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ANTHROPOMETRY, PHYSIQUE, AND PHYSICAL FITNESS OF 6 TO 11 YEAR OLD CHILDREN FROM A RURAL AND AN URBAN COMMUNITY IN OAXACA, SOUTHERN MEXICO

By

Swee Kheng Tan

A DISSERTATION

Submitted to
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ABSTRACT

ANTHROPOMETRY, PHYSIQUE, AND PHYSICAL FITNESS OF 6 TO 11 YEAR OLD CHILDREN FROM A RURAL AND AN URBAN COMMUNITY IN OAXACA, SOUTHERN MEXICO

By

Swee Kheng Tan

The present study investigated the physical fitness of rural and urban school children in Oaxaca, southern Mexico, in the context of anthropometric correlates, somatotype, and nutritional status. First, the contributions of body size and specific anthropometric dimensions to variation in indicators of health- and performance-related fitness were estimated. Second, relationships between somatotype and indicators of fitness were considered. Third, the growth status, physical fitness and relative fat distribution of stunted (height z-score below -2.0) and non-stunted children (height z-score equal to or greater than -2.0) were compared.

The sample comprised 329 rural (154 boys, 175 girls) and 318 urban (161 boys, 157 girls) school children 6.00-11.99 years of age. Anthropometric dimensions included weight, height, sitting height, four skeletal breadths, two limb circumferences, four skinfolds, and several derived variables. Somatotype was estimated with the Heath-Carter anthropometric protocol. Fitness items included right and left grip (strength), 35 yard dash (32.3 m, speed), standing long jump (explosive power), sit-and-reach (flexibility), timed sit-ups (30 seconds, abdominal strength and endurance), and a distance run (8 minutes in grades 1-3, 12 minutes in grades 4-6, cardiovascular endurance). Partial correlation, multiple regression, analysis of covariance, multiple analysis of covariance,

and principal components analysis were used in the comparisons of rural and urban and of stunted and non-stunted children.

Age, height, and weight explained most of the variance in the performances of rural and urban children. The addition of other anthropometric dimensions to the regression accounted for only slightly more of the variance and altered the estimated contributions of age, height and weight. The increase in the amount of variance explained in fitness was significant in the sum of right and left grip strength while the significance in the variance increased for the other fitness items were variable. There were no urban-rural contrasts in estimates.

Rural and urban boys, but not girls, differed in somatotype. Endomorphy discriminated urban and rural boys. Endomorphy was negatively correlated to fitness, whereas mesomorphy and ectomorphy were variably correlated with fitness. Age and somatotype accounted for a major portion of the variance in fitness, but estimated contributions varied with the tests.

Non-stunted children were larger than stunted children in height (as expected) and also in all other dimensions and derived variables except for the sitting height to standing height ratio, which indicated proportionally shorter legs in stunted children. Non-stunted children performed better than stunted children on only one item, absolute strength. Strength per unit estimated arm muscle was also greater in non-stunted children. Other fitness items did not significantly differ between stunted and non-stunted children. Relative subcutaneous fat distribution (trunk-extremity skinfold ratio and principal components) did not differ between stunted and non-stunted children.

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CHAPTER 1

Introduction

The present study is an extension of a broader study of secular change in the growth status and physical fitness of school children and living conditions of two communities in the Valley of Oaxaca, Southern Mexico, which were initially studied in 1968 and 1972, and more recently in 1999-2000 (Malina et al., 1972, 1980; Malina and Selby, 1982; Malina, 1999, 2002; Peña Reyes, 2002). Both communities have a history of chronic undernutrition and associated marginal living conditions. The current study examines in more detail issues related to the physical fitness of children living in the rural and urban communities.

Body size, proportions, physique, and body composition are factors that influence physical fitness. Stature (standing height) and body weight have been extensively used with chronological age and sex in the study of fitness and motor performance in the general population and in unique populations, such as the chronically undernourished. Although skinfold thicknesses are included as an independent component of health-related physical fitness, they can also exert an independent effect on other components of fitness (American Alliance for Health, Physical Education, Recreation and Dance, 1984).

A reasonably extensive research has evaluated the relationships of age, height, and weight with performances in a variety of fitness and motor tasks since the 1950s. Most of the studies were limited to correlational analyses, i.e., the strength of the linear association between chronological age, size, and the performance variables (Seils, 1951; Rarick and Oyster, 1964; Montoye et al., 1972; Malina and Buschang, 1985; Rocha

Ferreira et al., 1991). Although the concept of biological maturity, e.g., skeletal age, is not within the scope of the present study, several studies examined the contribution of biological maturity, in addition to age, height and weight, to physical fitness (Seils, 1951; Rarick and Oyster, 1964; Beunen et al., 1983; Katzmarzyk et al., 1997). Studies that considered the contributions of anthropometric dimensions other than body size to variation in performance are limited (Beunen et al., 1983; Malina and Buschang, 1985; Bénéfice and Malina, 1996; see also Malina, 1994).

Marginal living conditions and chronic undernutrition can alter body size and composition, which in turn may influence physical fitness and performance. Changes in body dimensions and composition can influence performance negatively or positively (Malina, 1975, 1994; Malina and Bouchard, 1991). Positive changes in body size over time are ordinarily viewed as an indicator of improved public health, diet, and general living conditions (Eveleth and Tanner, 1990). Physical performance in some tasks, e.g., strength and power tasks, have also improved over time and reflect to a large exgtent the increase in function of body size (Malina, 1978).

The growth status of children is commonly used as an index of the health and nutritional conditions in a community (World Health Organization [WHO], 1997). Improved living circumstances are reflected in greater growth in body size, whereas marginal living conditions and chronic undernutrition often result in stunted growth which, in turn, can influence physical fitness. Although it is recognized that genotype is intrinsic to body dimensions and physique, marginal living conditions and chronic undernutrition can compromise or alter genetic potential (Bouchard et al., 1997).

