the very active (5). Based on the score, the subject may be classified as inactive, when his/her score is < 3 or active (≥ 3). It is important to emphasize that those categories are related to MVPA.

PAQ-C was validated against an activity rating, other PA questionnaires, motion sensor (Caltrac accelerometer) and a fitness test. All correlations were significant and low to moderate (0.28 to 0.57), consistent with other validation efforts (Kowalski et al., 1997). Scale reliability analyses of PAQ-C showed acceptable item-scale properties (α=0.80 to 0.83) for either a combined sample of boys and girls or separately by sex (Crocker et al., 1997). PAQ-C also had acceptable test-retest reliability ($r_{intraclass}$=0.75 and 0.82 for males and females, respectively) (Crocker et al., 1997).

The questionnaire version for adolescents, PAQ-A, generates the score based on a 5-point scale of 8 out of 9 items, by applying the same procedures of the PAQ-C score. The item not included in the computation is that of reported sickness during the week. Suppressed items are those comparing PA of same sex and age peers. Psychometric properties were also investigated by Kowalski et al. (1997). The findings were consistent with those of PAQ-C. Similar psychometric results were found to PAQ-AD, which has the same structure of PAQ-A, with modified activity checklist and day segments according to work context of adults (Copeland et al., 2005).

THE BRAZILIAN PORTUGUESE VERSION OF PAQ-C

The original study

PAQ-C was translated into Portuguese for use in a dissertation project held in the city of Niterói, Rio de Janeiro, Brazil in 1997 (Silva, 1998). This project investigated cardiovascular risk factors among adolescents, including physical activity patterns. The main reason of using PAQ-C instead of PAQ-A was that there is a recess from Elementary to High School in Brazil, which can be used for some level of physical activity. The recommended procedure of back-translation (World Health Organization) was not established at that time. However, the Portuguese version of PAQ-C was evaluated by a language professional for appropriateness of translation as well as of written Portuguese. PAQ-C had the activity checklist modified to exclude sports that are not played in Brazil.

The sample of this project included 329 students (126 males and 203 females) with a mean age of 15.0±0.5 years. PAQ-C scores were 2.3±.6 for males and 2.0±.6 for females. There were no differences in physical activity scores between age groups (14 and 15 yrs) in each sex; however, the values represented low levels of activity for the subjects. In both sexes, mean values for the PAQ-C score were lower than those reported by Kowalski et al. (1997) in youth from 8 to 14 years. As physical activity decreases with age, this may explain the lower scores observed in this Brazilian sample, since the subjects were older than the sample upon which the PAQ-C was validated (Silva and Malina, 2000).

The lower scores may also indicate that the questionnaire was not sensitive to cultural differences related to the perception of physical activity in Brazilian youth. In fact, the correlation between the self-reported activity rating and the PAQ-C score was 0.40 ($p<0.001$), which is slightly lower than the coefficient of 0.63 reported by Kowalski et al.(1997).

Most subjects were classified as inactive; the prevalence was 85% for boys and 84% for girls. There was a trend for longer periods of TV watching among subjects at risk, especially in girls. Although Niterói was a medium sized city at that time, it also had and still has safety problems, including high crime rate, which is known to a decrease opportunities for physical activity (Ferreira et al., 2007).

The PAQ-C score did not explain the variance in body composition indicators (sum of 6 skinfolds, BMI, trunk-to-extremity and waist to hip ratios) or systolic blood pressure. However, the PAQ-C score was inversely related to diastolic blood pressure (R^2=0.03) and cardiovascular fitness (R^2= 0.04, measured by the 12-min run); however, it explained only a very small portion of the variance in those risk factors. The PAQ-C score in this sample seemed to protect subjects from risk of overweight (OR=0.42, CI=0.19-0.92) (Silva and Malina, 2003, 2004).

A PAQ-C validation study was held in the city of Florianopolis, Santa Catarina, with students of the Elementary and High School that is integrated to the Federal University. Participants wore pedometers and completed the Bouchard activity record for 7 days after the application of PAQ-C. Preliminary analyses of data showed low values of PAQ-C scores for the entire sample (175 subjects, 10 to 18 years of age). Correlation coefficients of PAQ-C score and MVPA and total activity from Bouchard record and weekdays and weekend pedometer counts ranged from 0.35 to 0.43 (unpublished data).

Other studies

Silva et al. (2005) studied CHD risk factors among adolescents from Maceió, Alagoas, Northeastern Brazil. They investigated elevated blood pressure, risk of overweight and overweight as well as physical inactivity and tobacco use in a representative sample of 1253 students (43.7% males). Prevalence of inactivity was reported as PAQ-C scores <3, and most of that sample (93.5%) was under this threshold. The data were stratified by sex, type of school (private or public) and SES, but differences in PAQ-C scores were only found between sexes. As the mean age was 12.4 ±2.9 years, Silva et al. expected a lower prevalence of inactivity in comparison to the findings of Silva and Malina (2000) due to their younger sample; nonetheless, they found a low negative association between PAQ-C score and age ($r=-0.27$, $p<0.05$). Rivera et al. (2010), using data of the same sample, showed no relationship of PAQ-C score and TV viewing ($r= -0.04$, $p>0.05$), although 65% of the students spent more than 3 hours of TV viewing per day (mean value = 3.6±2.3 hours per day).

PAQ-C was also used to ascertain the association between PA levels and obesity among 733 children from two slums in the Great Recife area, in Pernambuco, Northeastern Brazil (Alves et al., 2009). The children were engaged in the Programa de Saúde da Família (Family Health Program), which is coordinated by the Brazilian Ministry of Health and has the purpose of following up health conditions of individuals in their household by health practitioners. The results showed that 73.1% of children were at risk of overweight, while obesity was prevalent in 19.2%. Almost 60% of the sample was classified as inactive. There was a significant association between PAQ-C scores <3 and overweight /obesity (71.6% vs 56.7% normal weight, $p<0.05$). The authors indicated that living conditions and negative environment contributed to high prevalence of inactivity. Another contributor to low activity levels was TV viewing, since more than half of the sample spent more than 3 hours per day in such a behavior.

PAQ-C has been also used in research projects in our graduate program (Diniz, 2007; Dummel, 2007; Lima, 2011). Two theses investigated children and adolescents living in the state of Rio Grande do Sul, Southern Brazil (Diniz, 2007; Dummel, 2007). Dummel (2007) conducted a study in Três de Maio, a small size city in the state of Rio Grande do Sul. Cardiovascular risk factors (blood pressure, plasma HDL and total cholesterol, glycemia, eating pattern and physical activity level, family history, tobacco use and anthropometric measurements) were collected among adolescents in high school in both public and private settings. Physical activity assessment included PAQ-C and a check list for identifying time spent in MVPA. Sedentary individuals were classified if had PAQ-C scores < 3 or less than 300 minutes of MVPA. The results showed that 86.1% of subjects had habitual atherogenic diet, 32.6% increased abdominal adiposity, 25.9% low levels of HDL-c and 20.3% high levels of total cholesterol. For inactivity, prevalence using PAQ-C was 97.6% while for the check list it was 61.2%. PAQ-C mean scores for males and females were 2.09±0.5 and 1.86±0.4, respectively. Dummel did not observe any associations between inactivity and other risk factors in her sample.

Another project in the state of Rio Grande do Sul explored growth, physical activity level and food habits in youth aged 9 to 15 years, taking into consideration ethnic background, since this state had great immigration from European countries, mainly Germany, Italy and Poland, in the late 19th and beginning of 20th centuries (Diniz, 2007). Six cities were investigated in the Northwestern area of the state. The sample was composed by 1428 students (696 males). Polish-descendent students tended to show lower values for growth variables, although the differences were significant in only a few age groups. According to PAQ-C, 75.5% of the students were classified as inactive. Inactivity was positively associated with sex, ethnicity, parental education and hours of daily television watching. The German group presented a 43%

higher probability for being inactive than the Polish group. Socioeconomic status was associated with inactivity only for the Polish group. At least half of each ethnic group did not achieve the recommended daily consumption of fruits, vegetables and milk.

Lima (2011) used PAQ-C score as a control variable for the analyses of body composition components in HIV-infected children, who acquired infection through maternal transmission. The cross-sectional study investigated 51 children and adolescents (26 males) living in Florianópolis, Santa Catarina, with mean values of body mass, stature and age of 39.9±12.6 kg; 147.2±15.4 cm, and 12.5±2.7 years, respectively. Lymphocyte TCD4$^+$ count was obtained from medical records and revealed that most of subjects had no severe immunologic suppression (76% and 80.8% respectively for females and males). Dual-energy x-ray absorptiometry was used to measure body composition components. For Bone Mineral Density (BMD), Bone Mineral Content (BMC), percent of body fat (%BF) and lean body mass (LBM), z-scores were computed based on the National Health and Nutrition Examination Survey (NHANES) data. In all components, negative z-scores were found (z-BMD$_{subtotal}$ -1,22 sd, z-BF% -1,03 sd and z-LBM/stature^2 -0,81 sd). PAQ-C mean scores were 2.36±0.7 for males and 2.48±0.6 for females, indicating low levels of MVPA. It was expected that low levels would be associated with stage of disease; however, data showed no relationship between immunologic suppression category and PAQ-C score.

In summary, PAQ-C scores indicate low levels of MVPA among Brazilian youth. Efforts to identify individuals at risk of sedentary behavior are a priority in order to prevent health complications. Additional analyses of validation data will provide the psychometric properties needed to confirm the appropriate use of recognized research tool for assessing PA in children and adolescents.

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NEW DIRECTIONS IN THE STUDY OF MATURATION AND PHYSICAL ACTIVITY

Sean P. Cumming

Those interested in the study and promotion of physical activity in children and adolescents have focussed predominantly on the contributions of various psychosocial and environmental factors (Cumming & Riddoch, 2009). Although it is well documented that factors such as self-concept, motivation, and the built environment contribute to physical activity in youth, it is equally apparent that physical activity has a biological basis (Eisenmann & Wickel, 2009; Rowland, 1998; Sherar, Cumming, Eisenmann, Baxter-Jones, & Malina, 2010). As noted by Malina (2008), physical activity is, after all, a biological process that exists within a cultural context in which various meaning and values are ascribed to it. Thus, a true understanding of physical activity likely resides in the interactions of various biological, psychosocial and environmental factors (Malina, 2008).

A biological process that occurs in all children and youth and may contribute to variance in physical activity is maturation (Eisenmann & Wickel, 2009; Sherar, et al., 2010). Biological maturation denotes progress towards the mature (i.e., adult) state, and can be viewed in terms of tempo and/or timing (Malina, Bouchard, & Bar-Or, 2004). Whereas tempo implies the rate at which maturation progresses, timing refers to the time at which maturity-related events, such as age at menarche, or peak height velocity occurs. Within a chronological age group, children and adolescents can vary considerably in maturity timing, with certain individuals, or groups, maturing much earlier or later than others. For example, girls generally enter puberty two years in advance of boys.

Research examining the contribution of biological maturation to adolescent involvement in physical activity has produced mixed results (Sherar, et al., 2010). Although research has consistently shown that advanced maturation explains why girls are less active and more sedentary when compared against boys of the same chronological age (Cumming, Standage, Gillison, & Malina, 2008; Machado Rodrigues et al., 2010; Sherar, Esliger, Baxter-Jones, & Tremblay, 2007; Thompson, Baxter-Jones, Mirwald, & Bailey, 2003); the effects of maturity timing on individual variation in physical activity within sex are unclear (Sherar, et al., 2010). The physical and functional characteristics associated with advanced maturation in females are considered to be less conducive to successful engagement in most forms of physical activity, particularly activities or sports that involve elements of endurance or weight-bearing (Baxter-Jones, Thompson, & Malina, 2002; Malina, 1994). Accordingly, it has been hypothesized that early maturation in females will be associated with less involvement in most forms of PA (Sherar, et al., 2010). In support of this contention, a number of studies have found early maturing girls to be less active than their 'on time' or late maturing peers (Baker, Birch, Trost, & Davison, 2007; Cumming et al., in press-a; Cumming, et al., 2008; Cumming et al., 2011; Davison, Werder, Trost, Baker, & Birch, 2007; Hunter Smart et al., in press; Jackson, 2011; Riddoch et al., 2007), and less likely to be represented in competitive sports programmes (Baxter-Jones, et al., 2002; Malina, 1994). It should be noted, however, that an equivalent number of studies have no found no relation between maturity timing and PA in adolescent females (Bradley, McRitchie, Houts, Nader, & O'Brien, 2011; Drenowatz et al., 2010; Knowles, Niven, Fawkner, & Henretty, 2009; Niven, Fawkner, Knowles, & Stephenson, 2007; Romon et al., 2004; Sherar et al., 2009; Wickel & Eisenmann, 2007). That said, only one study, to date, has found early maturing girls to be more active than their peers (van Jaarsveld, Fidler, Simon, & Wardle, 2007).

The nature and direction of the relation between maturity timing and PA in adolescent males is less clear (Sherar, et al., 2010). The physical and functional characteristics associated with early maturation in males are considered to be more conducive to successful engagement in most structured or competitive forms of PA, particularly those that emphasise power, speed, and strength (Malina, 1994). Although early maturing male are more likely to be represented in competitive sports programmes (especially in the older age groups and more elite level programmes) (Malina & Cumming, 2003), there is limited evidence to suggest that early maturing males are actually more or less active than their peers (Sherar, et al., 2010). This suggests that late maturing males, though less likely to be active through competitive sports, remain active in other domains such as recreational play or exercise.

A criticism of research examining relations between biological maturation and physical activity in youth is that it is largely atheoretical, lacking a clear conceptual framework from which to explain and interpret findings (Cumming et al., in press-b; Sherar, et al., 2010). A number of existing conceptual models and hypotheses relating to adolescent and pubertal adjustment, such as Petersen and Taylor's (1980) Model of Biopsychosocial Development, Holmbeck's (2002) Framework for Understanding Adolescent Development and Adjustment, the Peer Socialization Hypothesis (Magnusson, Stattin, & Allen, 1985, 1986), the Puberty-Initiated Mediation Hypothesis (Ge & Natsuaki, 2009; Ge, Natsuaki, Jin, & Biehl, 2011), and the Contextual-Amplification Hypothesis (Ge, et al., 2011; Ge, Brody, Conger, Simons, & Murry, 2002) suggest possible mechanisms that may help explain relations between maturation and PA during adolescence.

Conceptual models of adolescent development and adjustment can be grouped into two main categories, namely *direct* and *mediated* effects (Petersen & Taylor, 1980). Direct effect models contend that maturation exerts a direct causal effect of adolescent psychology and behaviour. Accordingly, adolescent changes in psychology and behaviour, for example reductions in physical activity, are considered to reflect maturity associated changes in biology (i.e., body size, composition, physique, neuroendocrine changes) and attribute individual differences in behaviour to differences in antecedent variables (i.e., biology). Direct effect models would consider adolescent declines in physical activity as an inescapable consequence of the maturation process and 'invariant and universal' feature of adolescent and/or pubertal development (Petersen & Taylor, 1980).

DIRECT EFFECTS

Support for the existence of *direct effects* is limited. Though some evidence has linked hormones to changes in mood and behaviour (i.e., aggression, sexual behaviour), it is weaker and less consistent than is commonly believed (Buchanan, Eccles, & Becker, 1992; Petersen & Taylor, 1980; Walker, Sabuwalla, & Huot, 2004). This may, however, reflect methodological limitations (e.g., lack of precision and consistency in measurements of hormones and psycho-behavioural outcomes) rather than inadequacies in the theoretical paradigm (Petersen & Taylor, 1980). Despite the lack of evidence supporting the hormonal effects of maturation on psychology and behaviour, the potential for direct effects may be greater in the context of physical activity (Cumming, et al., in press-b). One of the most consistent findings in pediatric exercise science is that individuals become less active as they progress towards the mature state (Eisenmann & Wickel, 2009). The fact that this change is observed across most animal species (Ingram, 2000) also suggests a biological basis for the phenomenon. In support of this contention, research has consistently found that sex-related differences in physical activity and sedentary behaviour among adolescents of the same chronological age are attenuated and non-significant when differences biological maturation are controlled for (i.e., girls typically mature two years in advance of boys) (Cumming, et al., 2008; Machado Rodrigues, et al., 2010; Sherar, et al., 2007; Thompson, et al., 2003).

Further evidence supporting the potential for a direct effect of maturation on physical activity can be found in research examining the purpose of active play (Byers, 1998; Byers & Walker, 1995; Pellegrini & Smith, 1998a, 1998b). Active play is a behaviour that occurs frequently in early and late childhood, yet declines in adolescence through to adulthood. It can also be observed in many animal species, tending to peak around midlaction (Byers, 1998; Byers & Walker, 1995). These observations have led theorists to contend that play is a biologically driven phenomenon that aims to enhance development during time sensitive periods (Byers, 1998. Time sensitive effects that are permanent and specific to play include synaptic pruning, myelination of the neural fibre tracts, and muscle fibre type differentiation (Byers, 1998. Recognizing play as a biological drive, whose purpose is limited to childhood and adolescence, provides a compelling explanation as to why individuals become less active as the progress towards the mature state (Cumming, et al., in press-b). That is, play becomes biologically redundant once certain developmental processes are complete.

INDIRECT EFFECTS

Mediated effect[1] models contend that the psychological and behavioural effects of maturation are mediated and/or moderated by factors endogenous or exogenous to the individual, respectively (Petersen & Taylor, 1980). Mediating factors might include beliefs, self-perceptions, and fantasies and/or attitudes towards the body, physical

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[1] It should be noted that the term ‘mediated effects model’ is somewhat of a misnomer as such models recognize both mediated and moderate effects

activity, and/or maturation process(Cumming, et al., in press-b). Factors that might moderate relations between maturation and physical activity include peer acceptance, parental support, motivational climate, and cultural values and standards pertaining to the body, maturation, and/or physical activity (Cumming, et al., in press-b). Unlike direct effect models, mediated effect models attribute individual differences in pubertal adaptation to differences in the interpretation and social management of puberty (Petersen & Taylor, 1980). That is, how the individual interprets change during puberty and the meaning and value attached to change is considered to be more important than the change itself. Applying these principles to the context of physical activity, one would predict that youth who are encouraged to view puberty as a normal and positive aspect of the maturation process and not as a barrier to activity would be more likely to remain active through adolescence (Cumming, et al., in press-b).

Potential mediators of relations between maturation and physical activity in adolescents include physical self-concept, body image, self-esteem, acceptance and/or self-presentation anxieties, and attitudes and feelings related to the body, physical activity, and/or the maturation process (Cumming, et al., in press-b; Sherar, et al., 2010). Whereas a number of these potential mediators have been documented as correlates of maturation and physical activity, few studies have actually tested the extent to which these factors actual mediate relations between the variables of interest.

A variable that has received particular interest, as a mediator of relations between maturation and PA, is physical self-concept. Physical self-concept represents the individuals perceptions of the self as generated through his or her experiences with, and interpretations of, the environment related to the physical domain (Shavelson, Hubner, & Stanton, 1976). It has been documented as both a correlate of maturation (Craft, Pfeiffer, & Pivarnik, 2003; Niven, et al., 2007) and as a predictor and outcome of physical activity (Sabiston & Crocker, 2008; Weiss & Amorose, 2005). Advanced maturation in females is generally associated with lower perceptions of physical self-concept (i.e., body attractiveness, sport competence, physical condition, physical self-worth), though early maturing girls do report higher perceptions of strength (Cumming, et al., in press-b). In contrast, advanced maturation in males is typically associated with superior physical self-concept (Lintunen, Rahkila, Silvennoinen, & Osterback, 1988), though evidence is limited.

To date, only a limited number of studies have examined the degree to which physical self-concept actually mediates relations between maturation and physical activity. In a series of three studies testing a mediated effects model, Cumming and colleagues (Cumming, et al., 2011; Hunter Smart, et al., in press) tested the mediating effect of physical self-concept upon relations between maturation and physical in adolescent British females. In each study an inverse indirect relation was observed between maturity timing and physical activity. That is, early maturing girls were typically less active than their peers. Similarly, in each study, perceptions of self-competence were found to partially mediate relations between maturation and physical activity. More specifically, girls who were advanced in their maturation generally held lower perception of body attractiveness, sport competence, physical conditioning, and physical self-worth (yet greater strength), which, in turn, predicted less involvement in physical activity.