The evaluation of the growth and nutritional status of children in a community is based largely on the use of anthropometric indicators: weight-for-age, height-for-age, and weight-for-height (Waterlow et al., 1977; WHO, 1997). Growth stunting and wasting are estimated from height and weight relative to reference data for well-nourished children. The growth charts for United States children in the 1970s (Hamill et al., 1977) are used most often as the reference. Criteria for stunting and wasting are z-scores for height-for-age and weight-for-height, respectively, that are more than two standard deviations below the reference, i.e., z-scores greater than –2.0. Although the growth charts for the U.S. population are universally accepted as the reference (Yip and Scanlon, 1994; WHO, 1997), the applicability of this reference may have limitations, especially in developing countries (Walker and Walker, 1997).

Data on the height and weight of children from different parts of the world living in rural and urban communities are reasonably extensive (Meredith 1979, 1982). In general, children living in urban areas are heavier and taller age-for-age than their rural counterparts (Meredith, 1979, 1982; Eveleth and Tanner, 1990). Such rural-urban comparisons have been recorded since the early 1870s, primarily among children of European ancestry (Meredith, 1979, 1982). Similar data for Latin American populations, including Mexico, Central and South America, and the Caribbean, are also available, but are less extensive (Malina, 1990). Mexico, specifically the Valley of Oaxaca in southern Mexico, is the focus of this study.

Disparity in living conditions is evident in many developing countries where resources are distributed inequitably among areas. In Mexico, for example, there was economic progress and rapid growth of urban centers that was accompanied by poverty, underdevelopment, and undernutrition (Malina, 1990). The accelerated growth of children in urban centers is often associated with improved health and nutritional conditions associated with rural to urban migration (Turner, 1976). Such migratory movements from rural areas in Latin America often result in the formation of irregular, squatter settlements on the edges of cities, which are called colonias populares in Mexico (Selby and Murphy, 1979; Murphy and Stepick, 1991). Although the settlements are 'urban' or 'suburban', facilities available for health care and sanitation are far from the expectations of urbanized centers. Efforts to improve the living conditions of these communities are an ongoing process.

A primary concern with many developing countries, including Mexico, is the marginal living conditions in which children are reared and the presence of chronic mild-to-moderate undernutrition among children. Regional differences in the nutritional status of children are often prevalent within a country, mainly between rural and urban regions (Oumarou et al., 1993). In 1996, the estimated prevalence of mild-to-moderate undernutrition in Oaxaca, one of the poorest states in Mexico, was 17.1%, compared to 6.9% in Mexico City (Secretaria de Salud, 1998). Chronic mild-to-moderate undernutrition has implications for associated morbidity and mortality of children, and long term debilitating consequences on growth and functional development, which in turn, can have economic repercussions in a community.

Significance of the Study

In addition to height and weight, information on the relationship between physical fitness and other anthropometric dimensions is rather limited (Malina, 1975, 1994). The association between other anthropometric dimensions (segment lengths, skeletal breadths, limb circumferences, and skinfold thickness) and physical fitness tasks should be explored in a variety of populations as variation in body dimensions and proportions may influence outcomes differently. Reported correlations obtained in most studies indicate considerable overlap by sex, ethnicity, living conditions, and socioeconomic status (SES). There is a need to consider the effects of the living conditions and perhaps chronic undernutrition as sources of variation in the physical fitness of children in developing areas of the world.

Differences in living conditions between rural and urban communities are often prevalent in developing countries and countries in economic transition (e.g., countries in Eastern Europe). Given the differences in living circumstances, attained body size and composition may differ, and may influence physical fitness. As such, comparisons between children living in rural and urban conditions may provide insights into the contributions of specific anthropometric dimensions and estimates of body composition to explaining the variance in the fitness of children reared under marginal circumstances. Although the adverse consequences of chronic undernutrition are reflected in reduced body size and altered body composition, which in turn affect performance, the physical fitness of children from communities with a history of chronic undernutrition has not been extensively examined.

The populations examined in most studies of chronic undernutrition usually involve preschool children, i.e., those under 5 years of age. Although children below the age of 5 years are more sensitive to unfavorable living conditions and often show high morbidity and mortality, children of school age represent a population that has survived the vigorous selection processes associated with environments characterized by a high prevalence of infectious and parasitic diseases and marginal nutrition. Chronic undernutrition during the preschool years is associated with growth stunting, i.e., interference with linear growth. The consequences of early growth stunting for later performance need further study. Specifically, what are the consequences of stunting on physical fitness at school age? Satyanarayana et al. (1979) suggested that growth stunting by five years of age affected the absolute work capacity of rural Indian boys during adolescence. Power output (PWC 170) per unit body weight was generally similar in well-nourished and malnourished boys, but was considerably reduced in boys were who extremely stunted in growth. Some evidence for African children (Bénéfice et al., 2001a, 2001b) and Guatemalan adults (Schroeder et al., 1999) also suggests that stunting during the preschool years is associated with a proportionally greater accumulation of subcutaneous fat on the trunk during adolescence and adulthood.

Research Questions

There are two aspects to the questions in the present study. The first involves a comparison of children from the rural and urban communities, and the second involves a comparison of stunted and non-stunted children within the respective communities. Using the same population sample and with the inclusion of slightly older children (6 to 13 years of age), Peña Reyes (2002) reported significant rural-urban differences in body size, but inconsistent differences in the skeletal breadths, circumferences and skinfolds. For example, skinfolds did not significantly differ, except between 10-13 year old rural and urban boys. There were also significant rural-urban differences, in favor of the urban children, for most measures of physical fitness.

In the context of previous studies in the Valley of Oaxaca in southern Mexico, the present study investigated the following questions:

1. What are the anthropometric correlates of physical fitness in rural and urban school children, respectively? Specifically, what are the contributions of anthropometric dimensions to variation in the health- and performance-related physical fitness of rural and urban children?
2. What is the relationship between somatotype and the health- and performance-related physical fitness of rural and urban children? The Heath-Carter anthropometric somatotype protocol (Carter and Heath, 1990), with few exceptions, has not been used in samples of children with a history of marginal living and nutritional conditions; hence, this aspect of the study is exploratory and unique. In this context, the somatotypes of rural and urban children are initially described and compared.
3. How do growth stunted and non-stunted children within each community compare in body proportions, relative muscularity, subcutaneous fatness, relative subcutaneous fat distribution, and physical fitness?

Hypotheses

The following hypotheses were tested:

1. In addition to age, height, and weight, the anthropometric dimension(s) that add significantly to explaining the remaining variation in the performance of:

a) Static strength (sum of right and left grip strength) is estimated arm muscle circumference;

b) Running speed (35 yard / 32 meters dash) is estimated calf muscle circumference and estimated leg length;

c) Explosive power (standing long jump) is estimated arm and calf muscle circumference;

d) Lower back flexibility (sit and reach) is estimated leg length;

e) Muscular endurance (sit-ups) is estimated arm and calf muscle circumference;

f) Cardiovascular endurance (distance run) is sum of four skinfolds.

2. Rural and urban children 6-11 years of age do not significantly differ in Heath-Carter anthropometric somatotypes.

3. After controlling for age and the other two somatotype components, in urban and rural children 6-11 years of age:

    a) Endomorphy has a negative relationship to cardiovascular endurance (distance run);

    b) Mesomorphy has a positive relationship to measures of strength (sum of right and left grip strength), running speed (35 yard / 32 meters dash), explosive power (standing long jump), and muscular endurance (sit-ups); and

    c) Ectomorphy has a positive relationship to lower back flexibility (sit and reach).

4. a) Stunted and non-stunted children 6-11 years of age do not differ in relative muscularity and subcutaneous fatness, but do differ in relative body proportions related to sitting height and leg length.

   b) Non-stunted children 6-11 years of age perform better in tests of health- and performance-related physical fitness compared to stunted children.

5. Stunted children 6-11 years of age have a proportionally greater accumulation of subcutaneous fat on the trunk than on the extremities compared to non-stunted children.

Delimitations

1. The present study was developed within the context of a broader study designed to evaluate secular changes in growth status, physical fitness, and living conditions (Malina, 1999, 2002; Peña Reyes, 2002).
2. The sample is limited to children of primary school age range (grades 1-6 in Mexico) who were attending primary school in each community the time of data collection.
3. The sample is limited to children 6-11 years. The numbers of children 12 years and older enrolled in the primary schools in each community were small and to avoid potentially confounding effects associated with the onset of the adolescent growth spurt, they were not included in the present study.

Limitations

1. Although the school children were apparently healthy and free from overt disease, it is possible that some may have had conditions that could influence their performance on the fitness tests.
2. All participants were assumed to be cooperative and motivated throughout the test sessions.
3. The performance scores obtained for each of the physical fitness task items were assumed to be a true reflection of the participants' best efforts.
4. The nutritional status of the samples was based on their growth status (height and weight) and not on records of food consumption.

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CHAPTER 2

General Review of Literature

The review of literature is organized in a manner that first discusses general aspects of growth status and then the influence of growth status on the physical fitness of children with mild-to-moderate undernutrition and those living in rural and/or urban areas. The contributions of body size, physique, and composition to variation in physical fitness are then considered. Although the factors are addressed separately, it must be recognized that they are not mutually exclusive.

Nature of Malnutrition

Nutrition is a process that involves the relationship between food consumption and the functional ability of an individual (Malina and Bouchard, 1991). Basic nutritional requirements need to be met for normal growth and functional development. Any disturbances or imbalances in health and/or nutrition can ultimately affect child growth (de Onís et al., 1993; de Onís and Habicht, 1996). Protein-energy malnutrition (PEM) occurs when the protein and/or energy requirements to ensure optimal growth and function are not satisfied through the diet (Torún and Chew, 1994; WHO 2001). Currently, it is estimated that one in every four children in the world is affected with PEM, and 10.9 million children die from malnutrition per year (WHO, 2001). The primary cause of PEM is inadequate food intake, while the secondary cause is diseases "…that lead to low food ingestion, inadequate nutrient absorption or utilization, increase nutritional requirements, and/or increased nutrient losses" (Torún and Chew, 1994, p 950). The poorly nourished are more vulnerable to infections and it is estimated that an undernourished child suffers

160 days of illness per year (WHO, 2001). Insufficient nutritional intake and/or repeated digestive infections are two circumstances often prevalent in developing countries where nutritional and living conditions are marginal (Keller, 1988; de Onís et al., 1993).

The severity of PEM lies on a continuous spectrum so that its classification is somewhat arbitrary. The severe forms of PEM are kwashiorkor, marasmus, marasmic kwashiorkor, and undifferentiated depending on the signs, symptoms, and pathology of the conditions (Scrimshaw and Béhar, 1961; Torún and Chew, 1994). Mild to moderate forms of PEM are usually assessed with the use of anthropometry and age: weight-for-age, height-for-age, and weight-for-height (Waterlow et al., 1977; WHO, 1997). Although weight-for-age is the most valid indicator for children under 1 year of age, it does not discriminate between acute and chronic malnutrition in older children, especially those above 5 years of age (Waterlow et al., 1977). Weight-for-height is an indicator of current nutritional status, whereas height-for-age is an indicator of nutritional history (Waterlow, 1972).

Deficit in weight-for-age is defined as underweight, while deficits in height-for-age and weight-for-height are defined as stunted and wasted, respectively (Waterlow, 1972, 1973; WHO, 1997). Growth stunting and wasting, and underweight are estimated from height and weight relative to the U.S. reference data (Hamill et al., 1977). The criteria for classifying children as underweight, stunted, or wasted are based on z-scores that are > 2 standard deviations below age- and sex-specific reference values for United States children (WHO, 1997). Although the U.S. population is universally accepted as the reference for comparison between populations (Yip and Scanlon, 1994; de Onís and Habicht, 1996; WHO, 1997), it is recognized that the applicability of this reference has limitations. One limitation is applying the growth status of children from a developed country as the reference for those in developing countries (Walker and Walker, 1997). A second is the assumption that "...all child populations throughout the world have the same genetic potential for growth in size" (Waterlow et al., 1977, p 490; Waterlow, 1973), implying that there is no genetic variation in the growth of children. However, variation in growth in length/height among well-off children under 7 years of age in different populations is small compared to that between children from the extremes of SES within a population (Habicht et al., 1974).