As noted previously, the effects of maturation on behaviours such as PA may be moderated by social or cultural factors. The Peer Socialization hypothesis, advanced by Magnusson and colleagues (Magnusson, et al., 1985, 1986), contends that adolescents select peers who are similar in maturity status and, as a consequence, behave in manner that is consistent with their peer groups. Though there is emerging evidence to suggest that early maturing females are less active than their on-time or late maturing peers (Sherar, et al., 2010), it is not clear whether or not this is a result of their associations with older and less active peers. Accordingly, future studies should consider applying the Peer Socialization Hypothesis within the context of physical activity.

Similar to the peer socialization hypothesis, the Puberty-initiated Mediation Hypothesis (Ge & Natsuaki, 2009; Ge, et al., 2011) suggests that the physical and functional characteristics associated with variance in maturity timing hold social stimulus value for significant others (i.e., peers, parents, educators) influencing their perceptions of the adolescent and the nature and quality of their social interactions. Applied to the context of physical activity, the physical and functional characteristics associated with average-to-late maturation in females and average-to-early maturation in males would be considered to be more suitable for successful engagement in most forms of physical activity, especially sports (Malina, 1994). Accordingly, one would expect those individuals to experience a more positive and supportive environment within the context of physical activity (Cumming, et al., in press-b). In support of this contention, Summers-Efler (2004) found that social support from peers and parents, or lack thereof, play an instrumental role in helping adolescent females remain active through puberty. In a similar vein, Cumming and colleagues found that body size in gymnastics was closely related to girls perceptions of coaching behaviours, with girls who were shorter, light, and who carried less mass-for-stature reporting more frequent reinforcement and encouragement, instruction, general communication, and less punishment or ignoring behaviours (Cumming, Eisenmann, Smoll, Smith, & Malina, 2005).

The Contextual Amplification Hypothesis (Ge, et al., 2011; Ge, et al., 2002) has also been proposed to explain the impact of social and cultural factors upon adolescent adjustment. Much like the Peer Socialization and Puberty-initiated Mediation hypotheses, this hypothesis assumes that the sociocultural context in which the adolescent grows up plays an important role in moderating relations between maturity timing and problem behaviours, such as inactivity. Whereas protective or supportive contexts are expected to mitigate any negative consequences associated with variation in maturation (i.e. reduced activity, increased sedentary behaviour), adverse conditions would be expected to amplify these effects. For example, an early maturing adolescent female experiencing an environment that supports activity would be expected to remain as active as her average and late maturing peers. In contrast, an early maturing girl who received limited parental or peer support, grew up in a disadvantaged neighbourhood, or lived in a culture that frowned upon public exercise in females would be less likely to remain active.

To date, only a limited number of studies have explicitly investigated the potential for social and cultural factors to moderate relations between maturation and physical activity. Assuming that a more supportive social environment would mitigate any negative effects associated with advanced maturation on physical activity in females, Pindus and colleagues examined the extent to which peers acceptance moderated relations between maturity timing and physical activity in British adolescent females (Pindus et al., 2011). As expected, advanced maturation was found to be associated with less involvement in physical activity. However, early maturing girls who perceived high levels of peer acceptance were found to be as active as their 'on time' or 'late' maturing peers. In a related study, the moderating effect of parental support for physical activity on relations between maturity timing and physical activity in British adolescent females, aged 11 to 14 years was also studied (Jackson, 2011). Although advanced maturation was associated with less involvement in physical activity, a statistically significant moderating effect for parental support was not observed. Nevertheless, early maturing girls who reported higher levels of parental support reported, on average, higher levels of physical activity than those who reported lower levels of parents support.

Assuming that parental support might mitigate any negative impact of advanced maturation on physical activity in adolescents, Bradley and colleagues examined the relation between maturity timing and parental support on adolescent involvement in moderate-to-vigorous physical activity (MVPA) (Bradley, et al., 2011). Although pubertal timing was found to be unrelated to MVPA in both males and females, parental support moderated the effect of pubertal timing on MVPA in males. Closer inspection of the results suggested that higher levels of high parental monitoring was associated with reduced physical activity in late maturing males, but increased activity levels for early maturing males. The finding of this study should, however, be interpreted with caution as the growth models used to predict change in MVPA included exceptionally large numbers of independent and interactive predictor variables.

SUMMARY

Emerging evidence suggests that biological maturation and pubertal timing both contribute to variance in physical activity in adolescents. What is also clear is that the relations between biological maturation and physical activity are complex and that a variety of personal and social cultural factors may mediate or moderate relations between these constructs. Professor Malina has undoubtedly played a major role in leading and advancing this line of research, identifying the need to adopt a biocultural approach to the study of maturation and activity and encouraging fellow researchers in their efforts to study this phenomenon. In this respect, I and many of my colleagues will be eternally grateful for his contribution to the field of study, and for his continued advice, support and friendship.

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PHYSIQUE, ADIPOSITY AND RISK FOR CHRONIC DISEASE

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Claude Bouchard

INTRODUCTION

Professor Robert Malina has shown a lifelong interest in the study of physique and has made significant contributions to our understanding of the relationship between body type and disease risk. His approach has been grounded in the concept that "the whole is greater than the sum of the parts". Placed within the context of "human constitution", the development and consequences of physique have been central themes in the first and second editions of the seminal textbook *Growth, Maturation and Physical Activity* (Malina and Bouchard 1991; Malina et al. 2004). Dr. Malina has encouraged students and colleagues to consider holistic approaches to the study of human constitution and health. The latter notion is complex, and necessitates appropriate measures of physique, such as in somatotype assessment, and adequate statistical techniques like principal components analysis or canonical correlation. The rationale for studying the relationship between physique and disease risk is that individuals with specific body types are potentially at elevated risk for common diseases.

The notion that body habitus has a role to play in determining health risks has a long history in medicine and human biology. Early physicians understood that physique was an important consideration in assessing a patient's overall health status. However, variation in physique is difficult to measure, cannot be captured in a single measurement and does not lend itself to being represented by a simple number. Hundreds of years ago, Hippocrates suggested a simple generalized classification of habitus phthisicus (linear) versus habitus apoplecticus (lateral) (Malina et al. 2004). Numerous classification systems for human physique have emerged over the years, and the concept of the somatotype evolved particularly during the first half of the 20th century. Davenport was among the first to recognize the need for a quantitative assessment of physique (Davenport 1923). Subsequently Sheldon and colleagues used a series of reference photographs plus height and weight (a so-called anthroposcopic method) to somatotype individuals along three dimensions labeled ectomorphy, mesomorphy and endomorphy (Sheldon et al. 1954; Sheldon et al. 1940). The adoption of a system based on standardized and representative pictures combined with anthropometry allowed for the quantification of the somatotype in terms of three dimensions (ectomorphy, mesomorphy and endomorphy), which offered an objective, measurable index of physique. At about the same time, Parnell developed another typing system based on anthropometric indicators and referred to the components as fatness, muscularity and linearity (Parnell 1958). A modification of the anthropometric approach was reported by Heath and Carter in 1967. The Heath and Carter anthropometric somatotyping method has been the most commonly used over the last 40 years or so. Even though the latter approach rates the somatotype along the same three dimensions as the Sheldonian method, ectomorphy, mesomorphy and ectomorphy, they are not quantitatively fully identical.

Over the years, the endomorphic component of physique (body fatness) has dominated the discussion regarding health risks, and interest in overall physique has declined. More recent investigations have focused on determining the best way to measure total and regional adiposity as markers of disease risk. A critical question that remains to be answered is whether the association between health risks and some body types is stronger and more specific than what is captured in current indices of adiposity, body composition and fat distribution.

FAMILIAL RESEMBLANCE FOR PHYSIQUE

In order to better understand the extent to which physique is a modifiable characteristic, it is important to determine the degree to which it is influenced by genetic and environmental factors. Dr. Malina and colleagues have studied this issue using data from French-Canadian families from Montreal (Bouchard et al. 1980), the Québec Family Study (Song et al. 1993; Song et al. 1994) as well as in a sample from Northern Ontario, Canada (Katzmarzyk et al. 2000). Based on sibling correlations, the broad heritability estimates were 50%, 42% and 54% for endomorphy, mesomorphy and ectomorphy, respectively among 239 families from Montreal (Bouchard et al. 1980). Using data from 243 nuclear families enrolled in the Québec Family Study, the pattern of familial correlations suggested a significant familial resemblance for physique. The spouse correlations for the somatotype components were low and not significant, whereas the parent-child and sibling correlations ranged from 0.18 to 0.48 for endomorphy, 0.23 to 0.59 for mesomorphy, and from 0.14 to 0.47 for ectomorphy (Song et al. 1993). In a subsequent study, twin resemblance was considered as a strategy to further define the presence of genetic variation in physique. Data from 28 male and 34 female monozygotic (MZ) and 19 male and 21 female dizygotic (DZ) twin pairs indicated greater resemblance within MZ twin pairs than within DZ twin pairs, suggesting that genetic factors are playing a role in explaining variation in human physique (Song et al. 1994). In the family study we conducted in Northern Ontario, we computed maximal heritability estimates for somatotype from a familial correlation model. The maximal heritabilities for the somatotype components were 56%, 68% and 56% for endomorphy, mesomorphy and ectomorphy, respectively. Further, the maximal heritability for a composite somatotype score derived from principal components analysis was 64%, indicating a significant familial resemblance for physique (Katzmarzyk et al. 2000). Taken together, the results of the research conducted by Dr. Malina and his colleagues indicate a significant familial resemblance in physique, which has been corroborated by more recent studies (Jelenkovic et al. 2011; Peeters et al. 2007).

PHYSIQUE, CHRONIC DISEASE AND RISK FACTORS

Early studies identified an association between physique and risk of chronic diseases, particularly heart disease and hypertension (Gertler and White 1954; Robinson and Brucer 1940; Spain et al. 1963). These relationships between physique and chronic disease risk factors in adulthood were replicated in more recent times (Malina et al. 1997; Williams et al. 1997). For example, we examined the association between somatotype and cardiovascular disease (CVD) risk factors among 642 adults from the Québec Family Study. Correlations between individual somatotype components and risk factors were modest; however, stronger associations were more apparent at the extremes of the risk factor distributions (Malina et al. 1997). Those with a poorer risk factor profile tended to be more endomorphic and mesomorphic, and less ectomorphic than those with a better profile.

To our knowledge, the association between somatotype and risk of CVD death has not been investigated using a prospective design. We undertook an analysis of 1700 men 40-69 y of age who were participants in the 1981 Canada Fitness Survey. These men were followed for 13 y and their data were linked with the Canadian Mortality Database at Statistics Canada, yielding 21,349 person-years of follow-up. At baseline, somatotype components (endomorphy, mesomorphy, ectomorphy) were calculated by the Heath-Carter anthropometric method and principal components analysis was used to derive an underlying physique score (PC1). A total of 71% of the variance in the somatotype components was explained by PC1, which was characterized by positive loadings for endomorphy and mesomorphy and a negative loading for ectomorphy. A total of 41 deaths from CVD occurred during the follow-up period. There was elevated CVD mortality risk in the upper quintiles of PC1 (Q4 HR = 2.75; 95% CI 0.96-7.82 and Q5 HR = 3.18; 95% CI 1.14-8.85), compared to the lower quintile. Further, the pattern of hazard ratios for PC1 followed a j-shaped curve (see Figure 1). Overall the results indicate that there is an elevated risk of CVD mortality among men who have a physique characterized by high levels of endomorphy and mesomorphy and low levels of ectomorphy.

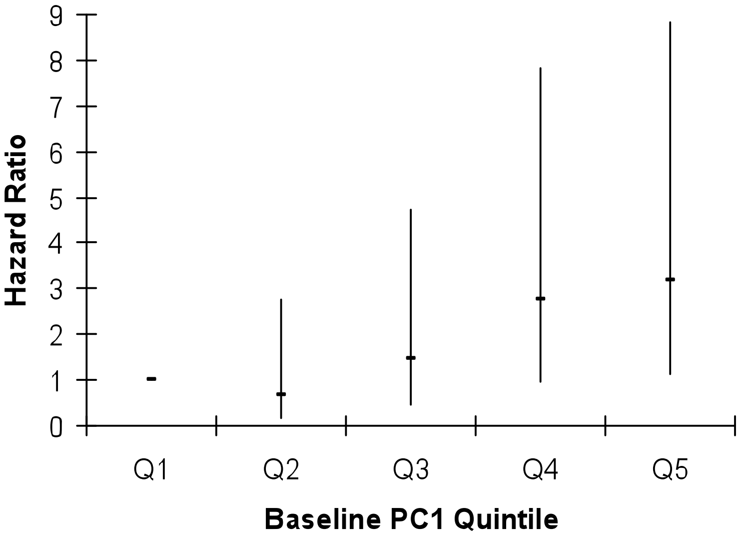

Figure 1. Hazard ratios for CVD mortality across baseline quintiles of the first principal component score of the three somatotype components in 1700 men from the 1981 Canada Fitness Survey. The model includes the effects of age, smoking and alcohol consumption. All men who died in the first two years of follow-up have been eliminated from the analysis. Bars indicate 95% confidence intervals.

PHYSIQUE IN CHILDHOOD AND ADULTHOOD

The degree to which the relationships between physique and chronic disease risk factors are established in childhood and how they translate or track into elevated risk as an adult has been one focus of Dr. Malina's interest (Malina et al. 2004). We examined the relationship between physique and chronic disease risk factors in children and youth 9-18 years of age from the Québec Family Study (Katzmarzyk et al. 1998). Canonical correlation analysis was used to quantify the relationship between the Heath-Carter somatotype and risk factor variables. The results suggest that a physique characterized by high endomorphy and mesomorphy, and low ectomorphy is associated with higher levels of triglycerides, LDL-cholesterol, and plasma glucose, and lower levels of HDL-cholesterol.

The stability or tracking of a person's physique over time is a subject of interest. Although a person may change an individual characteristic such as their body weight through changes in their lifestyle behaviors, the degree to which overall physique changes throughout the lifespan is not well understood. Several studies using longitudinal research designs have investigated the stability of physique over time in the same group of people (Malina et al. 2004) . The most common way of expressing stability or tracking of physique is by inter-age correlations. Given that the somatotype is a three-component index, it is best not to study one component in isolation, but to consider one component after statistically adjusting for the other two components.

Data from the Leuven Longitudinal Study revealed inter-age correlations of 0.79, 0.73 and 0.82 for boys between the ages of 13-18 years for endomorphy, mesomorphy and ectomorphy, respectively (Claessens et al. 1986). Further, Hebbelinck et al. (1995) reported inter-age tracking correlations of 0.29, 0.50, and 0.55 for males and 0.60, 0.36 and 0.73 for females for endomorphy, mesomorphy and ectomorphy, respectively between the ages of 12-17 years in Belgian youth, after statistically controlling for the other two components. Among younger South African girls 4 years of age, 2-year inter-age correlations ranged from 0.75 for endomorphy, 0.52 for mesomorphy, and 0.35 for ectomorphy, after statistically controlling for the other two components, while the corresponding correlations for girls 8 years of age were 0.75 for endomorphy, 0.46 for mesomorphy, and 0.50 for ectomorphy (Monyeki et al. 2002). Overall, the results of these and other studies indicate that somatotype is a relatively stable characteristic throughout the growing years and into adulthood.

PHYSIQUE, ADIPOSITY AND RISK FACTORS

Given the dramatic increases in obesity observed in recent years, there has been great interest in determining the health concerns associated with excess adipose tissue. At the same time, there has been diminished interest in overall physique as an independent risk factor. The most common method of assessing physique is the Heath-Carter somatotype, which requires the measurement of several body dimensions, elaborate computations, and sophisticated statistical analyses. Thus, the degree to which knowing the somatotype improves the prediction of disease risk beyond simpler anthropometric indicators of adiposity is of interest.

We undertook a study in the Québec Family Study to determine the independent roles that indicators of body adiposity (sum of skinfolds, trunk-to-extremity skinfold ratio) and somatotype might play in relation to CVD risk factors (blood pressure, lipids, glucose) in children and young adults (Katzmarzyk et al. 1999). A modest amount of the variation (up to 16%) in CVD risk factors was explained by the indicators of adiposity and the somatotype components. Indicators of adiposity and the somatotype components entered the stepwise regression models as predictors a similar number of times, explaining a similar proportion of the variance. Overall, the results of this single study do no appear to suggest that computing somatotype components adds value to the prediction of risk factors beyond measures of adiposity, but further research is required to better determine the independent nature of these associations.

In a recent report on somatotype and blood pressure in 980 boys and 922 girls, 6 to 13 years of age, from Ellisras, South Africa, systolic blood pressure was found to be weakly and negatively associated to ectomorphy (Makgae et al. 2007). No relations were observed between systolic or diastolic blood pressure with endomorphy and mesomorphy, even though the prevalence of hypertension reached 6% in boys and 11% in girls.

SUMMARY

Studies of the relationship between physique and health have a long tradition in human biology and medicine. Overall physique, often operationalized as the three-component somatotype, demonstrates a significant amount of familial resemblance, suggesting that there is a substantial genetic effect on human variation in ectomorphy, mesomorphy and endomorphy. A body of data supports the concept that a physique characterized by high levels of endomorphy and mesomorphy and low levels of ectomorphy, is associated with an increased risk of CVD and mortality. The somatotype and its relationship with chronic disease risk factors appears to begin in childhood, and evidence from several longitudinal studies has demonstrated that a person's physique is a relatively stable trait through childhood into adulthood. The degree to which the somatotype adds to the predictive ability of more common indicators of body composition, overall adiposity and adipose tissue distribution remains to be determined. Studies comparing ectomorphy, mesomorphy and endomorphy against direct measures of lean mass, fat mass, abdominal fat depot, visceral fat level, and hepatic and intramyocellular fat deposition would be helpful in evaluating a potential role for global measures of physique and body type, particularly as risk factors for common chronic diseases and premature mortality.

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SECTION III:
YOUNG ATHLETES

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TRACKING AND PREDICTION OF TRACK AND FIELD EVENTS IN UNTRAINED ADOLESCENT BOYS FROM 12 TO 17 YEARS OF AGE

Johan Lefevre
Paul Ponnet
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Martine Thomis
Gaston P Beunen

In this study tracking of track and field events (high jump, shot put, 60 m sprint and 6 minute endurance run) during adolescence (12 to 17 years) is studied and the predictive power of a variety of biological characteristics is verified. This interdisciplinary approach has demonstrated that track and field performances in late adolescence are, to a fairly high degree, predictable by the additive contribution from track and field performances, motor performances, somatic dimensions, and progression in track and field events, motor performance and/or somatic growth over a one year period (12 to 13 years).

INTRODUCTION

Many children and adolescents participate in sports and for a majority it is the major context of their physical activity behavior (Malina, 2010). Most likely only a limited number of youth participating in sports already show the characteristics of expert sports potential and only a very small minority will succeed and attain international excellence in their sport. Most countries, however, attempt to develop systematic structures and programs to identify and promote talented youth (Vaeyens *et al.*, 2009).

If talented adults can be identified at younger ages it raises the question if physical performance later in life can be predicted from characteristics earlier in life. This refers to the concept of tracking and prediction used in auxological research. Tracking is the maintenance of the relative position within a group over time (Clark *et al.*, 1976; Foulkes & Davis, 1981; Malina, 1990; McMahan, 1981). In exercise science it is mostly quantified by calculating inter-age correlations. Malina (2001) summarized the available evidence and concluded that most physical performance characteristics track reasonably well from childhood to adolescence and from adolescence to adulthood. In general, with increasing time interval the tracking coefficients decrease. Only a few studies tried to predict future physical performance from observations made earlier in life (Beunen et al. 2004).

In the present study it is hypothesized that: (1) three track and field events (high jump, shot put and 60 m sprint) and the 6 minute endurance run demonstrate moderate to moderately high tracking during adolescence and (2) that physical fitness and somatic dimensions contribute significantly to the prediction of results in these events in late adolescence.

METHODS

Subjects were sampled from two secondary schools in Flanders (Belgium). At the start of the study boys were between 10 and 13 years old. These boys were followed at annual intervals for six consecutive years. In total 144 adolescents (from 156 possible participants) gave their consent for participation. At the start of the study, they were placed into four groups, with a respective mean chronological age of 10, 11, 12 and 13 years. A total of 94 boys (65% response rate) completed the study and had complete records. For this manuscript, only data from the third group are used. Boys (n = 41) were about 12 years old (11.99 y ± 0.15) at the onset of the study. Final age at follow up was about 17 years of age (16.92 ± 0.17).

The project was approved by the Medical Ethics Committee of the Faculty of Physical Education and Kinesitherapy (presently Faculty of Kinesiology and Rehabilitation Sciences) of the KULeuven. The parents of the boys received a letter with an explanation about the main goals of the study, the reason why their son was included in the sample, and a brief description of the tests and measurements. Since the study design required a collection of longitudinal data, parents and youngsters were asked if they were willing to participate during six consecutive years. In addition, it was clearly stipulated that yearly an X -ray of the left hand and wrist would be taken, to assess skeletal maturity. Parents had to complete a form and gave their informed consent by signature.

Performances in high jump, shot put (4 kg), 60 m sprint and 6 minute endurance run at the age of 17 years were chosen as dependent characteristics. Independent variables at the age of 12 years were the track and field events (high jump, shot put, 60 m sprint, 6 minute endurance run) and 20 somatic variables (lengths, breadths, circumferences, skinfolds and Heath-Carter somatotype components), 15 motor fitness tests, and skeletal maturity.

Skeletal age was estimated according to the TW2 method (Tanner *et al.*, 1989). Relative skeletal age was calculated by subtracting chronological age from RUS-age (radius, ulna and short bones). Measurement procedures of all somatic variables have extensively been described by Claessens *et al.* (1990).

The choice of the motor fitness variables was based on the available evidence of biological characteristics that correlate with track and field events (high jump, shot put, 60 m sprint and 6 minute endurance run) (Burwitz *et al.*, 1994; Thomas, 1989). Three tests of static strength were included (arm pull, leg extension, bench press), five tests of explosive strength (vertical jump, vertical jump running approach, standing broad jump, multiple jump, reactive jump from a bench of 30 cm), two speed tests (plate tapping, 50 meters shuttle run), and one test of respectively muscular endurance of the lower body (leg lifts), muscular endurance of the upper body (bent arm hang), hip flexibility (sit and reach), total body balance (flamingo balance) and cardio-vascular endurance (6 minutes endurance run). Testing procedures of all tests have been described by Claessens *et al*. (1990). For the prediction of future performance from the age of 13 years, in addition to the previously mentioned characteristics, growth and development variables were calculated. This was done by calculating the differences between the measurements obtained at 12 and 13 years of age, respectively.

A major problem in longitudinal studies is the appearance of testing effects. Three comparable control groups of boys that were never tested before were used to verify the testing effect. The mean results of the longitudinal sample did not differ significantly ($p<0.01$) from those of the control groups at none of the occasions (second year, fourth year, sixth year).

The purpose of the main analysis was to explain performance in high jump, shot put, 60 m sprint and a 6 minute endurance run at the age of 17 years by tests and measurements observed at 12 and 13 years of age. Analyses were performed in a progressive way: (1) calculation of tracking in the four track and field events between 12 and 17 years, and 13 and 17 years of age, (2) calculation of stepwise multiple regressions using adjusted R^2 (SAS, 2004). Four different predictions were calculated with each of the four track and field events as dependent variables and progressively the motor variables and the somatic variables as independent variables. The track and field performance at the younger age, and the variables that entered significantly in former steps were forced into the regressions, so that the separate contribution of every set of variables could be computed. From 13 years onward also the possible contribution from progression (change) in track and field performance, motor performance and somatic growth between 12 and 13 years of age in the explanation of performance at 17 years was verified. The performance gain and somatic growth were progressively entered into the regressions to predict performance from 13 years onward. The significance level was set at $p < 0.05$.

RESULTS

Tables 1, 2, 3 and 4 show the best possible performance explanation at 17 years for respectively performance in high jump, shot put, 60 m sprint and 6 minute endurance run, through tests and measurements at 12 and 13 years of age.

For conformity with the subsequent stepwise analyses, tracking was quantified as the squared inter-age correlation. High jump performance at 12 years of age explained 40.1% of the performance at 17 years, which is higher than the performance explanation at 13 years (30.7%). Standard errors of prediction (SEP) were respectively 9.3 cm at 12 years and 10.0 cm at 13 years. Subsequently motor performance added 10.3% (from the age of 12 years) and 19.3% (from the age of 13 years) to high jump performance variation at 17 years. From the age of 12 years, standing broad jump (explosive leg power) entered the equation, and from the age of 13 years multiple jump (combination of explosive power and reactive leg power) and shuttle run (agility speed) added to the prediction. The addition of anthropometric dimensions (biacromial and biiliac widths) added another 12.1% (12 years) but did not contribute to the explained variance from 13 years onward. Both progression in track and field performance and somatic growth add significantly ($p < 0.05$) to the prediction. There is only an improvement in performance prediction through the progression in leg power (reactive jump) in the age interval 12-13 years. Explained variance in high jump performance now reached 55.0% from 13 years (5% increase), but was still lower than from 12 years (62.5%). High jump performance at 17 years of age was thus better predicted from the age of 12 years (62.5% with SEP=7.3 cm) than it was from 13 years of age (55.0% with SEP=8.0 cm).

Table 1. Prediction of high jump at 17 years from tests and measurements at 12 and 13 years.

	Model	Predictors	% explained variance	Total % explained variance	SEP (cm)
From 12 years	Track events	High jump	40.1	40.1	9.3
	+ Motor Perf.	Stand. broad jump	10.3	50.4	8.4
	+ Somat. Dim.	Biacr. and biiliac.	12.1	62.5	7.3
From 13 years	Track events	High jump	30.7	30.7	10
	+ Motor Perf.	Mult. jump & Shuttle run	19.3	50.0	8.5
	+ Somat. Dim.				
	+ Progr. (Δ) track				
	+ Progr. (Δ) motor perf.	Reactive jump	5.0	55.0	8.0
	+ Progr. (Δ) growth				

Progr. (Δ) indicates the progress in scores (delta) from 12 to 13 years of age

Table 2. Prediction of shot put at 17 years from tests and measurements at 12 and 13 years.

	Model	Predictors	% explained variance	Total % explained variance	SEP (cm)
From 12 years	Track events	Shot put	41.1	41.1	1.02
	+ Motor Perf.	6'run			
		Leg lifts	10.4	51.5	0.93
From 13 years	Track events	Shot put	40.8	40.8	1.02
	+ Motor Perf.				
	+ Somat. Dim.				
	+ Progr. (Δ) track	Shot put	6.3	47.1	0.97
	+ Progr. (Δ) motor perf.	Reactive jump & Leg lifts	16.6	63.6	0.80
	+ Progr. (Δ) growth				

Progr. (Δ) indicates the progress in scores (delta) from 12 to 13 years of age

Tracking coefficients for shot put were 41.1% and 40.8% from 12 and 13 years respectively. From 12 years motor performance (6 minute endurance run and leg lifts) added to the explained variance (10.4%) of the shot put performance at 17 years. Somatic dimensions did not further improve the prediction neither from 12 years nor from 13 years. The improvement in shot put between 12 and 13 years added another 6.3% in predictive power and the gain in leg power (reactive jump) and trunk/lower body muscular endurance (leg lifts) added another 16.6% of explained variance in shot put performance at 17 years of age.

Tracking for 60 m sprint was also fairly high, 46.6 % from 12 years and 47.5 % from 13 years. Power, static strength and muscular endurance added another 16% from 12 years and 18.4% from 13 years to the explained variance in sprint performance at 17 years. From 12 years maturation (relative skeletal age) also added 3.3% to the prediction. From 13 years, the gain in leg muscle development (calf circumference) and in leg length between 12 and 13 years improved the prediction by another 7.5%. In total 65.9% and 73.4% of the variance in 60 m sprint at age 17 was explained by characteristics observed at 12 and 13 years, respectively.

Table 3. Prediction of 60 meter sprint at 17 years from tests and measurements at 12 and 13 years.

	Model	Predictors	% explained variance	Total % explained variance	SEP (cm)
From 12 years	Track events	60 m sprint	46.6	46.6	0.35
	+ Motor Perf.	Reactive jump & Bench press	16.0	62.6	0.29
	+ Somat. Dim.	Relative skeletal age	3.3	65.9	0.28
From 13 years	Track events	60 m sprint	47.5	47.5	0.34
	+ Motor Perf.	Arm pull, Bent arm hang, vertical jump	18.4	65.9	0.28
	+ Somat. Dim.				
	+ Progr. (Δ) track				
	+ Progr. (Δ) motor perf.				
	+ Progr. (Δ) growth	Calf circumf. & leg length	7.5	73.4	0.24

Progr. (Δ) indicates the progress in scores (delta) from 12 to 13 years of age

Tracking in 6 minute endurance run was somewhat lower, 35.8% from 12 years but again considerable (49.5%) from 13 years. From 12 and 13 years static strength improved the predictive power by 5.3% and 4.7%, respectively. From 12 years also somatic dimensions (subscapular skinfold and calf circumference) added 13.4% to the explained variance in endurance run at 17 years. Furthermore, from 13 years, change in biceps skinfold thickness and skeletal breadths added 17.2% of explained variance in 6 minutes endurance run at 17 years. The total explained variance was 54.0% from 12 years and 71.4% from 13 years.

Table 4. Prediction of 6 minutes endurance run at 17 years from tests and measurements at 12 and 13 years.

	Model	Predictors	% explained variance	Total % explained variance	SEP (cm)
From 12 years	Track events	6' run	35.8	35.8	194
	+ Motor Perf.	Arm pull	5.3	41.1	186
	+ Somat. Dim.	Subscap. Skinf. & calf circumf.	13.5	54.0	163
From 13 years	Track events	6' run	49.5	49.5	172
	+ Motor Perf.	Bench Press	4.7	54.0	164
	+ Somat. Dim.				
	+ Progr. (Δ) track				
	+ Progr. (Δ) motor perf.				
	+ Progr. (Δ) growth	Biceps skinf., biacrom. epicond. femur & biiliac.	17.2	71.4	129

Progr. (Δ) indicates the progress in scores (delta) from 12 to 13 years of age

DISCUSSION

To our knowledge very little is known about tracking in sport specific events. Compared to physical fitness test results (Beunen, *et al.* 1979; Ellis, *et al.* 1975; Espenschade, 1940; Malina, 2001, Rarick & Smoll, 1967) tracking in the four track and field events (high jump, shot put, 60 m sprint and 6 minute endurance run), are fairly high ranging from $r = 0.55$ for high jump at 13 years to $r = 0.70$ for 6 minute endurance run at 13 years. Furthermore this longitudinal study demonstrated clearly that traditional physical fitness tests and somatic dimensions added significantly to the explained variance in performance in these track and field events at 17 years. The total explained variance of the track and field events observed at 17 years is surprisingly high ranging from $R^2 = 0.52$ for shot put at 12 years to $R^2 = 0.73$ for 60 m sprint at 13 years.

This biological approach demonstrated that track and field performances in late adolescence are, to a reasonable degree, predictable by the additive contribution from track and field performances, motor performances, somatic dimensions, performance progression and somatic growth in early adolescence (12 to 13 years). From the respective standard errors of prediction however (tables 1-4), it is clear that these errors are too large to permit accurate individual predictions. But, these results clearly demonstrate that the inclusion of classical somatic dimensions, physical fitness tests and to some extent skeletal maturity in the identification programs of talented youth, even before the adolescent growth spurt, makes perfect sense.

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AGE AT MENARCHE IN ATHLETES: INTERACTIONS AMONG CENTRAL MECHANISMS

Alan D Rogol

INTRODUCTION

It is indeed and honor and privilege to dedicate this chapter to Robert. M. Malina, Ph.D. I have chosen a subject upon which Bob has written extensively; that of menarche in athletes. Rather than take the "usual" approach and just catalog the age at menarche in various sports and the sub-disciplines within them (many, including himself, have done that extensively), he has taken the scientific/sociologic approach noting that these are young women first, and then athletes. He has extensively studied the effects of sibship, birth order, socio-economic class, etc, as covariates for the training time (volume), and intensity of that training [as reviewed in (Malina, *et al*, 2004)].

I shall not merely point out the multiple studies that Bob has done or reviewed, but shall emphasize the great variability of age at menarche among all adolescents before moving to an experimental basis likely accounting for secondary amenorrhea among adolescent athletes. The latter because it likely informs us about menarche as well, although this pivotal event in an adolescent girl's life has not been as extensively studied. I shall end with some more speculative findings in the discipline of hypogonadotropic hypogonadism, for the data presented point to variability in genes than affect both gonadotropin-releasing hormone (GnRH) physiology and the hypothalamic regulation of appetite. An intriguing hypothesis is that any variety of stress, in this case high energy exercise in the presence of diminished eating, and perhaps activation of the hypothalamic-pituitary-adrenal axis, may have an intensified effect on the reproductive axis (luteal phase defect and secondary amenorrhea, and by analogy, primary amenorrhea) in those women with heterozygous alterations in one of the several affected genes (Mitchell, *et al*, 2011; Caronia, *et al*, 2011).

Data for the age at menarche are simply descriptive (McIntyre and Kacerosky, 2011). They do account for variability within the specific group studied without attribution for the breadth of that variability. It should be noted that menarche is a very late event within pubertal maturation, lagging by several years the re-initiation of pulsatile GnRH (and thus luteinizing hormone, LH) secretion, the phases of follicular development, the growth spurt and external indicators of adolescent maturation-breasts and the addition and redistribution of body fat. Although puberty progresses in an orderly fashion, there is much variability in its onset, progression and completion (beyond menarche). However, once entrained the variability between stages (*tempo*), although still present, is less. Most girls will experience menarche between 2 and 2.5 years after breast budding, although some of those having breast budding early will have a more desultory progression to menarche (Styne & Grumbach, 2004). They may show breast budding 2 or 3 years earlier than average, but menarche only a few months before the median age of menarche for that ethnic/racial group (Rosenfield, 2009)

Utilizing data from the mid-1970's to the mid-1990's, as summarized by Malina, et al (2004) the median age at menarche for North American girls was approximately 12.4 years with a breakdown of 12.1 years for Blacks, 12.5 years for Mexican-Americans, and 12.6 years for Whites. These are reference data from extensive cohorts obtained from multiple National Health and Nutrition Examination Surveys (NHANES) studies and individual studies such as the Bogalusa Heart Study (Anderson, *et* al, 2003; Freedman, *et* al, 2002; Wattigney *et* al, 1999). Within Europe there is an extensive north-south gradient with median ages at menarche varying from 12.7 to 13 years in Sweden to 12.4 to 12.7 years in Italy [summarized in Malina, et al (2004)].

Over the past 150 years there has been a secular trend for the lowering of age at menarche moving from approximately 17 years to a relative plateau over the past 50 years, at least in the more developed portions of the world, of about 12.5 years (Wyshak & Frisch, 1982, Wattigney, *et al*, 1999). There are likely multiple and intertwining reasons for this decline and they include better nutrition and clean water, eradication of many infectious diseases, and improvements in overall health status. The psychological impact of earlier maturation has not been well studied, but there is seemingly a greater disparity between physical maturation and social/emotional development, recently (Hillard, 2008). In addition there is the potential for adverse health consequences on conditions such as breast cancer.

AGE AT MENARCHE IN ATHLETES

Professor Malina has extensively studied and written about this subject from the methodologic (prospective or longitudinal; *status quo*; and the retrospective) point of view. The first two are to be desired, but often do not account for the "elite" status in many younger girls or those who drop out during the trajectory toward elite status—thus having bias toward those adolescents who continue to train at high levels of energy expenditure. The retrospective sets of data are most prominent, for these studies are the "easiest" to perform, but have the potential for error of recall, likely greater the longer the time interval between the event (menarche) and when the adolescent is asked for the date of menarche. It may prove useful in such studies to corroborate the date with the athlete's mother.

A snapshot summary has been presented by Malina et al (2004) showing the median and 95 % confidence intervals for non-athletes in the studies reviewed (13.0 ± 1.0 years) with 95 % CI (11.0 to 15.0 years). Athletes in various sports are compared against that background with the greatest delays in gymnasts and ballet dancers and perhaps, slight acceleration in rowers and track and field athletes. These are of course global reference estimates without breaking down individual disciplines within, for example, track and field. As expected the aesthetic sports where high volumes of exercise are paired with diminished nutrient intake to satisfy the linear physic expected, for example ballet and diving, show on average, the greatest delay in menarcheal age. As noted by Malina, et al (2004) the sample sizes of adolescent athletes are generally small.

Longitudinal studies have even smaller numbers of girls and are potentially confounded by selective exclusion or drop out begging the question of selection for later maturing girls (more below re: gymnasts) or whether earlier maturing adolescents selectively drop out of gymnastics, ballet and other aesthetic sports. For example, artistic gymnastics is so selective that the elite athletes may approximate 0.1 % of those that partake in the sport [Malina, *et al.,* 2011]. Adolescents who compete at the International level are very significantly smaller and lighter than those of non-elite status and even more so compared to a non-athletic cohort. However, one must consider many more attributes of these elite adolescent athletes - their parents are shorter than average and the girls themselves are shorter than average for their age even before they began to train (Malina, *et al*, 2011). The growth and maturity characteristics differ among those who persist in the sport and those who drop out. Summarizing four small cohorts of female artistic gymnasts from Poland, Switzerland, Belgium, and Canada (Malina, *et al*, 2011; Claessens, *et al*, 1999; Roupas & Georgopoulos, 2011) found that girls who persisted in their training and competition were shorter on average at 12-15 years than those who dropped out. In contrast those who persisted were lighter throughout the age range. Those who persisted with training, reached peak height velocity late and attained menarche only slightly later; however, the sample sizes were very small.

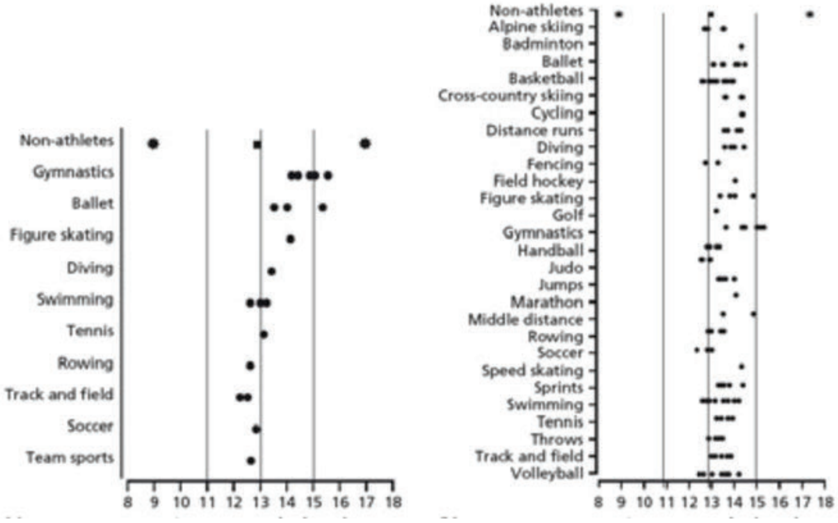

Figure 1. Mean ages at menarche in adolescent athletes grouped by sport: longitudinal and status quo studies (left), retrospective studies (right).

HYPOTHALAMIC-PITUITARY-GONADAL (HPG) AXIS

The hypothalamic-pituitary-gonadal axis is active during the latter two-thirds of fetal life in both sexes. At birth the abrupt disconnection of the placenta markedly diminishes the levels of placental-derived estrogens with immediate consequences of these lower levels on the hypothalamus and pituitary. During neonatal/infancy maturation in boys there is a well-described pattern of gonadotropin [predominantly luteinizing hormone (LH)] and testosterone levels. The previously suppressed gonadotropins [LH and follicle-stimulating hormone (FSH)] are suddenly released from negative feedback as estradiol levels decrease from birth. During the first few weeks of life LH and FSH levels increase followed by an increase in testosterone over approximately the first 12 weeks of life. This "mini-puberty" wanes to be followed by the juvenile "hiatus", which itself ends with the onset of pubertal maturation (Fuqua & Rogol, 2011).

The mean level of FSH is clearly higher in the female and remains elevated over the childhood baseline for approximately 2 years. The consequences of this are raised levels of estradiol. It is at these times (6-24 months) that girls may have thelarche (appearance of glandular breast tissue), which regresses after the second year and remains "suppressed" until the re-awakening of the HPG axis as pubertal maturation unfolds (Fuqua & Rogol, 2011).