At present, there is a global database that provides a standardized compilation of child growth and nutrition data for children under 5 years of age. The data were obtained from nutritional surveys conducted around the world since 1960, and are maintained and routinely updated by the World Health Organization (WHO, 1997). Available statistics showed that approximately 70% of the children with PEM live in Asia, 26% in Africa, and 4% in Latin America and the Caribbean (WHO, 2001). Geographically, Latin America and the Caribbean include countries within the Caribbean, Mexico, Central America, and South America (de Onís et al., 2000; WHO, 2001).

Given the context of the present study, attention is focused on growth stunting in Mexico and Central America. In 2000, the projected prevalence of stunting in preschool children was, on average, 32.5% (range 28.0-37.0) in developing countries of Africa, Asia, and Latin America and the Caribbean. Central America including Mexico had an estimated prevalence of stunting of 24%, which is about 3.9 million (range, 1.6-6.2 million) children (de Onís et al., 2000). Data for Mexico in 1996 indicated an overall prevalence of stunting of 33.9% in children under 5 years of age living in rural areas (de Onís et al., 2000). Information on the prevalence of stunting for older children in Mexico is limited. Data for 1994 indicated that 43.4% of first grade children (i.e., at school entry) in the state of Oaxaca were stunted. Only the state of Chiapas had a higher prevalence, 44.1% (Secretaria de Salud, 1998).

Recent data also indicate increasing rates of overweight and to a lesser extent obesity in developing countries that are already struggling with the overwhelming presence of undernutrition (de Onís and Blössner, 2000). Overweight is increasing in developing countries where segments of the population are undergoing rapid demographic change associated with economic development and rural-to-urban migration, and nutritional changes due largely to western influences (Popkin et al, 1996, 2001; Schroeder et al, 1999). The shift from undernutrition to overweight and perhaps obesity is mainly due to a change towards higher fat and lower carbohydrate diets, and reduced levels of physical activity (Popkin et al., 2001). In 1995, the prevalence of overweight among children under the age of 5 years in Latin America and the Caribbean was 4.4% (approximately 2.4 million) and 3.5% in Central America including Mexico (de Onís and Blössner, 2000). An increase in the prevalence of "diet-related" diseases in developing countries has increased the costs of public health care to comparable magnitudes as the costs for undernutrition (Popkin et al., 2001).

Undernutrition and Growth

Studies on undernutrition are often carried out in developing countries where nutritional and living conditions are marginal. Chronic undernutrition and/or episodes of infections lead to weight loss and impaired linear growth. Growth stunting most often occurs during the first two or three years of life and tends to persist into adolescence and adulthood. Stunted individuals are by definition shorter and are also lighter with reduced muscle mass (Spurr, 1984; Hoffman et al., 2000a).

Two questions are commonly addressed by studies examining the long-term consequences of undernutrition on growth and development. One is whether the early effects of nutritional deprivation result in permanent growth stunting, and the other is whether improvements in the nutritional environment enhance "catch-up" growth (Golden, 1996). The available data are somewhat inconclusive as to the "catch-up" growth hypothesis.

School children 6-12 years of age in the Valley of Oaxaca in the 1970s were shorter and lighter than better-off children of the same age and sex in the United States and Mexico (Malina, 1983). The Oaxaca data included children from rural and urban communities, and among these children, those from rural indigenous (Zapotec-speaking) communities were the shortest and lightest (Malina et al., 1981). The growth status of the children of Oaxaca suggests a profile of chronic, mild-to-moderate undernutrition.

Studies on African children, 4.0 to 6.5 years of age, reported that well-nourished children had greater body dimensions compared to two groups of malnourished children (Bénéfice et al., 1996). One of the malnourished groups included children who were exposed to chronic mild-to-moderate undernutrition, while the other group included children who were hospitalized for severe undernutrition during infancy and were subsequently nutritionally rehabilitated (Bénéfice et al., 1996; Bénéfice et al., 1999). Upon diagnosis, the nutritionally rehabilitated children were hospitalized for 6-8 weeks where they received medical and nutritional care and only left the center when the weight-for-height z-score reached –1.0 standard deviation. There were no differences among the three nutritional groups in weight-for-height and the body mass index (BMI) at the time of the study (Bénéfice et al., 1999), indicating that the children were proportionate in weight for height. The severely malnourished children had larger arm circumferences and suprailiac skinfolds than the mild-to-moderately undernourished children (Bénéfice et al., 1996). Though speculative, the greater accumulation of fat in the severely undernourished children could be due to hormonal changes during the course of starvation (Sawaya et al., 1998), or the body's tendency to store fat as a potential reserve for periods of energy inadequacy (Bénéfice et al., 1996).

Walker and Walker (1997) cautioned against mild-to-moderate undernutrition being viewed as totally underlying the growth and functional disadvantages observed in underweight school children. This caution was based on small differences in the health, well-being, learning, and physical abilities of African children 10-12 years of age who were below and above the 5th percentile of U.S. reference values for weight. Although the caution is warranted, using weight-for-age as an indictor of mild-to-moderate undernutrition may not be the most appropriate criterion to assess undernutrition in children 10-12 years of age. As noted earlier, weight-for-age is not sufficiently sensitive to differentiate the nature (acute or chronic) and severity (mild, moderate or severe) of undernutrition in children 5 years and older (Waterlow et al., 1977).