The first external sign of physiological puberty is most often thelarche. For this to occur there had to have been a re-awakening of the HPG axis where the very low concentrations of estradiol are no longer capable to restrain the pulsatile release of GnRH. The pituitary is sensitive to the frequency and amplitude of these GnRH pulses and responds with pulsatile LH and FSH release, the composition of the mixture depending on the frequency of the GnRH pattern (Fuqua & Rogol, 2011).

It is intriguing to note an inverse relationship between low birth weight and age of pubertal onset as well as menarche. In those with low birth weight, but subsequently become obese (BMI > 95th centile) menarche is advanced by approximately 6 months (McCartney, *et al*, 2009).

Luteinizing hormone induces the follicle to produce precursors to estradiol whereas FSH induces the enzyme aromatase to synthesize these precursors (androgens) into estrogens. Menarche occurs at least a year beyond continuously increasing estradiol levels and likely an alteration in negative feedback on the hypothalamus permitting a small window of positive feedback [increasing levels of estradiol lead to increases in LH secretion (ovulatory spike)], ovulation, and the formation of the corpus luteum. Obesity has an effect on the reproductive axis by perhaps having an earlier start of puberty, but often a not so early menarche given the higher levels of testosterone and lower levels of sex hormone-binding globulin, yielding higher levels of free (biologically active) testosterone (McCartney, *et al*, 2009). Just the opposite occurs with the thin athletes with a later start of activation of the HPG axis and the nutritionally-activated signals. This leads directly to an interaction of the signals of the HPG axis and those of appetite (satiety) as noted below.

APPETITE-SATIETY

Regulation of body weight is a precise, clearly complex, process that keeps caloric intake balanced to expenditure within an error range of approximately 1.25 % (Yanovsky, et al, 2000). There are a series of inputs into the central nervous system, likely integrated in multiple nuclei of the hypothalamus. These signals are hormonal, metabolic and neuronal and detect and alter the delicate balance of total energy to permit normal physiologic function (including reproduction) and body weight over years and decades. For women the issue of reproductive competence is closely allied with the total energy balance. A woman can survive famine more easily, if she is not reproductively competent. If the reproductive system can be dampened only to reawaken at times of positive overall energy balance, this is salutary for preservation of the species - fecundity during times of nutritional adequacy and infertility during times of critical caloric availability (van der Walt, *et* al, 1978).

This is clearly the case for the hunter-gatherers of the northwestern Kalahari Desert (van der Walt, *et al*, 1978). It is only recently that some of the neuroendocrine mechanisms have been unraveled. Functional hypothalamic amenorrhea (FHA) and its subset in athletes are characterized by hypoestrogenemia, in the presence of low or normal concentrations of gonadotropins without any known (medical) cause. Athletes with FHA are of low body weight, obtain sub-balance amounts of nutrients and exercise extensively (Chou, *et al*, 2011). As expected for their low subcutaneous fat mass, the leptin levels are low. Although the balance of orexigenic (for example, NPY acting through PYY receptors and anorexigenic hormones (for example, pro-opiomelanocortin, POMC) should be tilted toward food intake, these women do not increase their caloric intake to balance the energy output (Russell, *et al*, 2011).

LEPTIN DEFICIENCY

Children with congenital leptin or leptin receptor deficiency are stark examples of the importance of leptin action for energy balance. Girls with either gene deficiency (*LEP* or *LEPR*) are markedly obese even within the first year of life and have delayed puberty in the second decade. Leptin treatment of girls with *LEP* deficiency markedly alters the appetite, permits significant weight loss and entry ("permissive") and progression through puberty (Farooqi, *et al*, 1999, 2007). More recent data noting central action on appetite centers are summarized by Farooqi (2010).

Leptin activates the POMC neurons and inhibits Agouti-related peptide (AgRP)/NPY neurons within the arcuate nucleus of the hypothalamus to stimulate feeding—in fact this has been shown in female runners with HA—infusions of leptin (Welt, *et al*, 2004) or chronic administration of metreleptin (a longer-acting analog of leptin) have reversed HA in some of the athletes (Chou, *et al*, 2011). Loucks and colleagues have noted that the HPG axis of adolescents (younger gynecological age) is more susceptible to net energy decrements than in the gynecologically older woman (Loucks, *et al*, 2006).

OVARIAN CYCLES AND HYPOTHALAMIC AMENORRHEA

Thus, it does not seem such a leap of logic to suspect that the very early ovarian cycles of the pre-menarcheal adolescent may be quite sensitive to the combination of high energy expenditure, sub-sufficient caloric intake, and stress which might delay (or prolong) adolescent maturation, including menarche. Additionally, many elite artistic gymnasts, for example, conform to the growth and maturational characteristics of short, delayed girls [and their families (Malina, *et al,* 2011)]. It is not so surprising that these adolescent athletes may have the greatest delay in their maturational trajectory.

An additional factor may involve mutations in genes that control energy balance and the HPG axis. One might consider the genes which in their homozygous form cause idiopathic hypogonadotropic hypogonadism (IHH) - that is, permanent HH (Mitchell, *et al*, 2011) may in their heterozygous form delay menarche or increase the susceptibility to environmental factors that might lead to FHA (Carmina, et al, 2011). In a group of women with HA (N=55) including some who exercised more than 5 hr/week, weight loss and subclinical eating disorders, 7/55 (13%) were noted to have heterozygous mutations in a number of genes, fibroblast growth factor 1 receptor (*FGFR1*), prokineticin receptor 2 (*PROKR2*), Kallmann syndrome 1 sequence (*KAL 1*) GnRH receptor 1 (*GNRHR*). No mutations were found in 422 control women with normal menstrual cycles (Carmina, *et al*, 2011). These genes play fundamental roles in GnRH ontogeny and physiology including alterations in the pulsatile release of GnRH. Several of these, for example, *FGFR 1* (Sun, *et* al, 2007) and *PROKR 2* (Gardiner, *et al*, 2010) signaling also affect eating behavior, at least in mice.

An intriguing hypothesis that may account for many of these findings is that the delayed menarche in some of the adolescent athletes is due to a combination of genetic factors leading to a small, delayed maturational phenotype and low caloric intake, and the stress of training and competition perhaps modified by heterozygous alterations in a small subset of genes that affect hypothalamic function for GnRH physiology and energy balance. Whatever the predominant reasons for delayed menarche in adolescent athletes, it is clear that it is not a single cause and likely a series of causes, individual to each adolescent.

SUMMARY

What has Bob Malina taught me about the subject of age at menarche in athletes? It is to use the scientific method to tease out other (perhaps confounding) factors within the girl/adolescent athlete that might affect the simple relationship of athletic training/competition, however quantitated. His insight into the sociological and psycho/social aspects of the young woman's life is merely his way of making a very simple statement: the athlete is a girl/adolescent first with the sum total of her genetics and daily/family life upon which her athletic training/competition is superimposed.

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THE DIGIT RATIO (2D:4D) AND SPORT PERFORMANCE:
A study on elite female gymnasts

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Maarten W. Peeters

INTRODUCTION

The 2D:4D digit ratio is the ratio between the second (index) finger and the fourth (ring) finger lengths. This ratio represents an individual difference variable putatively related to prenatal gonadal hormonal exposure. A lower 2D:4D ratio is indicative of relatively higher prenatal testosterone than estrogen levels, which means that men may have, on average, lower digit ratios than women. So, the 2D:4D may represent sex differences (Manning, 2002). The digit ratio is also related with psychological characteristics like assertiveness and aggression (Manning, 2002), with the onset of menarche (Matchock, 2008, Helle, 2010), with homosexuality (Manning, 2002), with success among financial traders (Coates *et al.,* 2008), and with neck circumference (Fink *et al.,* 2006a). In addition, in different studies associations between 2D:4D and sporting ability were investigated (Hönekopp *et al.*, 2006; Manning & Taylor, 2001; Tester & Campbell, 2007; Manning *et al.,* 2007). The hypotheses set up in these studies were that a lower digit ratio is related to better sport abilities and better motor performance, in both males and females. Results of the studies are contradictory and not unequivocal and difficult to compare because of the use of different procedures to measure the digit lengths. Also, in many studies sporting abilities were not measured objectively, but based on information reported by the subjects themselves. In addition, published data on sporting ability and 2D:4D has mainly focused on male participants, and most of the studies focused on physical fitness or sport ability in general and not on one specific sport. To our knowledge there is no study available that focuses on a large sample of female gymnasts of world class caliber to investigate the association between the digit ratio and artistic gymnastic performance. The aim of this study was to compare the 2D:4D ratio of world-top female artistic gymnasts with the 2D:4D ratio of sedentary reference girls. It is hypothesized that the group of elite gymnasts have a significant lower digit ratio compared to the reference group.

METHODS

Samples

Gymnast sample. The sample (n = 145) of elite female gymnasts was a sub-sample of the participants of the 24th World Championships Artistic Gymnastics held at Rotterdam, The Netherlands, in 1987 (Claessens *et al.,* 1991). All gymnasts were of Caucasian ethnicity. Their chronological age varied from 13.2 to 21.8 years, with a mean age of 16.4 ± 1.6 years.

Reference sample. Girls from the Leuven Growth Study of Flemish Girls (Simons *et al.*, 1990) were used as the reference sample. Based on three conditions a sample of 178 girls was selected: (1) girls must be 13 years and older; (2) only girls for whom an X-ray of the left hand was available were selected; and (3) and girls in the reference sample must be sedentary, i.e. not practice any sports apart from the mandatory 2 hours/week of physical education classes in school, to be sure of a significant difference in sporting ability between the two samples. The mean chronological age of the selected girls was 15.7± 1.3 years, varying from 13.2 to 18.4 years.

Anthropometric dimensions

The following measurements were taken: weight; height; biacromial and bicristal breadths; humerus and femur widths; biceps and calf girths; and triceps, subscapular, supraspinale, and calf skinfolds. Body mass index (BMI) was calculated as weight (kg) / height (m^2). All measurements were taken by well-trained observers according to the measuring procedures as described by Claessens *et al.* (1990).

Body ratios of sexual dimorphism

Two *masculinity indices* were calculated. (1) The Bayer-Bailey ratio relates the breadth of the hips to that of the shoulders: IMAS = (bicristal breadth-cm / biacromial breadth-cm) x 100; and (2) the androgyny index according to Tanner (IADR): (3x biacromial breadth-cm) - (bicristal breadth-cm). Both indices are useful indicators of sex differences in the proportional relationship of the shoulders and hips. (Malina, 1995; Claessens *et al*., 2008).

Somatotype

The three somatotype components endomorphy (ENDO), mesomorphy (MESO) and ectomorphy (ECTO) were anthropometrically determined according to the Heath-Carter technique. For a detailed description how the three components were calculated reference is given to Claessens *et al*. (2008).

Skeletal age

Skeletal age (S-age) was assessed on an X-ray of the left hand and wrist according to the Tanner-Whitehouse II method (TW2L). Detailed information is given by Claessens *et al*. (2008).

Measuring 2D and 4D lengths

> *Measuring procedure.* Radiographs from the left hand of all the subjects of the two samples were available to measure and calculate 2D:4D. The lengths of the second and fourth finger were measured from the proximal end of the proximal phalanx to the distal tip of the distal phalanx using a caliper accurate to 0.1 mm (John Bull British Indicators LtD, England). Digit lengths of each sample were measured by two raters. The mean of the two raters was taken as the final measurement.

Reliability study. Before measuring all X-rays, a reliability study was conducted by three different raters. This study consisted of the measurement of thirty left-hand X-rays twice by each rater in a test and re-test manner. Interobserver measurement repeatabilities for 2D:4D ratios were assessed with intraclass correlation coefficients (ICC; Voracek *et al.,* 2007). The intraclass correlation for interrater reliability showed a reliability of 0.98 (ICC 3.1). ANOVA did not show any significant difference for 2D:4D between the raters. The technical error of measurement for all raters was <0.001 for all raters for 2D:4D. So it can be concluded that all measurements of 2D:4D were measured reliably.

Statistical analyses

Differences in 2D:4D and in anthropometric characteristics between the sample of elite gymnasts and the reference group were analyzed by means of a two-tailed t-test. An ANCOVA was used to compare the two samples for each variable with age as the covariate. The relationship between 2D:4D ratio and anthropometric characteristics for each sample were calculated by Pearson Product Moment correlation coefficients. The Statistical Analysis System program 9.2 (SAS Institute, 1988) was used to analyze the data.

RESULTS

Descriptive statistics (mean ± SD) of all variables are given in Table 1.
Chronological age (C-age) of the gymnasts is significantly higher compared to that of the reference sample, whereas their skeletal age (S-age) is significantly lower. Height, weight and BMI of the elite gymnasts are significantly lower compared to the reference sample. Also differences in somatotype can be observed. Gymnasts are more mesomorph and less endomorph compared to reference girls. As expressed by the Bayer-Bailey index (IMAS) gymnasts have, on average, broader shoulders relative to their hips, compared to the reference sample. For both groups a mean of 0.92±0.0 for the 2D:4D ratio is observed indicating no difference in the digit ratio between the gymnasts and reference samples.

Because of the significant difference in chronological age between the two samples, a multiple ANCOVA, with C-age as covariate, was conducted. The adjusted means of the 2D:4D ratio and of the anthropometric characteristics are given in Table 2.

Table 1. Descriptive statistics

	Reference girls (n=178)		Gymnasts (n=145)		t-value
	Mean	Sd	Mean	Sd	
C-age (years)	15.7	1.3	16.4	1.6	-3.75**
S-age (years)	14.9	1.1	14.6	1.2	2.59*
2D:4D	0.92	0.02	0.92	0.02	1.88
Height (cm)	162.2	6.4	155.1	6.5	9.87**
Weight kg)	54.1	9.0	46.2	6.2	9.43**
BMI (kg/m^2)	20.5	3.0	19.1	1.6	5.42**
ENDO	3.9	1.2	1.7	0.6	21.89**
MESO	3.0	0.2	3.7	0.6	-6.93**
ECTO	3.0	1.3	3.1	0.8	-1.18
IMAS	76.6	4.7	72.8	3.6	8.05**
IADR	77.2	5.0	76.5	4.5	1.47

**$p\leq0.01$; *$p\leq0.05$

Table 2. Adjusted means of 2D:4D and of the anthropometric characteristics

	F-ratio	LSMEAN ref. girls (n=178)	LSMEAN gymnasts (n=15)
2D:4D	3.55	0.92	0.92
Height (cm)	119.26**	162.5	154.7
Weight kg)	118.68**	54.7	45.5
BMI (kg/m^2)	39.80**	20.7	19.0
ENDO	434.46**	4.0	1.7
MESO	36.63**	3.0	3.6
ECTO	3.95*	2.9	3.2
IMAS	67.74**	76.7	72.7
IADR	4.96*	77.4	76.2

**$p\leq0.01$; *$p\leq0.05$

Although all variables were adjusted for C-age, it is observed that all the adjusted mean differences for the anthropometric variables between the two samples are still significant. For both samples an adjusted mean of 0.92 for the 2D:4D ratio is observed.

Correlations between the 2D:4D ratio on the one hand and C-age, S-age, and the anthropometric characteristics on the other hand are low and not significant, ranging from $r = 0.10$ (with BMI) to $r = -0.14$ (with height) in the reference sample, and from $r = 0.11$ (with height) to $r = -0.11$ (with ENDO) in the gymnasts sample.

DISCUSSION

The mean value of 0.92 for the 2D:4D ratio found for the reference sample is very low compared to the female population norms. An inspection of the right-hand 2D:4D ratio from a sample of 531 females showed a mean 2D:4D ratio of 1.00 (SD=0.03) (Manning, 2002).

A possible explanation for this low mean value observed for our reference sample is that the digit lengths were measured on X-rays in contrast to the measuring procedures used in many other studies. Mostly digit lengths were done on photocopies, printed scans or directly from the hand. Previous studies have compared different methods of digit ratio measurement (Kemper and Schwerdtfeger, 2009; Allaway *et al*., 2009; Manning *et al*., 2005; Manning, 2002). The fact that measurements on X-rays seem to yield lower digit ratios may be partially explained by the fact that measurements made on soft tissue or images of the soft tissue on the hand are taken approximately halfway along the proximal phalanx whereas bone measurements began at the proximal end of the phalanx (Manning, 2002). This hypothesis has not been subject to research yet but could possibly provide an explanation and may lead to standardization for the measurement of the 2D:4D ratio. At the same time when measuring on photocopies, printed scans or directly on the hand, the soft tissue is also measured whereas when measuring finger lengths on X-rays only the bone length is recorded. In a study of Paul et al. (2006a), concerning the heritability of the 2D:4D ratio, measurements of the finger lengths were also made on X-rays. In a sample of 456 female twin pairs a mean 2D:4D ratio of 0.92 (SD=0.001) was observed for both hands, which is similar to the 2D:4D ratio found in the present study. Manning *et al*. (2000) had already observed that measurements of 2D:4D from photocopies and radiographs are significantly correlated, although mean radiograph-derived 2D:4D showed lower ratios than those from photocopies and showed less sexual dimorphism. It can thus be stated that the low 2D:4D ratio of 0.92 found in our reference sample is the result of the fact that the measurements were done on X-rays.

For the gymnasts' sample, we hypothesized a lower 2D:4D ratio, compared to the value found for the reference sample, but no significant difference between both mean ratios was observed, 0.92 for both samples. So the 2D:4D ratio, on average, may not be a discriminating factor for artistic gymnastic performance. This is consistent with the findings of a study of Paul *et al.* (2006b) about the relationship between 2D:4D and sporting ability across a range of 12 sports in a sample of 607 female participants. The subjects were asked to give the highest competitive level in their sport activity on a five-point scale, with 'social participation only' as the lowest level (=1) and 'national level' (=5) as the highest level. Measurements of the digit lengths were done on X-rays. The overall age-adjusted level achieved in any sport was significantly negatively associated with mean 2D:4D. But, when analyzed separately, mean digit ratio was only significantly associated with running level. There was no significant relationship between 2D:4D and the level in a subsample of female gymnasts. A mean left-hand 2D:4D ratio of 0.93±0.02 was found, which is similar to the value of 0.92 found in the present study.

Although the findings of our study are consistent with the findings of Paul *et al.* (2006b), they are in contrast with previous studies in which significant relationships between 2D:4D and sporting ability in females were observed. The 2D:4D ratio is moderately related to performance in endurance running of young adults with correlations varying from r = 0.30 to r = 0.50 (Manning *et al*., 2007). In contrast little evidence is found for the relationship between 2D:4D and acceleration and strength. Correlation coefficients between 2D:4D and sprinting speed were weak (r = 0.15; p = 0.02) in a study of Manning & Hill (2009). van Anders (2007) found no significant association between 2D:4D and grip-strength in a sample of 99 women (mean age 23.76±5.66 years). This suggests that the widespread relationship between 2D:4D and sport performance may have more to do with aerobic efficiency than with strength and acceleration (Manning & Hill, 2009). It is possible that strength and acceleration are two more important modifying determinants in artistic gymnastic performance, compared to aerobic capacity. The physical capacities that serve as a basis for gymnastic talent are speed, quickness, flexibility and strength (Brown 2001). Gymnasts do not perform competitive routines longer than 90 seconds. Therefore, the oxidative energy system is probably not a dominant energy system for gymnastics. The anaerobic dominance of gymnastic performance is supported by several studies (Sands *et al*., 2003).

The masculinity indices and somatotype are, just like the 2D:4D ratio, determinants of sexual dimorphism. Like men have on average a lower 2D:4D ratio, men have on average a higher mesomorphy component, a lower endomorphy component, and a lower Bayer-Bailey masculinity index, compared to women. As expressed in several previous studies (Claessens *et al*., 1991) elite female gymnasts demonstrate a more 'masculine' body morphology compared to age-related reference girls. This is also demonstrated in the present study. The sample of elite gymnasts has a significant lower masculinity index (IMAS), which means that the gymnasts have on average broader shoulders relative to their hips, compared to the reference girls, 72.8 and 76.6 respectively. When looking to the body as a 'Gestalt', a significant difference was found in somatotype between the two samples. Gymnasts demonstrated on average a somatotype of 1.7/3.7/3.1 compared to an average somatotype of 3.9/3.0/3.0 of the reference sample. Elite gymnasts are characterized by an ecto-mesomorphic somatotype whereas reference girls are characterized as meso-endomorphic. Mesomorphy is characterized by the predominance of muscle, bone and connective tissue, whereas endomorphy describes the degree of roundness and fatness of the body. Although both samples can be sexually discriminated on the basis of anthropometric characteristics, the 2D:4D, ratio does not.

In addition, when testosterone is negatively related to 2D:4D (Manning, 2002), it is expected that more male forms of 2D:4D would correlate with more male forms of anthropometric characteristics like masculinity indices and somatotype. Some previous studies have investigated the relationship between 2D:4D and anthropometric characteristics. Fink *et al*. (2003) investigated the relationship between 2D:4D with body mass index, waist-to-hip ratio and waist-to-chest ratio. Some evidence was found that 2D:4D also correlates with indices of sexually dimorphic traits of the human body. Body fat distribution was in that study measured by the waist-to-hip ratio. However, no significant associations were observed for male and female 2D:4D and the waist-to-hip ratio. In females, neither a significant relationship between body mass index and 2D:4D was found. A higher value of 2D:4D correlated significantly with a lower value of the waist-to-chest ratio. This is consistent with the literature as oestrogens should largely influence chest circumference in females. In a study of Gallup *et al.* (2007) the relationship between handgrip strength and three measures of body morphology (shoulder-to-hip ratio, waist-to-hip ratio, 2D:4D) was investigated in a sample of 82 male and female college students. A significant positive relationship between 2D:4D and waist-to-hip ratio in females could be observed. No significant relationship between handgrip strength and 2D:4D was found. Because mostly other body ratios of sexual dimorphism were used in the literature compared to those used in the present study, comparison of results is difficult. Although most of the anthropometric characteristics used in the present study were discriminating factors between the gymnasts and the reference samples, no significant correlations were observed between 2D:4D and these anthropometric characteristics.

The present study is to our knowledge the first study that investigated the relationship between 2D:4D in a large sample of female gymnasts of world-class level , by comparing their 2D:4D ratio with that of a reference sample of sedentary girls. The high level performance of the gymnast sample is based on the fact that all gymnasts participated at the World Championships Artistic Gymnastics held in Rotterdam, 1987 (Claessens *et al.*, 1991). The reference sample consisted of girls who were all sedentary. There was thus an obvious difference in sporting ability between both groups. In many studies about the relationship between sporting ability and 2D:4D, the level of sporting ability was based on information reported by the subjects themselves. Even, in the present study, all anthropometric variables were measured objectively, whereas in a lot of previous studies data (e.g. height and weight) were reported.

A possible limitation of our study is that all measurements of the digit lengths were taken on the left hand. In most studies the digit lengths were taken on the right hand to calculate 2D:4D. This is based on the fact that results of previous studies have demonstrated that sex differences in 2D:4D and correlations of 2D:4D with target traits are more pronounced for the right hand than for the left hand. Testosterone-dependent physical traits tend to be more strongly expressed on the right side of the body compared to the left side (Manning, 2002).

In conclusion, although other anthropometric characteristics of sexual dimorphism were significantly different between the two samples, the present study cannot discriminate sedentary women/girls from World-class gymnasts using the 2D:4D ratio. Furthermore, no significant correlations were found between 2D:4D ratios and anthropometric and age characteristics, both chronological and skeletal.

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BIG LEAGUE DREAMS: A BRIEF LITERATURE REVIEW AND COMMENTARY ON THE YOUTH BASEBALL PLAYER

JC Eisenmann

Bob Malina, left side of priest, and his father and coach, Joe Malina, right side of priest.

INTRODUCTION

This paper provides an overview of the literature on the youth baseball player. I chose this topic for the Festschrift because aside from our interest in child growth, maturation and physical activity, Professor Malina and I share a passion for baseball and the study of the child and adolescent athlete. His interest in baseball stems from stickball and the New York City Police Athletic League; and mine from riding my bicycle with my baseball glove hanging from the handlebar looking for a neighborhood "pickup" game (on a related note, we have engaged in conversations of the lack of unstructured play among contemporary youth). We have both coached our sons' youth baseball teams. Interestingly, he is a New York Mets fan, while I am a Yankees fan. It is likely that Professor Malina's interest in the game of baseball influenced two of his first papers on throwing (Malina, 1968; 1969). Finally, it is perhaps fitting that I am writing this chapter in October – the month of the Major League Baseball playoffs and the World Series.

The author coaching Little League baseball, May 2005.

THE SCIENTIFIC AND MEDICAL LITERATURE ON YOUTH BASEBALL

A search of PUBMED (http://www.ncbi.nlm.nih.gov/pubmed) was conducted on October 5, 2011 and revealed 1882 papers using the term 'baseball'. Limiting the search to 0-18 year olds resulted in 684 papers; however, many of these papers focused on biomechanics and/or injuries, mainly associated with throwing (i.e., shoulder and elbow injuries, etc.). When the search term 'injury' was added, 404 papers were identified thus 59% of the papers on baseball in youth are related to injury. Since I am neither a biomechanist nor an expert in athletic injuries, I will only summarize some of this literature. Obviously, additional research is warranted on the aspects of the physical growth and maturation of the young baseball player. Additional sources were provided by searches of Google and GoogleScholar.

"THE NATIONAL PASTIME": PARTICIPATION RATES

Baseball has long been referred to as the national pastime in American culture. Therefore, it seems many youth (mainly boys but some girls) would participate in the sport. A few papers have indicated that baseball is a common physical activity preference of U.S. children and adolescents. For example, baseball was the fifth most common activity of 6-8th grade (11-14 year olds) boys in North Carolina behind football, basketball, bicycling, and running (Harrell et al., 2003).

Little League baseball is the most widely known youth baseball organization probably because the U.S. regional qualifying games and the entire Little League World Series are televised on ESPN and ABC. Little League is actually the world's largest organized youth sports program with nearly 180,000 teams across the world (www.

littleleague.org). In 2010, about two million youth played in the U.S. compared to about 2.5 million in 1996, an overall decline of 25%. Likewise, the National Sporting Goods Association also reports that the number of youth aged 7 to 17 playing baseball fell 24% from 2000 to 2009. The only growth in youth baseball participation occurred in those who play more than 50 times a year (i.e., sport specialization – see section below). At the high school level, there are about 15,786 programs in the U.S., a number that ranks third among boys' sports.

In general, youth sport is an important outlet for physical activity in children and adolescents (Wickel & Eisenmann, 2007). Few studies have documented the energy cost of playing baseball. Recently, Leek et al. (2011) documented accelerometer-determined physical activity during organized baseball practices in youth aged 7-14 years in San Diego County, California. The overall mean for moderate-to-vigorous physical activity was about 50 minutes (approximately 50% of practice time; mean practice time ranged from 35 to 217 minutes) with about 30% of participants meeting physical activity recommendations (≥60 minutes of moderate-to-vigorous physical activity) via baseball practice. The authors concluded that "The health effects of youth sports could be improved by adopting policies that ensure participants obtain moderate-to-vigorous physical activity during practices". However, it is important to remember that youngsters need to develop skill and learn the game as well – not just partake in moderate-to-vigorous physical activity!

GROWTH AND MATURATION OF YOUTH BASEBALL PLAYERS

In general, there are limited data on the growth and maturation of youth baseball players compared to other sports (Malina, 1994). Two early studies first noted the size and maturity differences of talented young baseball players in the Little League World Series (Hale, 1956; Krogman, 1959). A more recent study corroborated these findings. French et al. (French, Spurgeon, & Nevett, 2007) compared body size of youth baseball players from a local league team and 1995 Dixie Youth World Series teams with U.S. growth charts. In both samples, pitchers, shortstops, and first basemen exhibited larger body size (greater standing height, sitting height, lower limb height, upper limb length) than children who played other positions. The height of local little league players was similar to the median of reference data at ages 7-9 years. The height and weight of skilled players in both samples approximated the 75th percentiles at ages 10-13 years. The results suggest that baseball players exhibit larger body size than the normal population at young ages, and that body size may be an important criterion used by coaches to select and assign young players to certain positions. As for the latter point, Carda and Looney (1994) showed differences in height, weight, lean body weight and somatoplots among Division I collegiate players. Pitchers were found to be taller than infielders and outfielders and displayed more endomorphy and less mesomorphy than the outfielders. Among the infielders, first basemen were taller than second basemen and third basemen while shortstops were found to be taller than second basemen. With respect to weight, first basemen and catchers were found to be heavier than second basemen. The second basemen had less lean body mass than all other infield groups.

Only one longitudinal study of young baseball players could be found (Nariyama, Hauspie, & Mino, 2001). This study included 126 Japanese junior baseball players in addition to 39 basketball, 83 soccer, and 53 volleyball players, and 36 non-athletes. On average, baseball players were 0.2-0.3 standard deviations above the population mean with the final height being about 2 cm greater in baseball players than non-athletes. In addition, the mean age at take off (9.8+1.1 yrs), age at peak height velocity (13.1±1.0 yrs) and peak height velocity (9.3±1.2 cm) did not differ between baseball players and controls.

RELATIVE AGE EFFECT

In the early 1980s the observation was made that there are skewed distributions of birth dates in elite hockey players (Barnsley, 1988). Among players in two Canadian elite junior hockey leagues, birthdates decreased in frequency from January (the cutoff date for age groupings in youth hockey) through December. Among professional National League Hockey players, about 40% were born in the first quarter of the year, 30% in the second, 20% in the third, and less than 10% were born in the final quarter. Further investigations in a variety of chronological age grouped team sports (i.e., soccer) have reported that elite young athletes were more likely born in the early months of the selection year, a phenomenon known as the *relative age effect*.

As for baseball, the magnitude of the effect among Major League Baseball players is less than that found among other sports like soccer and hockey (Thompson & Barnsley, 1991). However, when examining the data by month instead of quarter that a baby born in the U.S. in August has a 50-60 percent better chance of making the big leagues than a baby born in July. Among (all star) Little League players, there is also a small effect (Thompson, Barnsley, & Stebelsky, 1992).

Cote et al. (2006) have extended this concept to determine whether when (birthdate – i.e., relative age effect) and where (birthplace) an athlete is born influence their likelihood of playing professional baseball. A relative age effect was found, and there was a birthplace bias towards smaller cities with professional athletes being over-represented in cities of <500,000 and under-represented in cities of >500,000. The authors concluded that contextual factors associated with birthplace contribute more influentially than relative age and that these factors are essentially independent in their influences on expertise development.

FUNCTIONAL CAPACITIES AND MOTOR SKILLS IN BASEBALL: GENERAL CHARACTERISTICS AND TRAINABILITY

Baseball is a game that requires the fundamental motor skills of throwing, catching, hitting and running. In baseball vernacular, the "five-tool" player is a complete performer - one who excels at hitting for average, hitting for power, baserunning skills and speed, throwing ability, and fielding abilities (http://en.wikipedia.org/wiki/Five-tool_player). Obviously, success in baseball requires exceptional locomotor, projection (throwing and striking), and reception (catching) skills and muscular strength and explosive/sprint/agility abilities. However, at younger ages it is important that proficiency in these fundamental motor skills are developed so that youngsters can enjoy the game of baseball.

Few studies have specifically documented the functional capacities of youth baseball players. In fact, aside from training studies where strength, etc. were measured at baseline, I could not locate a single paper where the primary purpose was to document the functional capacities and motor abilities of young baseball players. Due to the paucity of data on functional capacities and motor skills in youth baseball players, this section provides a brief overview of the motor skill development of throwing, hitting, and running, and the trainability of these skills.

Throwing

Motor skill development and biomechanics. The description of the motor sequence of the overhand throw has deep historical roots dating to 1938 (Wild, 1938). In addition, sophisticated biomechanical (kinetic and kinematic) descriptions have also been published. In general, the mature (stage 4) movement pattern is described as an opposition of movement as a contralateral forward step is added to previous stages. Basically, the foot opposite of the throwing arm steps (strides) forward in the preparatory phase. The weight of the body is then transferred forward from the rear foot (throwing arm side) to the opposite foot (stride foot) as the hips, trunk and shoulders rotate to the glovehand side of the body. By about age 5-6 years 60% of boys are able to execute the mature throwing pattern (Branta & Haubenstricker, 1984).

Once the mature motor pattern emerges, there is plethora of literature on the biomechanics of throwing, mainly in adults. Much of this interest in overhand throwing mechanics is due to the common occurrence of injuries to the throwing arm (see section on injury below). A three-dimensional biomechanical analysis of pitching technique in 24 adolescents (Nissen et al., 2007) showed the following: Average excursion of motion was: pronation/supination 63±15 degrees, wrist flexion/extension 44±14 degrees, and ulnar/radial deviation 12±4 degrees. Explosive forearm motion occurred between ball release and maximal glenohumeral internal rotation with a peak pronation velocity of 2051±646 degrees$\cdot s^{-1}$. Internal glenohumeral rotation range of motion was 125±13 degrees and mean peak internal glenohumeral rotation velocity was 3343±453 degrees$\cdot s^{-1}$. Thorax and pelvic motion peak velocities and accelerations occurred before the peak elbow varus moment, which occurred at 59% of the pitch cycle. The peak shoulder, elbow, and wrist velocities and accelerations occurred after the peak elbow varus moment. The pelvis squared to the plate at 51±10% pitch cycle and the thorax at 59±7% of the pitch cycle with maximal glenohumeral external rotation at 65% of the pitch cycle and ball release at 78±3% of the pitch cycle.

The author's 15-year old son (Kaleb) pitching, June 2011.

Training studies. To strengthen the throwing arm for either performance (i.e., throwing velocity) or injury prevention, coaches, trainers, and players (and sometimes parents) use several techniques ranging from general resistance training to tubing exercises to throwing programs with weighted baseballs over specified distances, etc. In the adult literature, training studies have been divided into 4 categories: a) specific resistance training with an overload of velocity, b) specific resistance training with an overload of force, c) specific resistance training with a combination of overload of force and velocity, and d) general resistance training according to the overload of force (Van Den Tillaar, 2004). To date, few training studies examining the influence of throwing programs on performance have been conducted in children or adolescents.

A common approach to improving throwing arm strength is "long-toss". This type of program involves throwing at specified distances. Axe et al (1996) developed an age-specific distance-based interval throwing program for Little League-aged athletes (9-12 years) based on a mathematical model from maximal distance and speed measurements. However, the effectiveness of the throwing program was not been evaluated. Only one study (Escamilla et al., 2010) examining the effects of a conditioning program on maximum throwing velocity in young players has been published despite several coaches and commercial facilities offering such programs. In this study, thirty-four 11-15 year old baseball players were randomly divided into control and training groups. The training group performed 3 sessions per week, 75 minutes per session for 4 weeks. The training program consisted of a sport-specific warm-up, resistance training with elastic tubing, a throwing program, and stretching. After the 4-week program, throwing velocity increased from 25.1±2.8 to 26.1±2.8 m·s^{-1} (56.2 to 58.4 mph) in the training group with no change in the control group (from 24.2±3.6 to 24.0±3.9 m·s^{-1}; ≈54 mph) (Escamilla et al., 2010).

Hitting

Motor skill development and biomechanics. Between age 6-7 years 60% of boys are able to execute the mature pattern for striking (Branta & Haubenstricker, 1984). Three-dimensional kinematic and kinetic analysis of adults shows that the hitter starts the swing with a weight shift toward the rear foot and the generation of trunk coil. As the hitter strides forward, force applied by the front foot equal to 123% of body weight promotes segment acceleration around the axis of the trunk. The hip segment rotates to a maximum speed of 714 degrees·s^{-1} followed by a maximum shoulder segment velocity of 937 degrees·s^{-1}. The product of this kinetic link is a maximum linear bat velocity of 31 meters·s^{-1} (69 miles per hour) (Welch, Banks, Cook, & Draovitch, 1995). However, there are differences between adult and youth hitters. Escamilla and colleagues (2009) showed a small number of temporal differences between youth and adult hitters, with adult hitters taking significantly greater time than youth hitters during the stride phase and during the swing. Compared with youth hitters, adult hitters a) had significantly greater lead knee flexion when the hands started to move forward; b) flexed the lead knee over a greater range of motion during the transition phase (31 degrees versus 13 degrees); c) extended the lead knee over a greater range of motion during the bat acceleration phase (59 degrees versus 32 degrees); d) maintained a more open pelvis position at lead foot off ground; and e) maintained a more open upper torso position when the hands started to move forward and a more closed upper torso position at bat-ball contact. Moreover, adult hitters had greater peak upper torso angular velocity (857 degrees·s^{-1}versus 717 degrees·s^{-1}), peak left elbow extension angular velocity (752 degrees·s^{-1}versus 598 degrees·s^{-1}), peak left knee extension angular velocity (386 degrees·s^{-1} versus 303 degrees·s^{-1}), and bat linear velocity at bat-ball contact (30 meters·s^{-1} versus 25 meters·s^{-1}). These adult-child differences, especially the angular velocities, are probably in part due to the differences in body size, neuromuscular strength, and neuromotor recruitment.

Training studies. Szymanski and colleagues (Szymanski et al., 2007a; 2006; Szymanski, Szymanski, Bradford, Schade, & Pascoe, 2007b; Szymanski, Szymanski, Molloy, & Pascoe, 2004) have conducted a series of studies investigating the influence of resistance training and additional supplemental resistance exercises, namely wrist/forearm exercises and rotational medicine ball exercises on muscular strength and bat velocity in high school baseball players. The training programs consist of 3 days per week of periodized full-body resistance exercises (squat, bench press, etc.) along with additional rotational and full-body medicine ball exercises or wrist and forearm exercises for 2 or 3 days per week over 12 weeks. Overall, these studies have shown: 1) a general, periodized resistance exercise program improves muscular strength and bat velocity, 2) a 12-week stepwise periodized training program can significantly increase wrist and forearm strength and linear bat velocity, and additional wrist and forearm training increases wrist and forearm strength beyond general resistance training but increased wrist and forearm strength did not contribute to further increases in linear bat velocity, and 3) rotational medicine ball training 2 or 3 days per week improves rotation strength beyond general resistance exercise and further enhances bat velocity.

Running (Sprinting ability and agility)

Motor skill development. By about 4 years of age 60% of boys are able to execute the mature running pattern (Branta & Haubenstricker, 1984). In general, running speed (40 yard dash time, etc.) improves sharply from 5 to 8 years of age and then continues to improve throughout childhood and adolescence. Depending on if the test involves a standing or running start, some of the improvement may be due to initial reaction time and acceleration. Changes in agility (i.e., shuttle run, etc.) show a similar pattern of change.

Training for speed/agility. Running speed and agility are key attributes to athletic performance in sports such as baseball. In contrast to the literature on training for endurance capacity, few studies have been conducted in youth examining the effects of training for running speed and/or agility and none have been specifically conducted in youth baseball players. To enhance running speed and agility, various approaches have been utilized including repeated sprints of varying distance, plyometrics, and/or resistance training. A comprehensive review of these training methods and studies is beyond the scope of this chapter. In general, these approaches are effective at producing small but significant changes in sprint speed and agility test results in adolescent athletes. Studies in prepubescent children are less extensive so conclusions cannot be drawn.

BASEBALL ACADEMIES AND EARLY SPECIALIZATION

"Baseball Academies" and private lessons. The previous section reviewed the limited published studies on training to improve specific functional capacities and skills required in baseball. Despite the paucity of evidence showing improvement in baseball-related capacities, there are several specialized commercial entities that train/coach young baseball players in terms of skill development and performance. For example, a Google search using 'baseball academy' yielded hundreds of such facilities across the U.S. (i.e., Mountain West Baseball Academy, All Star Baseball Academy, The Baseball Zone, etc.). It is common for these clinics to charge $40-100 per hour for individual hitting or pitching lessons ("personal coaches"). Likewise, many of these facilities or other strength and conditioning-type centers offer programs to improve baseball-specific functional capacities (hitting power, throwing velocity and speed) using various methods or gadgets that lack scientific scrutiny.

The Dominican Republic experience. It is perhaps important to mention here that "true" baseball academies (i.e., boarding schools) are common in the Dominican Republic. According to Major League Baseball, 234 players or 27.7% of the 846 players are foreign born, representing 14 countries and territories. The Dominican Republic leads all with 86 players (37% of foreign born). Currently, 28 of 30 Major League Baseball teams have an academy in the Dominican Republic (mlb.com).