Several studies have examined the physical development of adolescents and adults with a history of undernutrition. In Senegal, childhood stunting did not affect the BMI of girls during puberty; rather, body mass and subcutaneous fat mass were comparable to those of adolescent girls who were not stunted (Bénéfice et al., 2001a, 2001b). Body height, lengths, and diameters of the "stunted" girls were, however, consistently shorter and/or smaller than the "non-stunted" girls, indicating a failure of “catch-up” growth after the original insult. The previously stunted adolescent girls also had greater accumulation of subcutaneous fat on the trunk compared to their non-stunted counterparts (Bénéfice et al., 2001a, 2001b), possibly indicating a greater stimulation of hormonal changes in fatness due to puberty (Bénéfice et al., 2001a). However, the hormonal changes in fat could also be a consequence of malnutrition as suggested by Sawaya et al. (1998). Similarly in rural Guatemala, stunting in early childhood was associated with greater abdominal fatness and percent body fat (Schroeder et al., 1999) and reduced fat-free mass (Martorell et al., 1992) in adulthood. Stunting in samples in Colombia and the Ecuadorian Amazon, however, was not associated with reduced fat-free mass (Orr et al., 2001). These studies, though suggestive, illustrate difficulties with field assessments of body composition. The index of abdominal fatness in the Guatemalan study, for example, was the waist-hip ratio, which is not necessarily an accurate indicator of relative fat distribution. Moreover, the waist-hip ratio may not be an appropriate indicator for describing subcutaneous fat distribution in children and adolescents due to potentially confounding effects of proportional changes in muscular and skeletal growth (Malina, 1974; Johnston, 1992; Sarría, 1992).

Wilson and colleagues (1999) reported a negative relationship between gastrointestinal parasitic infection and weight and stature of 6 to 16 year old Colombian boys. Infected boys were 1.61 times more likely to be stunted than their non-infected counterparts. The infected boys also had proportionally more trunk subcutaneous fat than their non-infected peers.

Nutritionally stunted children in developing countries tend to have a higher risk of becoming obese than non-stunted children. After controlling for the effects of income, Popkin et al. (1996) reported risk ratios of overweight for being stunted in 3 to 9 year old children as 7.8, 3.5, 2.6, and 1.7 in Russia, China, South Africa, and Brazil, respectively. Chronically undernourished stunted children appear to fluctuate considerably in body weight from underweight to overweight/obese when food sources are available. Hoffman and colleagues (2000b) suggested that stunted children have an impaired ability to oxidize fat, which may underlie the increased prevalence of overweight among stunted individuals.

Undernutrition and Performance

Relatively few researchers have considered chron · PE as a factor in the negative consequences for physical performance in school age children and adolescents (Malina, 1984). A good deal of the work has focused on infancy and early childhood. The few studies of school age children and adolescents have generally compared the performances of undernourished and well-nourished samples to evaluate the association between nutritional status and performance.

Chávez and Martinez (1984), for example, studied two groups of infants 2-24 months from rural Mexico. One group of infants received nutritional supplement, i.e., mashed food and bottled milk, while the other did not. Children who received the nutritional supplement were more physically active than the unsupplemented group. The differences in activity level between the groups increased with age. These findings are consistent with previous studies of 7-18 month old Indian infants where the well-nourished infants had significantly greater activity scores and time in play than undernourished infants (Graves, 1976, 1978).

The strength and motor performance of rural children, 6-13 years of age, from a Zapotec-speaking community in Oaxaca and living under conditions of chronic mild-to-moderate undernutrition were compared to better nourished American children of the same age (Malina and Buschang, 1985). The absolute levels of performance in strength and motor tasks were significantly poorer in the rural Zapotec children, but when performances were expressed relative to body size, performance levels were commensurate with reduced body size. Malina and Buschang (1985) concluded that absolute body size and nutritional status influenced performance. A subsequent analysis investigated the strength and motor performance of the children from rural Oaxaca, Mexico, with a sample from coastal Papua New Guinea (Pere village on Manus Island), and a well-nourished American sample. Although the children from Oaxaca and Pere village were weaker, the motor performances of children from Pere compared favorably to the American children (Malina et al., 1987).

Well-nourished Senegalese children, 4-6 years of age, performed better in the standing long jump, ball throw for distance, shuttle run, and static strength than two malnourished groups of children of the same age (Bénéfice et al., 1996). Mild-to-moderately malnourished children performed poorer in the power and coordination tasks than severely malnourished children. The severely malnourished group included children who were severely undernourished during infancy and were subsequently nutritionally rehabilitated for about 6 to 8 weeks with medical and nutritional care at the time of study. A principal components analysis of the anthropometric dimensions of these samples resulted in two factors, general body size and body composition, which were subsequently used in an analysis of variance in performance of the three samples of children. General body size had high, positive loadings that accounted for 41% of variance in performance, whereas body composition had moderately high, positive loadings that accounted for 25% of the variance in performance. Overall, general body size had a positive influence on the endurance run, jump, throw, agility, and hand-grip, whereas body composition had a negative influence on all the task performance.

A subsequent analysis of the Senegalese children, 4-6 years of age, examined the effects of undernutrition on motor coordination and performance (Bénéfice et al., 1999). Well-nourished children performed better than the undernourished children on all coordination and motor fitness items. Children who were severely malnourished during infancy and rehabilitated performed significantly poorer on grip strength compared to mild-to-moderately undernourished children. Body dimensions explained 7% to 50% of variation in motor performances, with stature as the main predictor. Performances were significantly influenced by body size; hence, reduced body size as a consequence of chronic undernutrition is clearly a disadvantage for performance. Growth stunting and reduced body size generally had a negative association with performance among the Senegalese children. Ten year old African boys who were undernourished (low BMI) had significantly greater grip strength per unit body mass compared to overweight boys, although they had less absolute grip strength (Naidoo, 1999). However, the performances and fitness of daily activities do not include adjustments for body size. Hence, being 'bigger is better' for many fitness and performance tasks (Spurr, 1984).

Mildly undernourished Colombian boys, 6-16 years of age, had reduced absolute oxygen uptakes, but similar maximal uptakes per unit body weight compared to well-nourished boys (Spurr et al., 1983; Spurr, 1983). Spurr and colleagues (1983) suggested that the differences observed between the absolute and relative $\dot{V}O_2max$ values in undernourished Colombian boys were due to smaller body size and possibly differences in body composition. In a subsequent analysis of the Colombian boys, small body size associated with parasitic infections also contributed to lower VO_2max (Wilson et al., 1999).