Early specialization. To some extent the type of training described above lends to early specialization in sport. Much has been written about early sport specialization and the related intensive training typically associated with it (Brenner, 2007; Malina, 2010). The main concerns and risks of early specialization center around both physical (overuse injury, overtraining) and psycho-social (burnout, social isolation, overdependence) issues (Malina, 2010). Furthermore, Malina writes that "Commitment to a single sport at an early age immerses a youngster in a complex world regulated by adults, which is a setting that facilitates social, dietary, chemical, and commercial manipulation". And finally, "Early identification of "talent" is no guarantee of success in sport during childhood, let along during adolescence and adulthood."

INJURY RATES IN YOUTH BASEBALL

Although baseball is generally considered a safe activity, it is estimated that there are over 100,000 acute baseball injuries yearly among 5-14-year old U.S. youth (Yen & Metzl, 2000). Compared to youth baseball leagues, injury rates in high school-aged athletes are easier to track due to surveillance systems and coverage of high school events by certified athletic trainers/sports medicine staff. In a nationally representative sample of 100 U.S. high schools for the 2005-2006 and 2006-2007 school years (Collins & Comstock, 2008), there was an estimated 131,555 baseball-related injuries (injury rate of 1.26 injuries per 1000 athletic exposures). The most commonly injured body sites were the shoulder (17.6%), ankle (13.6%), head/face (12.3%), hand/finger (8.5%), and thigh/upper leg (8.2%). The most common injury diagnoses were ligament sprains (incomplete tears) (21.0%), muscle strains (incomplete tears) (20.1%), contusions (16.1%), and fractures (14.2%). Although the majority of injuries resulted in a time loss of <7 days, 9.7% resulted in medical disqualification for the season and 9.4% required surgery.

Ball impact particularly to the chest results in a small but steady number of fatalities each year, many of which are widely publicized events. This catastrophic injury is known as commotio cordis. More specifically, it results from a disruption of the heart rhythm following a blunt blow to the precordial region of the heart at a critical time during the cycle of a heartbeat which triggers ventricular fibrillation (Abrunzo, 1991). Of 182 cases of commotio cordis reported in the U.S. Commotio Cordis Registry, 85 (47%) occurred during practice or competition (Doerer, Haas, Estes, Link, & Maron, 2007).

THROWING ARM INJURIES AND THE DEVELOPMENT OF PITCH LIMITS

Injury to the throwing arm is a common acute and chronic injury in youth baseball. Two reports have indicated that nearly half of pitchers report pain during a season (Lyman, Fleisig, Andrews, & Osinski, 2002; Lyman et al., 2001) with the frequency of elbow pain (26%) and shoulder pain (32%) being similar (Lyman et al., 2001). More recently, it was found that the risk of a youth pitcher sustaining a serious throwing injury (elbow or shoulder surgery or retirement due to throwing injury) within 10 years is 5% (Fleisig et al., 2011). Injury to the throwing arm has long been a concern in youth baseball (Maller & Torg, 1972), but has more recently been systematically studied with consideration of pitch volume (i.e., innings or number of pitchers/count) and pitch type (i.e., curveballs). Little League baseball has been instrumental in supporting the development of pitch count regulations, and in doing so have relied on the expert advice of Dr. James Andrews, renowned orthopedic surgeon of rotator cuff injuries and Founder and Medical Director of the American Sports Medicine Institute. These studies have consisted of following young pitchers for 1, 2, 5, and 10 years (Lyman et al., 2001; 2002).

In terms of pitch volume, it is not uncommon for a talented young pitcher to be relied upon to pitch a few times per week (besides often playing other key positions – shortstop or catcher – during non-pitching play, and possibly playing on more than one team)(Fleisig et al., 2011). The number of innings pitched is a risk factor for shoulder injury in youth baseball pitchers. Players who pitched more than 100 innings in a year were 3.5 (95% confidence interval = 1.2 to 10.4) times more likely to be injured. However, the number of innings pitched as a measure of pitching volume has limitations since some pitchers may throw several pitches per inning (walking several batters, etc.) with lower innings pitched. Thus, pitch count (e.g., actual number of pitches thrown) is a more accurate way to measure throwing arm use. In a 1-year (single season) study (Lyman et al., 2002) of 476 baseball pitchers ages 9 to 14 years there was a significant association between the number of pitches thrown in a single game and during the season and the rate of elbow and/or shoulder pain. Specific risk factors for elbow and shoulder pain are shown in Table 1. Based on this study, Little League Baseball became the first national youth baseball organization to adopt the pitch count (in 2008), instead of the number of innings pitched, as a more accurate way to measure the use of the pitching arm. A recent study has shown that pitch count regulations reduce the risk of shoulder injury in Little League Baseball by 50 percent (Little League Baseball, 2010).

Table 1. Risk factors for elbow and shoulder pain in young baseball pitchers.

Risk factors for elbow pain	Risk factors for shoulder pain
• increased age	• decreased satisfaction
• increased weight	• arm fatigue during the game pitched
• decreased height	• throwing more than 75 pitches in a game
• lifting weights during the season	• throwing fewer than 300 pitches during the season
• playing baseball outside the league	
• decreased self-satisfaction	
• arm fatigue during the game pitched	
• throwing fewer than 300 or more than 600 pitches during the season	

There is also concern for increased throwing arm injury given that some young pitchers may pitch on more than one team, and concomitantly play catcher. Indeed, pitching in travel ball "elite" and "select" programs and pitching in "showcase" events were associated with an increased risk of elbow and shoulder injury for those who also pitched in Little League Baseball and high school (Little League Baseball, 2010). Another study reported a trend for increased arm injury among pitchers who also played catcher (Fleisig et al., 2011).

Besides pitching count, another concern regarding pitching among many involved with youth baseball is the breaking ball (i.e., curveball and variations). The curveball is a type of pitch that imparts forward spin to the ball causing it to 'break' across and/or downward as it approaches the plate. The curveball is considered a more advanced pitch than the fastball and has often been suggested to pose a risk of injury to the elbow and shoulder. Therefore, many youth coaches and parents suggest that a pitcher be 16 years old (skeletally mature) before throwing the curveball. However, there is limited information that has described how young pitchers are impacted by throwing curveballs. In the earlier study by Lyman et al (2002), breaking ball pitches were shown to increase throwing arm pain with the curveball associated with a 52% increased risk of shoulder pain and the slider with an 86% increased risk of elbow pain. However, two recent long-term (5 and 10-year) studies found that throwing breaking pitches at an early age was not an injury risk factor (Little League Baseball, 2010; Fleisig et al., 2011).

Despite the attention on both pitch count and pitch type, the strongest risk factor for injury is a previous history of injury. One study found that previous injury predisposes young athletes to over five times greater risk of incident elbow and shoulder injury (Little League Baseball, 2010).

FINAL THOUGHTS AND COMMENTS

Considering that Professor Malina spent his childhood in New York City, I found the following conclusion of a paper to be amusing - …the distribution of 25,000 wooden baseball bats to attendees (i.e., "Bat Day") at Yankee Stadium did not increase the incidence of bat-related trauma in the Bronx and northern Manhattan (Bernstein, Rennie, & Alagappan, 1994). And finally, Karvonen (1976) found an increased longevity among American baseball players. May you have a long and enjoyful life Professor Malina.

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CHARACTERISTICS OF CONTRASTING SKELETAL MATURITY STATUS AT THE BEGINNING OF LONG-TERM SOCCER TRAINING

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INTRODUCTION

Participation in youth team sports is based primarily on chronological age groups which often span two years. Variation in size, function and skill associated with age per se and with maturity status within two-year age groups can be considerable. Studies of young athletes are often limited to growth and maturity status independent of functional capacities and sport-specific skills; the same is true of studies of function and skill (Malina 1994, Malina, Bouchard & Bar-Or 2004). As a result, potential interactions among size, maturity, function and skill are often overlooked as youth progress in a sport.

Behavioral dimensions such as goal orientation, motivation, and perceptions of ability and success, have not ordinarily been considered in studies of young athletes that focus on biological and performance characteristics. Interactions between biological and behavioral variables may influence sport performance per se and persistence in a sport, and thus merit consideration. Observations of boys in the Adolescent Growth Study of the University of California (Berkeley), for example, indicated variation in behavioral characteristics associated with biological (skeletal age) maturity status (Jones 1949, 1958, 1965, Jones & Bayley 1950, Eichorn 1963). Early maturing boys received greater social recognition from peers, were more at ease in social interactions, were considered more physically attractive and physically efficient, and were treated more favorably by adults compared to late maturing boys. On the other hand, late maturing boys were generally considered more eager, expressive and more attention seeking but lower in social prestige than early maturing boys. Although dated, the results highlight the potential relevance of interactions between biological maturity and behaviors among adolescent boys which are implicit in commonly used models of adaptations to puberty (Petersen &

Taylor 1980, Lerner 1985). The identification and quantification of potentially relevant behavioral variables may thus be of interest.

Achievement or goal orientation (Nicholls 1984) is a potentially relevant behavioral variable for success in sport. A task-oriented individual views his performance in terms of self-improvement, learning and effort, while an ego-oriented individual views his performance or ability relative to others (Duda 1995, McArdle & Duda 2002). It is generally assumed that a task orientation is more adaptive than an ego orientation specifically from a motivational perspective. This in turn may influence continuation or discontinuation of participation in a sport. A comprehensive evaluation of correlates of goal orientation for physical activity, including sport, however, did not include any biological markers (Biddle, Wang, Kavussanu & Spray 2003).

Given performance advantages associated with early maturation in boys, specifically size, strength, power and speed (Malina et al. 2004), it may be reasonable to assume that advanced maturation is associated with increased ego orientation. Evidence suggests that ego-oriented athletes tend to view ability as a stable concept and are more likely to attribute success to natural ability (Sarrazin, Biddle, Famose, Cury, Fox & Durand 1996). The performance advantages associated with advanced maturity among adolescent boys might be perceived by them as natural ability. They may also be identified as having superior ability by coaches and peers. This in turn may contribute to higher levels of ego orientation. On the other hand, performance limitations of late maturing boys associated with small body size and less muscular strength compared to early maturing peers of the same age may contribute to task orientation, specifically focus on practice and training to improve ability and in turn mastery (Dweck & Leggett 1988).

The purpose of this study is to compare the growth and maturity status, functional capacities, sport-specific skills and goal orientation of youth soccer players aged 11-12 years. Variation in body size, function, sport-specific skill and goal orientation of youth soccer players associated with differences in biological maturity status is specifically compared.

METHODS

Sample

The sample included 87 male soccer players 11.0 to 12.9 years from five clubs in the midlands of Portugal. All players were born in 1989 through 1992. The organization of youth soccer in Portugal uses two year age groups. Accordingly, players born in 1991 and 1992 were classified as infantiles (11.0-12.9 years). Players were from local clubs. Infantiles had a median of 3 years experience in the sport with a range from 1 to 5 years, while initiates had a median of 3 years of experience with a range of 2 to 6 years. Teams participated in a 9-month competitive season (September/May) through the Portuguese Soccer Federation. Players participated in three training sessions per week (each about

90 minutes) and one game per week, usually on Saturday. The study was approved by the Scientific Committee of the University of Coimbra and each club. Athletes and their parents provided informed consent. Subjects were also informed that participation was voluntary and that they could withdraw from the study at any time.

Protocol

All data were collected within a two week period under standard conditions in an indoor facility at the University of Coimbra. Chronological (decimal) age was calculated as the difference between date of birth and date of the hand-wrist radiograph for the assessment of skeletal maturity (see below).

Anthropometry

Weight, height, sitting height and four skinfolds (triceps, subscapular, suprailiac, medial calf) were measured by a single trained observer following the protocol described in Lohman, Roche & Martorell (1988). Players wore shorts and a t-shirt and shoes were removed. Leg (subischial) length was estimated as height minus sitting height. The sitting height/standing height ratio was calculated. The skinfolds were summed to provide an estimate of overall subcutaneous adiposity.

Functional Capacities

Aerobic and anaerobic function, agility and muscular power were tested. The yo-yo intermittent endurance test – level 1 (Bangsbo 1994; see also Reilly 2001; Reilly & Doran 2003; Balson 1994) was used as the measure of aerobic performance. Level 1 of the yo-yo intermittent endurance test requires the subject to perform a series of 20-meter shuttle runs following a cadence set by an audio metronome with a 5-second rest interval between every 40 meters. Speed is increased at intervals, i.e., the time between the signals is shortened. The objective of the test is to perform as many shuttles as possible and the score corresponds to the total amount of meters covered until the athlete is no longer able to maintain the required speed, e.g., if a subject completed 40 shuttles, his score was 1600 meters (40x2x20). The relationship between the yo-yo intermittent endurance test and the PACER (progressive aerobic cardiovascular endurance run test, Léger, Mercier, Gadoury & Lambert 1988) was examined in 69 male soccer players 13-18 years (Figueiredo, Coelho e Silva & Malina 2004). The correlation between tests was 0.78 ($p \leq .01$) and the shared variance between the intermittent and continuous tests was 61%. In a study of adult soccer players ($n=81$, 23.5±4.0 years) at three competitive levels (low, high [amateur] and professional) the intermittent test had higher predictive value in discriminating players by competitive level (Lemmink, Verheijen & Visscher 2004).

Anaerobic fitness was assessed with the 7-sprint protocol (Bangsbo 1994, see also Reilly 2001, Reilly & Doran 2003). The test includes 7 consecutive sprints (about 35 m with a slalom) with a recovery period of 25 seconds between sprints during which the subject runs/walks from the end line back to the starting line. The time for each sprint was recorded by a digital chronometer connected to photoelectric cells (Globus Ergo Tester Pro). The protocol provides for the following indicators: the faster sprint from the first two trials (measure of speed), the slower sprint from the last two trials, and the mean of all sprints. Prior to the study, the relationship between the 7-sprint test and the Wingate test was examined in 29 male soccer players 15.7±0.7 years (Figueiredo, Coelho e Silva & Malina 2003). The first and the third sprints had the highest correlation with relative anaerobic peak power. The outcomes of the 7-sprints were more correlated with anaerobic peak than with anaerobic mean power. Correlations were also of higher magnitude when anaerobic peak power was expressed as watts per kilogram of body weight. Note, however, that the correlation between the fastest sprint and relative anaerobic peak power was moderate ($r=0.44$, $p\leq 0.01$), suggesting that anaerobic outcomes were not independent of test modality (cycling x running).

Agility was assessed with the 10x5-meter shuttle. The test includes running speed and ability to change directions rapidly. Two trials were performed and the better of the two was retained for analysis.

Explosive power was assessed with the vertical jump using the ergo-jump protocol which includes two components: squat jump and counter-movement jump (Bosco 1994). Two trials were administered for each test and the better trial was retained for analysis.

Soccer Skills

Four tests of soccer skill were administered: ball control with the body, dribbling speed, shooting accuracy and the wall pass. The test battery was selected on the basis of a principal component analysis of eight tests of soccer skills, six from the Portuguese Soccer Federation - ball control with the body, ball control with the head, dribbling speed, dribbling with a pass, passing accuracy, and shooting accuracy (Federação Portuguesa de Futebol 1986) and two others, a wall pass and slalom dribble test (Kirkendall, Gruber & Johnson 1987), administered to 39 youth players (Coelho e Silva, Figueiredo & Malina 2004). Results of the principal components analysis indicated two factors which accounted for 57% of the variance. Seven of the eight tests loaded on the first factor (40% of the variance) while the test of shooting accuracy loaded very high on the second factor (17% of the variance). The slalom dribble and the test of passing accuracy loaded on the two extracted factors and were thus excluded from the test battery. The test of ball control with the body had higher communality than the test of ball control with the head and was thus retained. The wall pass had higher communality than dribbling with a pass and was retained in the test battery. Thus, the final battery included four tests of soccer skill: ball control with the body, dribbling speed, shooting accuracy and wall pass.

Maturity Status

Posterior-anterior radiographs of the left hand-wrist were taken. The Fels method (Roche, Chumlea & Thissen 1988) was used to estimate skeletal age (SA). The Fels method utilizes specific criteria for each bone of the hand-wrist and ratios of linear measurements of epiphyseal and metaphyseal widths. Ratings are entered into a program (Felshw 1.0 Software) to calculate SA and its standard error of estimate. All radiographs were assessed by a single observer. In addition to SA, stage of pubic hair was assessed at clinical examination by a trained physician. Stages as described by Tanner (1962) were used.

Goal Orientation

A Portuguese version (Fonseca and Biddle 1996) of the Task and Ego Orientation in Sport Questionnaire (TEOSQ, Duda 1989, Chi & Duda 1992) was completed by all players. The TEOSQ includes 13 items which are rated on a 5 point Likert scale ranging from strongly disagree (1), disagree, neutral, agree and strongly agree (5). Seven items reflect a task orientation while 6 reflect an ego orientation. Examples of a task focus are: "I learn a new skill and it makes me want to practice more" and "I learn something that is fun to do," while examples of an ego focus are: "I'm the only one who can do the play or the skill" and "I can do better than my friends." Cronbach's alphas (task, 0.76; ego, 0.85) indicate acceptable internal consistency. Confirmatory factor analysis using an independent sample indicated acceptable fit of the data (CFI = 0.91, GFI = 0.93, SRMR = 0.07).

Quality Control

A sample of 32 players was measured and tested on a second occasion within one week. Intra-observer technical errors of measurement for anthropometric dimensions and coefficients of reliability for the functional capacity and soccer skill tests were calculated. The technical error of measurement is the square root of the squared differences of replicates divided by twice the number of pairs:

$$\sigma_e = \sqrt{\sum d^2/2N} \text{ (Malina, Hamill \& Lemeshow 1973).}$$

It is also known as the measurement error standard deviation. The coefficient of reliability is based on the ratio of within-subject (r) and inter-subject (s) variances:

$$R = 1 - (r^2/s^2) \text{ (Mueller \& Martorell 1988).}$$

Higher values indicate greater reliability. Technical errors and reliability coefficients for the present study are summarized in

Table 1. Intra-observer technical errors of measurement (σ_e) for anthropometric dimensions and reliability coefficients (R) for functional capacity and soccer skill tests.

Anthropometry	σ_e	Functional Capacity and Skill	R
Weight, kg	0.47	Squat jump	0.83
Height, cm	0.27	Counter-movement jump	0.87
Sitting height, cm	0.31	Agility shuttle run	0.84
Skinfolds, mm		Intermittent endurance run	0.88
Skinfold triceps	0.52	Best sprint	0.81
Skinfold subscapular	0.53	Mean sprint	0.88
Skinfold suprailiac	0.72	Ball control	0.77
Skinfold medial calf	0.47	Dribbling speed	0.74
		Wall pass	0.83
		Shooting accuracy	0.71

Technical errors for anthropometric dimensions compare favorably with corresponding intra- and inter-observer errors in several health surveys in the United States and a variety of field surveys, including studies of young athletes (Malina 1995), while reliability coefficients indicate moderate to high reliabilities which are adequate for group comparisons.

Maturity Classification

The difference between SA and CA (SA minus CA) provides an estimate of relative skeletal age (RSA). The difference between SA and CA was used to classify players as follows:

Late (delayed), SA younger than CA by > 1.0 yr
Average (on time), SA ± 1.0 yr CA
Early (advanced), SA older than CA by > 1.0 yr
Mature, skeletally mature.

The classification criteria are similar to previous studies that used the difference between SA and CA to classify youth athletes in several sports into contrasting maturity categories (Krogman 1959, Rochelle, Kelliher & Thornton 1961, Peña Reyes, Cardenas-Barahona & Malina 1994, Malina, Peña Reyes, Eisenmann, Horta, Rodrigues & Miller 2000, Malina, Dompier, Powell, Barron & Moore 2007, Malina, Chamorro, Serratosa & Morate 2007, Malina et al. 2004). The band of ±1.0 year approximates standard deviations for SA within half-year CA groups in the Fels sample of boys 12 through 16 years, 0.94 to 1.26 years (Roche et al. 1988). Using a band of one year also allows for the error associated with the assessment of SA and provides a broad range of youth who are classified as on time in maturity status. A narrow range, e.g., a band of ±3 months to define early and late maturity (e.g., Kemper, Verschuur & Ritmeester 1986), is well within the range of the error of SA assessment. The median standard error of estimate for SA assessments of the total sample (n=159) was 0.30 year with a range from 0.27 to 0.42 year.

Analysis

Descriptive statistics were calculated by competitive age group for all variables except stage of PH; for the latter, the distribution of stages was noted. ANOVA was used to compare CA, body size and proportions, functional capacities, soccer skills and goal orientation by competitive age group and among late, average (on time) and early maturing players. An alpha level of 5% was accepted. Effect size was estimated with partial eta squared (η^2). If a comparison was significant among maturity groups, pairwise comparisons with a Bonferroni adjustment were used to identify which groups differed.

RESULTS

Skeletal age approximates chronological in 11-12 year old players. Pubic hair stages 1 through 3 are represented among 11-12 year old players with the majority in PH1 (n=47, 54%), about one-third in PH2 (n=30, 34%) and few in PH3 (n=10, 11%). The classification of players by skeletal maturity status is summarized in Table 2: 17 are late (20%), 45 are on time (52%) and 25 are early (29%) in skeletal maturation. Distributions of stages of pubic hair development are also summarized by skeletal maturity classification in Table 2: 15 of 17 late maturing players are in PH1 (88%); 41 of 45 players classified as on time are in PH1 (53%) and PH2 (38%); while stages PH1 (32%), PH2 (44%) and PH3 (24%) are represented in players classified as early maturing.

Table 2. Distribution of players by maturity status (SA minus CA) and distribution of stages of pubic hair by skeletal maturity status.

	Late (n=17)	On Time (n=45)	Early (n=25)
PH 1	15	24	8
PH 2	2	17	11
PH 3	0	4	6

Characteristics of players of contrasting maturity status are summarized in Table 3. Skeletal age is included in the tables to illustrate the maturity contrasts of the groups. Chronological ages of players of contrasting skeletal maturity status do not differ, but early maturing boys are significantly heavier and taller with longer segment lengths than average (on time) and late maturing boys. The gradient is early > on time > late maturing. The gradient is significant for subcutaneous adiposity. The sitting height ratio does not differ among maturity groups.

Table 3. Age, body size, functional capacities, sport-specific skills and goal orientation of 11-12 year old players classified as late, on time and early in skeletal maturation and results of ANOVAs and estimated effect size (η^2).

	Late (n=17)	On time (n=45)	Early (n=25)	F	p	η^2
Chronological age (CA), yrs	11.9±0.6	11.8±0.5	11.7±0.6	0.63		0.15
Skeletal age (SA), yrs	10.1±0.8	11.8±0.8	13.6±0.6			
Weight, kg	33.6±3.6	37.5±5.1	42.1±7.1	12.55	<0.01	0.23
Height, cm	139.4±4/5	144.6±5.9	148.4±7.3	11.12	<0.01	0.21
Sitting height, cm	70.6±2.5	72.7±2.7	75.0±2.7	14.12	<0.01	0.25
Estimated leg length, cm	68.7±3.5	71.9±3.9	73.3±5.2	6.09	<0.01	0.13
Sitting height ratio, %	50.7±1.5	50.3±1.1	50.6±1.4	0.86		0.02
Sum of skinfolds, mm	23.2±7.0	32.4±12.3	38.5±18.5	6.33	<0.01	0.13
Fastest sprint, sec	8.28±0.43	8.38±0.52	8.41±0.52	0.37		0.10
Mean sprint, sec	8.63±0.46	8.82±0.63	8.85±0.63	0.75		0.02
Agility shuttle run, sec	20.24±1.23	20.61±1.29	20.67±1.45	0.60		0.01
Endurance run, m	1774±725	1308±657	1208±788	3.57	<0.05	0.08
Squat jump, cm	23.3±6.3	24.7±5.1	24.9±5.6	0.92		0.02
Counter-mov. jump, cm	22.7±5.4	25.8±5.5	26.3±5.2	1.22		0.03
Ball control, # hits	23.6±21.1	26.3±25.7	19.6±14.6	0.75		0.02
Dribbling speed, sec	15.56±1.51	15.76±1.93	15.93±1.82	0.21		0.01
Wall pass, points	19.2±2.1	17.5±3.1	17.5±3.1	1.59		0.04
Shooting accuracy, points	6.9±2.1	6.8±2.4	6.8±2.4	0.47		0.01
Task orientation	4.4±0.4	4.3±0.5	4.3±0.4	0.25		0.01
Ego orientation	2.1±0.6	2.1±0.7	2.0±0.7	0.00		0.00

Functional capacities and soccer-specific skills, with few exceptions, do not differ among boys of contrasting maturity status within each age group. Only aerobic endurance differs among maturity groups. Late maturing boys have greater endurance capacity than on time and early maturing boys who do not differ (Table 3). The difference persists when height and weight are statistically controlled with ANCOVA (not shown). Task and ego goal orientations also do not differ among players of contrasting maturity status and no gradient in means across maturity groups is suggested.

DISCUSSION

Variation in body size associated with contrasting maturity status in youth soccer players was similar to that for adolescent males in general among whom boys advanced in skeletal maturity are taller and heavier than those on time and late in skeletal maturity (Malina et al. 2004). On the other hand, soccer players who vary in maturity status did not differ consistently in functional capacities and soccer-specific skills, which contrasts observations of adolescent males in general among whom there is a maturity gradient of early > on time > late in tests of strength, speed, power and agility (Jones 1949, Lefevre, Beunen, Simons, Renson, Ostyn & Van Gerven 1988, Lefevre, Beunen, Steens, Claessens & Renson 1990). The differences among boys of contrasting maturity status also tend to persist when maturity-related variation in height and weight are statistically controlled (Beunen, Ostyn, Simons, Renson & Van Gerven 1981). Performance differences among maturity groups are apparent by 13 years of age and tend to be greatest at 14 and 15 years (Jones 1949, Lefevre et al. 1988, 1990, Malina et al. 2004). The lack of consistent differences in functional capacities and skills among soccer players of contrasting maturity status thus contrasts that noted in adolescent boys in general. The lack of functional and skill differences among adolescent soccer players likely reflects selective practices and/or positive influences of regular fitness and skill training associated with the sport. A related factor for which data are not currently available may selective drop out or persistence in the sport.

In contrast to other functional capacities tested, later maturing 11-12 year old soccer players performed significantly better on the endurance shuttle run. Comparative data for the yo-yo intermittent shuttle run test of aerobic endurance in boys of contrasting maturity status are not available. Among Polish boys 11-14 years enrolled in a sports school, absolute peak oxygen uptake (L/min) differed significantly among early, on time and late maturing boys, while relative peak oxygen uptake (ml/kg/min) did not (Malina, Beunen, Lefevre & Woynarowska 1997). Absolute peak oxygen uptake was lower in later maturing boys across all ages. Although the overall comparison was not significant, relative peak oxygen uptake was higher, on average, in late maturing compared to on time and early maturing boys 11 through 13 years, but the difference among maturity groups was negligible among 14 year old boys of contrasting maturity status (Malina et al. 1997). The results suggest an important role for lower body mass in endurance performance of adolescent boys, including soccer players. Among adolescent male athletes, including a subsample of soccer players, pubertal status had an effect on aerobic power in addition to that of age and body size (Baxter-Jones, Goldstein & Helms 1993).

Among players 11-12 years (early adolescence), athletes spanning the skeletal maturity spectrum from late (delayed) to early (advanced) were represented. The height, weight and maturity of boys in the present study were consistent with other observations for youth soccer players (Malina 1994, 2003), and also with the hypothesis that late maturing boys are excluded from soccer either voluntarily as in dropping out or systematically as in cutting and/or early maturing boys are preferentially selected as age and sport specialization increase (Malina 2003). The trends were also consistent for estimates of skeletal maturity based on both the Fels (Roche et al. 1988) and Tanner-Whitehouse (Tanner, Whitehouse, Cameron, Marshall, Healy & Goldstein 1983) methods in Mexican (Peña et al. 1994), Portuguese (Malina et al. 2000) and Spanish (Malina, Chamorro, Serratosa & Morate 2007) youth players.

Stages of pubic hair were consistent with skeletal maturity of the youth soccer players, although there was more variation in the former. The variation is due, in part, to method as the scales for pubic hair and skeletal age differ. Further, stage of pubic hair indicates pubertal status at the time of examination and does not provide information on when a player entered the stage or how long he has been in the stage (Malina et al. 2004). Among players 11-12 years, stages PH1 through PH3 were represented (Table 3), but most (88%) late maturing boys were prepubertal (PH1).

The present study is limited to youth soccer players in Portugal and a question of potential interest is the growth and maturity status of the players relative to the general population of Portuguese youth. The younger age group of soccer players tended to be, on average, slightly shorter and lighter than Portuguese boys of the same age from Madeira (Freitas et al. 2002) and the Azores (Maia & Lopes 2007). In contrast, the older players tended to be, on average, similar in height and weight to boys from Madeira; they were also similar in height to boys from the Azores but were lighter in weight. The comparisons of body weight need to be tempered; youth soccer players in each age group had, on average, consistently thinner skinfold thicknesses than boys from Madeira and the Azores which would suggest proportionally more lean mass. It was not possible to compare the skeletal maturity status of the youth soccer players with the general population as data utilizing the Fels method are not presently available. Of relevance, Portuguese boys from Madeira tended to be advanced, on average, in skeletal maturity (Tanner-Whitehouse 2, radius-ulna-short bone scores) compared to age-matched boys from Belgium (Freitas et al. 2004).

Players did not differ in task orientation, but older players had a significantly lower ego orientation than younger players (Table 2). This may reflect increased emphasis on individual and team improvement associated with experience in the sport. In an independent sample of club soccer players 13-16 years of age (n=40) in Portugal (Gonçalves, Freitas, Cardoso, Lourenço, Coelho e Silva, Lee & Chiatzirantis 2005), task orientation (4.23±0.74) was similar while ego orientation was considerably higher (2.80±0.91) than in the present study. Corresponding data for an older sample elite Dutch youth soccer players (16.4±2.0 years) indicated, on average, a slightly lower task score (3.90±0.64) but a higher ego score (3.64±0.73) compared to younger players in the present study (Van-Yperen & Duda 1999). In the Dutch sample, improvement in skilled performance during a season, as assessed by coaches, was associated with higher task orientation. On the other hand, an ego orientation, described as "a dysfunctional motivational pattern," was associated with negative peer acceptance among Norwegian youth soccer players 12-19 years of age (Ommundsen, Roberts, Lemyre & Miller 2005). Although this study utilized a different scale for the assessment of task and ego orientation compared to that used in the present study, the results suggest than goal orientation may influence peer relationships among adolescent male soccer players.

In the present study, youth soccer players of contrasting maturity status did not differ in task or ego orientation. This contrasted expectations that advanced maturation would be associated with increased ego orientation and late maturation would be associated with increased task orientation. Ego-oriented athletes are more likely to attribute success to natural ability (Sarrazin et al. 1996) and performance advantages associated with advanced maturity (Malina et al. 2004) might be perceived by adolescent boys as natural ability. Success in sport at early adolescent ages, which may be due in part to maturity mismatches, may lead to boys advanced in maturity status to be labeled as having superior ability by coaches and peers. These factors may in turn contribute to higher ego orientation in early maturing athletes. On the other hand, performance limitations of late maturing boys associated with small body size and less muscular strength and power compared to early maturing peers may lead them to focus on practice and training to improve ability and mastery of sport skills and in turn higher task orientation. Models of adaptations to puberty include the underlying biological changes and their overt manifestations. Petersen & Taylor (1980), for example, offered a model that focuses on exogenous and endogenous factors that may mediate between biological changes during puberty and psychological outcomes. Lerner (1985), on the other hand, proposed a contextual model that emphasizes the "goodness of fit" between physical and psychological changes during puberty and the context within which they occur. Both models deal with adolescents in general, and have not been often applied to a sport context with its specific demands (Monsma and Malina 2004, Monsma, Malina and Feltz 2006). The models noted have their roots in developmental psychology but each has commonalities with the biocultural framework in studies of human variability and adaptation to the environment (Baker 1966, Lasker 1969). The biocultural approach applied to youth implies that biological growth and maturation do not proceed in isolation of the behavioral realm which is largely rooted in culture.

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SPORT SELECTION IN UNDER-14 MALE SOCCER PLAYERS(a)

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CHARACTERISTICS OF YOUTH SPORT PARTICIPANTS AND NON-PARTICIPANTS IN MEXICO CITY

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INTRODUCTION

Sport is a primary context for physical activity for youth and has high social value in many societies. Given the media's overwhelming interest in youth competing in sports at national and international levels, it is not surprising that the important role that organized sport plays in the health and development of children and adolescents is often overlooked. The highly talented are a very visible minority whereas the overwhelming majority of youth who participate and never attain elite levels often pass under the radar (Malina, 2009). This is of particular concern since only a small percentage of youth will ever play sports at a professional or international level, whereas the majority of youth can benefit physically and psychologically from participating in sports (Malina, 2008).

A consequence of our preoccupation with elite young athletes is that relatively more is known about elite young athletes in contrast to youth sports participants in general. This is especially apparent in the literature dealing with the physical growth and biological maturation of young athletes (Malina et al., 2004). The literature on sport-related injuries in youth often includes both the general participant and the elite (Malina, 2001a). In contrast, the literature on overuse injuries and burnout is generally concentrated on the elite (Weinberg and Gould, 2010; Gould and Dieffenbach, 2003).

The literature dealing with characteristics of the general population of youth sports participants, in contrast, is less extensive and uneven. Although considerable discussion of psychosocial outcomes associated with participation in youth sports exists, a good deal of the literature deals with social influences. Social influences include parents, coaches, and peers – in contrast to the psychosocial characteristics of participants and the influence of sport on aspects of psychosocial development such as self-concept and self-esteem, perceived competence in sport and social interactions, peer interactions, parent-child and coach-child relationships, values of fair play, and so on.

A motivational theory that has received much attention in the context of competitive youth sports is Achievement Goal Theory (Nicholls, 1984). This theory assumes that the manner in which the individual defines success and judges competence explains motivated behaviors and adjustment in achievement domains, such as sport. Nicholls identified different ways in which individuals define success and gauge their levels of competence, labeling them task-involvement and ego-involvement (Nicholls, 1989). When an individual is task-involved, subjective success and competence are self-referenced. Task-involved individuals feel successful when they improve upon previous performances, give their utmost effort, and/or learn or master a new skill. In contrast, ego involvement occurs when success and competence are judged in relation to the accomplishments of others. An ego-involved individual will, for example, feel successful when out-performing others or doing as well as others with less effort. Whereas task-involvement fosters positive adaptation in achievement contexts, the motivational consequences of ego-involvement are largely dependent upon outcome of the achievement-related pursuit. That is, ego-involved individuals only report positive experiences when they win, regardless of how well they have performed. Not surprisingly ego-involvement is associated with more negative psycho-behavioral adjustment in sports (e.g., greater anxiety, unsportsmanlike behavior) particularly when coupled with low perceptions of competence (Roberts, 2002; Smith et al., 2007).

Youth involved in sport tend to be more physically active on a regular basis compared to non-participants. Evidence derived from a three-day diary (Katzmarzyk and Malina, 1998) and questionnaires (Trost et al., 1997; Pfeiffer et al., 2006; Aarnio et al., 2002) indicates that sport participants are more physically active than non-participants. Accelerometry data for boys 6-12 years indicate increased time in moderate-to-vigorous physical activity on the days of sport participation (Wickel and Eisenmann, 2007). Though limited, one study suggests reduced physical inactivity, specifically less television time among youth involved in sport (Katzmarzyk and Malina, 1998).

The preceding information is derived largely from studies in the United States and Europe. Corresponding data for Latin American youth are not as readily available. The purpose of this study is to compare the characteristics of youth sports participants and non-participants resident in Mexico City. Growth and weight status, physical activity, time viewing television and playing video games, perceptions of parental sport and physical activity, and goal orientation are specifically compared in youth sport participants and non-participants 9-18 years of age.

METHODS

Subjects were participants in a survey of the growth status, physical activity and sport participation of school youth resident in Mexico City (Siegel et al., 2011). The total sample included 1095 youth 9-18 years of age. The project was approved by the University Committee for Research Involving Human Subjects of Michigan State University and was sponsored by the Escuela Nacional de Antropología e Historia (ENAH). The project was approved by authorities of the schools involved and each participant provided informed consent.

All youth were enrolled in primary (primaria), secondary (secundaria) and high school (preparatoria) schools in the Federal District at the time of the survey. Social class or socioeconomic status (SES) was estimated on the basis of school location and home location (delegación and colonía) and occupation of parents as reported by the students. With the assistance of school authorities and colleagues at ENAH, this information was used to classify the SES of each participant as low, middle and high. A similar protocol was used in another survey of physical activity of Mexico City youth, i.e., classification of SES on the basis of school attended (Hernandez et al., 1999). Allowing for limitations of method of designation, the distribution of subjects by SES was: low, 41%; middle, 33%; and high, 26%.

A subsample of 591 youth completed questionnaires dealing with sport participation in organized sport, which by definition implied the presence of a coach and regular practices and competitions during a season. Of these, 168 boys and 109 girls indicated current active participation in organized non-school sport, and 18 boys and 19 girls indicated current active participation in organized school sport. Of the latter, 8 boys and 5 girls participated only in school sport. Thus, they were combined with non-school participants to provide samples of 176 male and 114 female youth sport participants. The remaining school sport participants were also involved in non-school sponsored sport. SES did not differ between participants and non-participants in youth sports among boys (χ^2= 0.35, ns) and girls (χ^2= 1.37, ns). Compared to the total sample (above), the subsample of sport participants and non-participants included proportionally fewer low SES youth (27%) and more middle SES youth (48%), while the percentage of high SES youth was similar (25%).

At the time of the survey, 75 boys (43%) and 45 girls (40%) indicated participation in only one sport. The remainder indicated participation in multiple sports. The three most popular non-school sports were soccer (76%), basketball (58%) and swimming (48%) for boys, and basketball (64%), swimming (56%), and gymnastics (43%) for girls. Although the number was small, the corresponding school sports were swimming (78%), basketball (61%), and volleyball (44%) in boys, and basketball (68%), swimming (47%), and soccer (42%) in girls.

The Physical Activity Questionnaire (PAQ) developed for Canadian youth was used to estimate physical activity over the past seven days. The PAQ has two forms, one for older children (Kowalski et al., 1997a) and another for adolescents (Kowalski et al., 1997b). The former is designed for children from fourth to eighth grades and the latter for youth from eighth to twelfth grades. The only difference between the questionnaires for older children and adolescents is an item about activity during recess for children. The Mexican school system has a 30-minute recess period in primary schools and a 20-minute period in secondary schools. Given the age of the sample and recess periods in both primary and secondary schools, the PAQ form for adolescents was used.

The PAQ required the student to recall activities over the past seven days, which was consistent with evidence suggesting that a record of seven days provided a reliable estimate of the usual pattern of physical activity in youth (Trost et al., 2000). In the PAQ, physical activities were described as sports, games or dances that make the individual breathe hard, make the legs feel tired, or make the individual sweat (Crocker et al., 1997). Specific questions included the following: frequency of participation in sport and non-sport physical activities during free time; participation in physical education; activities at lunch time (in addition to eating); activities immediately after school, during evenings, and on weekends; and an overall estimate of physical activity during free time. Items were answered on a five-point scale. The average of the scores on each item provided an estimate of overall physical activity (PAQ score) which ranged from 1 (low) to 5 (high). A PAQ score <3.0 was approximately equivalent to 1.5-3 METS, a score 3.0-3.99 indicated about 3-5 METS (moderate activity) and a score >4.0+ indicated about ≥6 METS. In the most recent compendium, moderate activities generally ranged from 3.5 to 6 METS, while vigorous activities were > 6.0 METS (Ainsworth et al., 2000).

Test-retest correlations for the PAQ were 0.75 and 0.82 in Canadian boys and girls, respectively (Kowalski et al., 1997a). The PAQ was moderately correlated with several indicators of physical activity in Canadian youth 13-20 years (Kowalski et al., 1997b). On the other hand, correlations between the PAQ (Crocker et al., 2001) and another 7-day physical activity recall instrument and estimates of activity with Tritrac and Caltrac monitors were low, leading the authors to question the viability of mechanical recorders for assessing physical activity over extended periods. Correlations between the PAQ and accelerometry were somewhat higher in rural, urban and Old Order Mennonite Canadian youth 9-12 years (Tremblay et al., 2003), while correlations between the PAQ and overall physical activity and moderate-to-vigorous activity measured with an Actigraph monitor in youth were moderate (Janz et al., 2008). The PAQ was also relatively stable across a two-year interval between 11 and 13 years of age (Janz et al., 2008).