Small body size, regardless of its origin or cause, tends to adversely affect performances. Guatemalan children who were stunted at 3 years of age or earlier had reduced grip strength as adults (18 years or older) compared to those who were not stunted during childhood (Martorell et al., 1992). In communities where nutritional and living conditions are marginal, the economy depends largely on intensive manual labor, reduced strength and work capacity can have significant repercussions on the productivity and livelihood of the population (Malina, 1986).

The timing and intensity of nutritional stress is central to the resulting effects on physical fitness (Malina and Bouchard, 1991). It is assumed that the earlier onset and greater intensity of undernutrition, the poorer would be performances. Under the unfavorable conditions of undernutrition, males are generally more sensitive and are more affected by these environmental stresses compared to females (McCance, 1966; Malina et al., 1985; Stinson, 1985).

Stunting and Fat Distribution

Significant changes in the relative distribution of subcutaneous adipose tissue occur during puberty and the adolescent growth spurt (Malina and Bouchard, 1991; Malina, 1996). During adolescence, boys tend to develop thicker skinfolds on the trunk relative to the extremities, while girls tend to accumulate similar amounts of subcutaneous fat on the trunk as on the extremities (Baumgartner et al., 1986; Baumgartner and Roche, 1988; Malina 1996). Studies have also shown ethnic variation in the distribution of subcutaneous fat (Mueller, 1988; Malina et al., 1995; Malina 1996; Naidoo, 1999), although results vary among ethnic groups. American adolescent girls of Asian and Mexican ancestry have proportionally more subcutaneous fat on the trunk than those of European and African ancestry (Malina et al., 1995), whereas some data also indicate proportionally more subcutaneous fat on the trunk among Americans of African ancestry (Mueller, 1988; Malina, 1996). Among 10 year old African boys, those of East Indian ancestry had a greater accumulation of adipose tissue on the trunk relative to the extremities compared with boys of African and European ancestry (Naidoo, 1999).

Most studies of subcutaneous fat distribution have been conducted on children, adolescents and adults from industrialized countries (Garn, 1955; Baumgartner et al., 1986; Baumgartner and Roche, 1988; Malina et al., 1995; Malina, 1996; Van Lenthe et al., 1996). Few studies have evaluated the distribution of subcutaneous fat in populations of developing countries where undernutrition is chronic (Schroeder et al., 1999; Bénéfice et al., 2001a, 2001b).

Studies that have examined the long-term consequences of early stunting on the distribution of subcutaneous fat are limited to two follow-up studies, one in Guatemala (Schroeder et al., 1999) and the other in Senegal (Bénéfice et al., 2001a, 2001b). These follow-up studies evaluated the growth status of adolescent and adult samples who were classified as stunted or non-stunted at 6-18 months (Bénéfice et al., 2001a, 2001b) and at 36 months (Schroeder et al., 1999) of age, respectively. The evidence suggested proportionally greater accumulation of subcutaneous fat on the upper body in stunted adolescents and adults. The study of adolescents used skinfolds, whereas the study of adults used the waist-hip ratio. Bénéfice et al. (2001a) suggested that the tendency to accumulate subcutaneous fatness on the trunk "...may represent transitory changes in fatness under the influence of hormonal stimulation during puberty" (p. 57). Based on an elevated prevalence of overweight in mildly stunted 7-11 year old girls from a shanty town (favela) in São Paulo, Brazil, Sawaya et al. (1998) proposed that the hormonal changes associated with malnutrition may render individuals more susceptible to weight (and presumably fat) gain in the presence of high fat diets.

Rural-Urban Differences in Growth

Differences in the living conditions under which children are reared have an effect on growth. Under apparently 'better' living circumstances, growth potential is more likely to be achieved, whereas under marginal conditions growth can be compromised. Earlier data from Europe consistently show that children living in urban areas are larger and mature earlier than those living in rural areas (Meredith, 1979, 1982; Eveleth and Tanner, 1990). The positive effects of urbanization on growth are presumably associated with improved living conditions related to health care and diet. These include, for example, a constant food supply, clean access to public water and sanitation, health services, available quality medical services, educational institutions, and recreational and welfare facilities within a community (Eveleth and Tanner, 1990). Although urban children are, in general, taller and heavier than their rural peers (Meredith, 1979, 1982), socioeconomic status (SES) can influence the benefits associated with urbanization. More recent European data do not show marked rural-urban differences expect for several countries in Eastern Europe. Data from the United States indicate negligible rural-urban differences in growth status (Hamill et al., 1972).

Growth studies of children from developing countries, specifically Latin America, indicate rural-urban differences, but nutritional status and access to food and health resources are mediating factors. At present, Latin America is faced with increased rural to urban migration that has resulted in a sector of the lower class that does not have access to resources although it has the "advantage" of living in a city. In developing countries, rapid urban growth due to expansions of urban slums and marginal areas are not necessarily associated with improved growth status in children, but relatively few studies have compared the growth status of Latin American children living in rural and urban communities (Graham et al., 1980; Malina et al., 1981; Peña Reyes, 2002).

Malina et al. (1981) compared the growth status of children 6-14 years from rural and urban communities in southern Mexico. The children were from three different types of communities: two colonias in the city of Oaxaca (urban), two rural Ladino communities, and two rural Zapotec-speaking communities in the Valley of Oaxaca. The Ladino communities were more westernized in lifestyle and agricultural practices compared to the rural Zapotec-speaking communities, which practiced subsistence agriculture using traditional techniques. The rural children from the Zapotec-speaking communities were shorter and lighter, and had reduced muscle mass compared to children from the Ladino communities and urban colonias. Children from the rural Ladino communities were slightly larger in height and weight than children from the colonias, implying that children living in rural communities with westernized lifestyles are better off than those living in the urban slums.

Similar findings were reported on Peruvian children from four relatively prosperous rural agricultural villages and a poor urban community in Lima (Graham et al., 1980). Slight height differences favored the urban children, particularly among boys. There was no difference in stature between rural and urban girls. The rural children also had lower weights and thus less weight-for-height compared to the urban children.

Cameron and colleagues (1992) compared two groups of urban children from average to high SES and two groups of rural children (from presumably lower SES), 5-19 years of age, in South Africa. Anthropometric dimensions included weight, height, sitting height, biacromial and bi-iliac breaths, head and arm circumferences, and four skinfolds. The higher SES urban children were consistently, though not significantly, taller and heavier than all other groups of children. However, 'average' SES urban children were consistently and at times significantly, smaller and lighter than their rural counterparts. Among 9 year old Nigerian boys, urban boys were, in general, larger in body size and skeletal robustness than rural boys. Arm and abdominal skinfold thicknesses were also greater for the urban than rural boys (Spurgeon et al., 1984). Among Japanese children, 9-17 years of age, the amount of subcutaneous fat in urban children was significantly greater compared to rural children, although height and weight were comparable (Matsui and Tamura, 1975).

Rural-Urban Differences in Performance

In contrast to comparisons of the growth status of rural and urban children, corresponding comparisons of performance are relatively limited. A comparison of the weight, height and physical fitness (dash, agility, ball throw, vertical jump, and squat-thrust) of 10 year old rural and urban Polish children indicated rural-urban differences in fitness that favored the urban children (Pilicz and Sadowska, 1973). In this sample of Polish children, rural and urban boys did not differ in height and weight, whereas urban girls were significantly taller, but not heavier, than rural girls. Children from four rural and two urban districts of Japan were compared for aerobic capacity (Matsui and Tamura, 1975). Rural children were superior in their endurance ability to urban children.

Similarly, Corlett and Mokgwathi (1987) compared the endurance running ability of rural and urban Tswana children and noted superior endurance performance in the rural children. Rural and urban children, aged 7-12 years, living in Bostwana were also compared in height, weight, upper arm circumference and hand grip strength (Corlett, 1988). The urban children were stronger than their rural peers. Even when body size was statistically controlled, the superior performance in grip strength persisted with increasing age, but to a lesser extent.

Cultural and social conditions of a community also influence the development of motor proficiency. Munetaka et al. (1971) evaluated the contribution of community differences to the growth and motor development of 4-5 year old children living in three different communities in Japan: an island, a housing development, and an urban area. Four body dimensions and 13 motor ability items were measured. The average family size was larger in the island sample, while the urban sample had a higher percentage of parents who were either senior high school or college graduates. Body dimensions between the groups were not significantly different. The island sample was superior in coordination and flexibility test items, while the urban sample was superior in all other motor ability items.

Anthropometric Correlates of Fitness

Body Dimensions

Children who are shorter and lighter generally tend to perform poorer on fitness tasks than taller and heavier peers (Malina, 1975, 1994; Malina et al., 1987). Body weight is negatively correlated with performances on jumping and running tasks, and positively correlated with performances on throwing tasks (Seils, 1951; Rarick and Oyster, 1964; Malina, 1975, 1994). These trends imply that lighter children perform better in activities involving movement or projection of the body through space (jumping and running) compared to heavier peers, who perform better in object projection tasks (throwing). Absolute body mass is also a major contributor to static muscular strength (Malina, 1975, 1994).

Stature and weight correlate better with strength than with other fitness variables, particularly during middle childhood, indicating that a child who is bigger tends to be also stronger (Malina, 1975; Malina and Buschang, 1985; Malina and Bouchard, 1991; Bénéfice and Malina, 1996). However, height and weight have only low to moderate correlations with other motor fitness variables such as the grip strength, jump, dash, shuttle run, and distance throw (Seils, 1951; Espenschade, 1963; Rarick and Oyster, 1964; Montoye et al., 1972; Malina, 1975; Rocha Ferreira et al., 1991; Bénéfice and Malina, 1996), and the correlations overlap by sex, socioeconomic status and ethnicity (Malina, 1994).

Since age, stature, and weight are related to performance, studies have used partial correlation analyses to evaluate relationships among age, body size, and performances on a variety of tasks (Table 2.1). The partial correlations are variable and overlap by sex, SES, ethnicity, and nutritional status (Seils, 1951; Rarick and Oyster, 1964; Malina and Buschang, 1985; Rocha Ferreira et al., 1991; Malina, 1975, 1994; Bénéfice and Malina, 1996). When stature and weight are statistically controlled, age is positively related with performances on several motor tasks, which is consistent with the notion that neuromuscular maturation and/or experience associated with age is positively related with some fitness (Malina and Bouchard, 1991; Malina, 1994). Similarly, correlations between stature and performances are mainly positive after age and body weight are controlled. Body weight, on the other hand, is often negatively related to performances, after controlling for age and stature, specifically those performances involving projection or movement of the body through space.

Body mass is a predictor of static strength in children and accounts for a major part of the variance in strength tests (Malina and Buschang, 1985; Rocha Ferreira et al., 1991; Bénéfice and Malina, 1996; Katzmarzyk et al., 1997). As noted earlier, Malina and Buschang (1985) compared the grip strength and motor performances of 6-13 year old children from a rural Zapotec-speaking community in the Valley of Oaxaca, Mexico, to better nourished American children. The absolute size, strength and motor performances of undernourished Zapotec-speaking children were less than those of the American children. However, when body size was controlled, the differences were reduced. In fact, the Zapotec children had better throwing performances per unit body size and similar grip strengths compared to the American children. Hence, variation in performance is influenced by absolute body size. The residuals of other anthropometric dimensions (a skinfold, estimated muscle circumference, segment lengths, and skeletal breadths), after controlling for the combined effects of age, height and weight, were regressed on grip strength and motor fitness in the sample of Zapotec children. Few of the variables added significantly to explaining the remaining variation in the performances of Zapotec children.