Several items in the PAQ were not used to derive the physical activity score, but provide information on time spent viewing television and playing video games and perceived physical condition and perceived activity level compared to age and sex peers. Responses on perceived physical activity and fitness compared to peers provided an estimate of convergent validity of the PAQ (Kowalski et al., 1997a, 1997b). Perceived physical activity included five options compared to peers of the same age and sex: very inactive, less active, just as active, a little more active, or much more active. Perceived fitness (physical condition) included three options compared to peers of the same age and sex: less fit, more fit, or very fit compared to others. A question asking the student to classify his/her parents as not-active or active in sport/physical activity was also included. Since parental activity was reported by the child, it was labeled 'perceived sport/activity status of the parents'.

The PAQ was translated into Spanish and field tested in a pilot survey of approximately 100 children 9-12 years of age from three schools in middle to high SES neighborhoods. Changes were made as needed without altering the essence of the PAQ. The Spanish translation of the PAQ was subsequently finalized and administered to the survey sample in the classroom setting. Specific procedures were explained by a member of the research team to the students. The research assistant remained in the classroom while the students completed the PAQ; he/she also answered questions as necessary, and checked each questionnaire for completeness.

Height and weight of each participant were measured; the BMI was calculated. Children were classified as thin, normal weight, overweight or obese using international criteria (Cole et al., 2000, 2007). The criteria for thinness approximated two standard deviations below age- and sex-specific reference means and the WHO criterion for grade 2 thinness in adults (BMI<17.0 kg/m^2). The term thinness was used, as the terms wasting and underweight are often confusing (Cole et al., 2007). Three boys, all sport participants, were classified as thin (low BMI for age), two 12 years and one 16 years of age. Given the ages, it is possible that the thinness of the subjects could reflect late timing of the adolescent growth spurt (Malina et al., 2004). Given the small number, they were included with normal weight boys.

The Task and Ego Orientation in Sport Questionnaire (TEOSQ, Duda, 1992) was also translated into Spanish and administered to the non-school sport participants. The TEOSQ was completed by 103 boys (30 non-participants and 73 sport participants) and 66 girls (23 non-participants and 43 sport participants) 14-18 years of age.

Descriptive statistics for age, height, weight, BMI, PAQ scores, television time, video game time, and total screen time (combined television and video game) were calculated by age group and sex for youth sport participants and non-participants in two age groups, 9-13 years and 14-18 years, as this division generally mirrored the age ranges and cutoffs between primary school and high school. The TEOSQ, as noted, was limited to youth 14-18 years. MANOVA was used to compare participants and non-participants by age group within sex. Bonferroni adjustments for multiple comparisons were used. If age differed significantly between participants and non-participants, MANCOVA, with age as the covariate, was used. Distributions of participants by weight status (normal, overweight, obese), perceived physical activity and fitness compared to age and sex peers, and perceived physical activity/sport status of adults were compared with Chi square. A significance level of $p<0.05$ was accepted, though with small sample sizes in some comparisons, marginal p levels were noted.

RESULTS

Comparisons of body size and weight status are summarized in Table 1. Male sport participants are, on average, taller than non-participants in the two age groups. The difference is significant only among older youth. Age and body size do not differ between female sport participants and non-participants. The distributions of sport participants and non-participants by weight status do not differ in either sex.

Table 1. Age, body size and weight status of youth sport participants and non-participants 9-13 and 14-18 years of age.

	Non-Participant		Participant		F	p
	Mean	SD	Mean	SD		
9-13 Years						
Boys	(n=17)		(n=80)			
Age, yrs	11.2	0.8	12.0	0.8	14.75	<0.001
Height, cm	143.5	7.0	148.9	8.1	6.52	<0.01*
Weight, kg	39.8	7.6	43.8	11.3	1.94	n.s.
BMI, kg/m^2	19.3	3.3	19.6	4.0	0.74	n.s.
Normal weight	71%		70%			
Overweight	23%		26%		χ^2=0.00, ns	
Obese	6%		6%			
Girls	(n=25)		(n=45)			
Age, yrs	11.9	0.8	11.8	0.9	0.01	n.s.
Height, cm	148.4	7.9	148.9	6.7	0.07	n.s.
Weight, kg	44.3	11.5	45.1	11.6	0.08	n.s.
BMI, kg/m^2	19.9	3.7	20.2	4.2	0.09	n.s.
Normal weight	68%		69%			
Overweight	28%		27%		χ^2=0.02, ns	
Obese	4%		4%			
14-18 Years						
Boys	(n=57)		(n=90)			
Age, yrs	16.5	0.6	16.4	0.7	0.83	n.s.
Height, cm	168.0	6.1	170.2	5.9	4.74	<0.05
Weight, kg	63.2	11.9	63.0	10.3	0.01	n.s.
BMI, kg/m^2	22.3	3.8	21.7	3.0	1.34	n.s.
Normal weight	72%		80%			
Overweight	21%		19%		χ^2=2.57, n.s.	
Obese	7%		1%			
Girls	(n=101)		(n=62)			
Age, yrs	16.5	0.6	16.5	0.7	0.05	n.s.
Height, cm	157.4	6.0	159.0	6.3	2.54	n.s.
Weight, kg	54.9	9.0	54.6	7.3	0.06	n.s.
BMI, kg/m^2	22.1	3.3	21.6	2.5	1.31	n.s.
Normal weight	80%		82%			
Overweight	26%		18%		χ^2=0.64, n.s.	
Obese	4%		0%			

*After adjusting for age, the difference in height is not significant.

In contrast to body size, sport participants of both sexes have, on average, higher PAQ scores than non-participants (Tables 2a and 2b). Perceived physical activity relative to peers does not differ between male sport participants and non-participants in both age groups, but older boys involved in sport perceive themselves as more physically fit compared to those not involved in sport. In contrast, girls in both age groups who are active in sport perceive themselves as more physically active and fit relative to peers not active in sport.

Table 2a. Age, physical activity (PAQ) and perceived physical activity (PPA) and fitness (PPF) compared to age and sex peers of youth sport participants and non-participants 9-13 years.

	Non-Participant		Participant		F	p
	Mean	SD	Mean	SD		
Boys	(n=17)		(n=80)			
Age, yrs	11.2	0.8	12.0	0.8	14.75	<0.001
PAQ	2.6	0.7	3.0	0.7	4.46	<0.05*
PPA re-peers						
Much less active	0%		4%			
Little less active	23%		16%			
About same	71%		44%		$\chi^2=2.29$, ns	
Little more active	0%		20%			
Much more active	6%		16%			
PPA re-peers						
Less fit	6%		8%			
More fit	53%		31%		$\chi^2=1.20$, ns	
Very fit	41%		61%			
Girls	(n=25)		(n=45)			
Age, yrs	11.9	0.8	11.8	0.9	0.01	n.s.
PAQ	2.2	0.6	2.9	0.5	25.40	<0.001
PPA re-peers						
Much less active	12%		5%			
Little less active	16%		9%			
About same	68%		53%		$\chi^2=6.93$, $p<0.01$	
Little more active	4%		21%			
Much more active	0%		12%			
PPA re-peers						
Less fit	12%		4%			
More fit	72%		29%		$\chi^2=13.93$, $p<0.01$	
Very fit	16%		67%			

*After adjusting for age, the difference in PAQ is not significant.

Table 2b. Age, physical activity (PAQ) and perceived physical activity (PPA) and fitness (PPF) compared to age and sex peers of youth sport participants and non-participants 14-18 years.

	Non-Participant		Participant		F	p
	Mean	SD	Mean	SD		
Boys	(n=59)		(n=95)			
Age, yrs	16.5	0.6	16.4	0.7	0.83	n.s.
PAQ	2.3	0.7	2.7	0.7	11.66	<0.01
PPA re-peers						
Much less active	8%		12%		χ^2=1.32, ns	
Little less active	22%		16%			
About same	44%		34%			
Little more active	24%		29%			
Much more active	2%		10%			
PPA re-peers						
Less fit	5%		2%		χ^2=7.99, p<0.01	
More fit	59%		39%			
Very fit	36%		59%			
Girls	(n=105)		(n=68)			
Age, yrs	16.5	0.6	16.5	0.7	0.05	n.s.
PAQ	2.0	0.6	2.5	0.7	24.99	<0.001
PPA re-peers						
Much less active	13%		4%		χ^2=11.64, p<0.001	
Little less active	33%		21%			
About same	38%		37%			
Little more active	13%		32%			
Much more active	3%		6%			
PPA re-peers						
Less fit	8%		4%		χ^2=6.94, p<0.01	
More fit	76%		61%			
Very fit	16%		35%			

Television and video game time do not differ between sport participants and non-participants in either sex, but with the exception of boys 9-13 years, youth spend considerably more time viewing television than playing video games. Among boys 9-13 years, means for time viewing television are 2.8±2.4 and 3.2±2.3 hours in non-participants and sport participants, respectively. Among boys 14-18 years, corresponding means are 2.7±2.3 and 3.0±2.2 hours, respectively. Among girls 9-13 years, means for time viewing television are 3.4±1.6 and 2.7±2.1 hours in non-participants and sport participants, respectively; corresponding means are 2.5±1.9 and 2.4±1.7 hours, respectively, among girls 14-18 years.

Perceptions of parental physical activity and sport do not differ between sport participants and non-participants (not shown), although proportionally more sport participants 9-13 years perceive their fathers as active (p=0.07).

Among youth 14-18 years, male sport participants and non-participants do not differ in goal orientation, while female non-participants reported a higher ego orientation score than sport participants (Tables 3a and 3b). Among sport participants 14-18 years, males reported a higher mean value for ego orientation ($p<0.05$) than females, while task orientation scores do not differ (Table 4a). On the other hand, among non-sport participants, females have higher task ($p<0.05$) and ego ($p=0.07$) orientation scores than males (Table 4b).

Table 3a. Goal orientation of youth sport participants and non-participants 14-18 years in boys.

	Non-Participants (n=30)		Participants (n=73)		F	p
	Mean	SD	Mean	SD		
Age, yrs	16.4	0.6	16.5	0.7	0.41	ns
Task	3.7	0.9	3.9	0.7	2.79	ns
Ego	2.5	0.8	2.8	0.9	1.28	ns

Table 3b. Goal orientation of youth sport participants and non-participants 14-18 years in girls.

	Non-Participants (n=23)		Participants (n=43)		F	p
	Mean	SD	Mean	SD		
Age, yrs	16.6	0.6	16.6	0.7	0.00	ns
Task	4.2	0.7	4.0	0.7	0.57	ns
Ego	3.0	0.9	2.4	0.7	9.54	<0.01

Table 4a. Goal orientation of youth sport participants 14-18 years by sex.

	Males (n=73)		Females (n=43)		F	p
	Mean	SD	Mean	SD		
Age, yrs	16.5	0.7	16.6	0.7	1.00	ns
Task	3.9	0.7	4.0	0.7	0.67	ns
Ego	2.8	0.9	2.4	0.7	5.85	<0.05

Table 4b. Goal orientation of youth sport non-participants 14-18 years by sex.

	Males (n=30)		Females (n=23)		F	p
	Mean	SD	Mean	SD		
Age, yrs	16.4	0.6	16.6	0.6	2.08	ns
Task	3.7	0.9	4.2	0.7	5.34	<0.05
Ego	2.5	0.8	3.0	0.9	3.34	0.07

DISCUSSION

Of the 591 (292 males, 299 females) students 9-18 years who completed the sport participation questionnaires, 58% of males and 36% of females indicated participation in organized sport (school or non-school sponsored). These values are comparatively higher than those reported for US youth of a similar age range. A survey of United States youth 10-18 years showed percentages of sport participants of 40% and 22% for males and females, respectively (Ewing and Seefeldt, 1988; 1996). In a study of mid-Michigan middle school students, 30% of males and 29% of females reported participation in organized sport in mid-winter (Katzmarzyk and Malina, 1998). The prevalence of sport participation in the current study was higher than those previously reported in the literature, and males had a higher prevalence of participation than females. While the percentages of the Mexican males and females who participated in sport were seemingly high, sample size or definition of organized sport perhaps accounted for some of the variation. Both school and non-school sponsored sports were combined in the estimates. It was possible that some boys, and possibly some girls, included "pick-up" games in their responses, despite the requirement in the survey that a coach needed to be present to qualify the activity as an organized sport. If this was the case, then the responses of participants versus non-participants may, in fact, be more accurate than was first believed. That is, the respondents who participated in sport in all forms may be represented, rather than just those who had a coach and regular practice. If this was the case, however, the applicability of this survey to other estimates of sport participation has a limitation.

A shortcoming of the present study was the lack of a question regarding self-organized sport participation. Soccer, or fútbol, in Latin America has long been a street game that children just pick up and play when they have free time, and they often play every day, or at least on a regular basis. By not assessing this type of sport activity, information may be lacking on true levels of participation in sport. In addition, basketball now has a more informal component in Mexico for both males and females, as does volleyball for females. If the subjects did indeed count these self-organized games in their list of sports, then the prevalence of sport participation may not be so out of line with prior reports. Nevertheless, this interpretation does beg the question of how many

Mexican youth participate in organized sport with regular practices, games or competitions, and a coach or trainer.

The higher percentages of participation in organized sport in Mexico City youth compared to United States youth, but relatively low levels of physical activity (especially in the older males and females) as estimated by the PAQ-A, also begs the following questions: To what extent does sport participation contribute to general physical activity levels in Mexican youth? How active are Mexican youth when they participate in sport? Does participation in sport entail regular involvement in exercise and conditioning? Does it involve both competition and practice? What are the frequency, intensity and duration of training? None of these questions were really addressed with the instruments used in the study. Similar questions arise with American youth, and energy expenditure is rarely documented. In a study of mid-Michigan youth 12-14 years of age, the percentage of estimated total daily energy expenditure attributed to participation in organized sport was 20% for males and 16% for females. The percentage of energy expenditure in moderate-to-vigorous activity which was attributed to youth sport participation was 55% and 65% for males and females, respectively (Katzmarzyk and Malina, 1998). Thus, youth who participated in organized sport expended more energy in physical activity than youth who did not participate in organized sport. Therefore, if urban Mexican youth are similar to mid-Michigan youth, the amount of energy expended by sport participants may be greater than that expended by non-sport participants. As Mexican youth who participate in sport have significantly higher PAQ scores than non-participants, the current data appear to support this idea.

The comparison of the mean values of ego and task orientation across sex and participants/non-participants is of interest. In males, participants in the current study reported marginally higher levels for task and ego orientation compared to non-participants, though not at a statistically significant level. In females, participants and non-participants did not differ significantly in terms of task-orientation; however, non-participants reported significantly higher perceptions of ego-orientation. As noted previously, high levels of ego-orientation couple with low perceptions of competence predicts negative adaptation in achievement contexts. It is possible that low levels of ego-orientation may be especially protective of sport participation in adolescent Mexican females. In support of this contention, female participants reported significant lower levels of ego orientation that male participants; whereas female non-participants reported slightly higher levels of ego orientation than their male peers. In light of these observations, future researchers should further consider the role of achievement goals, competence, and the motivational climate in relation to Mexican adolescents involvement in sports and physical activity. It is possible that an overemphasis on competition and interpersonal comparison may have a debilitating effect upon the involvement of Mexican adolescent females engagement in sports and other achievement related forms of physical activity.

Urban Mexican school age females in this study were perhaps less likely to be sport participants, which reflected cultural expectations and patterns. In the not too distant past, adolescent Mexican girls, especially those from rural communities, were expected to devote themselves primarily to household chores (Lewis, 1960). In a field survey from 2000-2002, required daily household activities of rural indigenous girls 9-17 years were related largely to food preparation, cleaning and washing (Malina et al., 2008). While this is no longer the case for most urban Mexican girls, the 15th birthday (quinceañera) of Mexican girls is still of particular importance in the culture as a representation of the transition from child to adult status.

In addition, adolescents in many countries, both male and female, have lower levels of physical activity than pre-adolescents (Reynolds et al., 1990; Pate et al., 1994; Malina, 2001a, 2001b). There is a negative association between physical activity and age in adolescent females and males (Aaron et al., 1993; Ewing and Seefeldt, 1988; Andersen et al., 1998), and results of the current study are consistent. While females are less active than males in both age groups used in this study of urban Mexican youth, the relative decline with age appears similar, and also appears less extreme in sport participants versus non-sport participants.

In summary, urban Mexican youth of both sexes involved in sport have, on average, higher levels of physical activity than youth not involved in sport. In addition, perceived physical activity and fitness relative to peers does not differ between boys involved and not involved in sport, whereas girls active in sport perceive themselves as more physically active and fit relative to their peers.

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SECTION IV:
FROM THE DESK OF ROBERT MALINA

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GASTON P. BEUNEN (1945-2011)

Robert M Malina

The pediatric exercise science community lost a beloved colleague and scholar with the untimely passing of Gaston Beunen in August. Gaston collapsed while playing tennis and subsequently died of coronary complications.

Gaston anticipated participating in the Pediatric Work Physiology conference in Exeter in September continuing his long term involvement with the group. He participated in 18 of the 26 meetings organized by the European Group for Pediatric Work Physiology between 1973 and 2010, including two jointly hosted with the North American Society for Pediatric Medicine.

Gaston devoted his entire academic career to the Katholieke Universiteit te Leuven in Belgium. He completed his baccalaureate and master's degrees in physical education at the university in 1965 and 1967, respectively, and his doctoral degree in 1973. He was intimately involved in the mixed-longitudinal study of Belgian boys 12-20 years of age, part of which formed the basis for his doctoral dissertation. He formulated and directed the comprehensive analysis of the longitudinal component of the study, specifically the adolescent growth spurts in body dimensions and motor performances. After several years, Gaston directed a follow-up study of the longitudinal sample which developed into the Leuven Longitudinal Study of Lifestyle, Fitness and Health, marking a shift (albeit to some extent) to interest in factors affecting adult health. The project is still ongoing. The study of boys was followed by a cross-sectional survey of the growth, maturation and physical fitness of girls 6-18 years of age, the Leuven Growth Study of Flemish Girls.

With the sport sciences moving in many directions, Gaston developed an interest in quantitative genetics and with several colleagues he initiated the Leuven Longitudinal Twin Study. Interests in the genetic domain continued in the Leuven Genes for Muscular Strength project. Finally, Gaston served as coordinator of the Flemish Policy Research Center for Sport, Physical Activity and Health between 2002 and 2006. He became an emeritus professor in 2006, but continued his research activities and collaborations at the university and elsewhere.

Gaston has published extensively not only in English but also in his native Flemish. He regularly reviewed manuscripts for many scientific journals and also served on the editorial boards of several journals. Gaston was a member of the editorial board of Pediatric Exercise Science since the inception of the journal in 1988.

Involvement in professional organizations was important to Gaston. He was a Fellow of the American College of Sports Medicine and the recipient of a Citation Award of the College (2001), a Fellow of the European College of Sports Science, and an International Fellow of the American Academy of Kinesiology and Physical Education and the recipient of the Lynn Vendien Outstanding International Fellow Award of the Academy (1986). More recently, Gaston was the recipient of the Medal of Honor of the University of Ghent (2007).

Gaston was both a student and scholar of human growth, maturation and performance in the context of physical education, the sport and physical activity sciences, and human biology. He consistently asked good questions and more importantly had the scientific and quantitative skills to address the issues. He excelled in analyses of longitudinal data and more recently in applications of advanced multivariate methods to studies of growth, performance and genetics.

Although Gaston's academic career and accomplishments were outstanding and unparalleled by many in our field, he will be remembered for his friendly and human demeanor and his willingness to share knowledge and experiences not only with colleagues but also with many students and emerging professionals throughout the world. Gaston's commitment to students was especially evident in the promotion or co-promotion of 163 master's theses and 14 doctoral dissertations at the Katholieke Universiteit te Leuven.

To me personally, I lost a dear friend, perhaps a younger brother. Gaston and I first met, albeit briefly, at the pre-Olympic Scientific Congress in Quebec in 1976. We subsequently met at several meetings which culminated in an invitation to be a visiting professor at the Katholieke Universiteit te Leuven in 1981, during which time we collaborated on the mixed-longitudinal study of Belgian boys. This marked the beginning of our research collaboration and more importantly a long friendship not only for Gaston and me, but also for our families.

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