Bénéfice and Malina (1996) examined the contribution of body dimensions and composition to the variation in the fitness of Senegalese children. Stature and weight explained about 30% to 50% of the variation in the performances of fitness tasks in children younger than 10 years of age. Among children older than 10 years, weight was the best predictor of performances of the fitness tasks, but the proportion of variance in motor performance explained by weight alone was only 10 to 25%.

Stature, on the other hand, was the main predictor of performance in the fitness tasks for children younger than 6 years of age.

Studies evaluating the relationships between specific segment lengths and circumferences and performance are limited. Malina (1975) examined the relative relationship of leg length (sitting height subtracted from stature) to the performances of selected fitness tasks for children 6-12 years of age. The relationships between leg length and running, jumping, and throwing were low and perhaps reached the moderate range (correlation coefficients: 0.00 to +0.34). Previous studies also indicated low relationships between leg length and various performance tasks (Clarke, 1957; Clarke and Degutis, 1964; Baacke, 1964). Correlations between leg length and performance were, in general, of the same magnitude or slightly less than those between stature and performance. The comparable association of stature and leg length with performance is expected, as leg length is a major component of stature.

Limb circumferences are positively related to performance, particularly strength tasks (Malina, 1975, 1994; Bénéfice and Malina, 1996). The strength of a muscle is proportional to its cross-sectional area (Malina, 1984). Limb circumferences are related to body mass, so that a question of interest is the relationship between limb circumference and performance after statistically controlling for body mass. Small body size and/or a reduction in muscle mass is associated with less absolute strength. Children with smaller arm circumferences have lower static strength measurements compared to those with larger arm circumferences (Malina et al., 1987; Malina and Buschang, 1985).

Physique

Physique refers to the general shape or form of the body as a whole (Malina, 1975, 1978, 1992; Malina and Bouchard, 1991). There are several methods for assessing physique (Sheldon et al., 1940, 1954; Parnell, 1958), but the most common method and that which will be used in the present study is the Heath-Carter anthropometric somatotype protocol (Carter and Heath, 1990; Malina, 1995). The Heath-Carter method uses several anthropometric dimensions to estimate the three components of somatotype: endomorphy, mesomorphy, and ectomorphy (Carter and Heath, 1990; Malina, 1995).

Endomorphy refers to relative fatness, and softness and roundness of contours throughout the body. It is estimated from the sum of three skinfolds adjusted for height in the Heath-Carter anthropometric protocol.

Mesomorphy refers to the robustness of musculoskeletal development, i.e., a predominance of muscle, bone, and connective tissues. It is estimated from two extremity skeletal breadths (biepicondylar breadth of the humerus and bicondylar breadth of the femur), two limb circumferences corrected for skinfold thickness (flexed arm circumference and the triceps skinfold, and calf circumference and the medial calf skinfold), and height.

Ectomorphy refers to relative linearity or slenderness, and the predominance of surface area over body mass. It is estimated from the reciprocal ponderal index, height divided by the cube root of weight.

The lowest possible rating with the Heath-Carter protocol is 0.1, and the upper end is open. In practice, most scores range between 1 and 7, which is the range of the fixed scale initially described by Sheldon and colleague (1940, 1954). A somatotype is a composite that represents the contribution of each component. On average, children in the age range of the present study (6-11 years), tend to have a balanced somatotype, e.g., 3-4-3 or 3-3-3, where the first number refers to endomorphy, the second to mesomorphy and the third to ectomorphy. A somatotype of 2-5-2 indicates dominant mesomorphy, while somatotypes of 5-2-2 and 2-3-5 indicate dominant endomorphy and ectomorphy, respectively.

Variability in the range of ratings of somatotype components is reasonably large within and/or between populations. Among males, ratings range from 1.0 to 10.5 for endomorphy; 1.0 to 9.5 for mesomorphy, and 0.5 to 9.0 for ectomorphy. Corresponding ranges among females are 1.5 to 10.0 for endomorphy, 0.5 to 6.0 for mesomorphy, and 0.5 to 6.5 for ectomorphy (Carter and Heath, 1990). On average, males tend to become more mesomorphic, while females become more endomorphic with age during childhood (Carter and Heath, 1990; Malina and Bouchard, 1991).

The Heath-Carter anthropometric somatotype method was developed on adults and the samples used to validate the method were largely adult males (Carter and Heath, 1990). Hence, the applicability of the method "...to the growing and maturing individual, to females, or to the clinically ill, may require adjustment" (Malina, 1992, p. 94-95).

It is important to note that the three components of somatotype together constitute an individual's physique. However, the specific component ratings are often analyzed individually without controlling for the effects of the other two components, thus limiting the essence of the somatotype concept. Cressie et al. (1986) recommended a multivariate analysis of variance (MANOVA) approach to analyzing the Heath-Carter somatotype so as to maintain "...the essential quality of component dominance together with the relationship of the three components in the individual subject" (p.197).

Studies examining somatotype have largely described or compared the physiques of individuals in different populations, and athletes in a variety of sports (Carter and Heath, 1990). The Heath-Carter anthropometric somatotype protocol has also been applied to samples of healthy children and adolescents primarily of European ancestry (Carter and Heath, 1990; see also Malina and Bouchard, 1991), but has been used to a lesser extent in Latin American children.

The protocol was used with school children of both sexes 7 through 18 years of age in Guatemala (Alexander et al., 1993) and Venezuela (Alexander, 1992), and with boys 6 to 15 years of age in Chile (Godoy et al., 1994). The studies in Guatemala and Venezuela were done in the context of national physical fitness surveys of school children and the results were presented as descriptive statistics by age and sex. Relationships between somatotype components and physical fitness were not addressed. The study in Chile was limited to boys attending a private school (i.e., upper class) in Santiago and focused on age changes in somatotype components in small samples followed longitudinally over one year.

In contrast, the Heath-Carter anthropometric somatotype method has not been commonly applied to populations living under marginal health and nutritional conditions. Murguia et al. (1990) applied the protocol to a large sample of children and adolescents of both sexes 5-20 years of age from different areas of Yucatan, Mexico. The samples were from a traditional Indian community (subsistence maize agriculture) and from municipalities which were more “modern” areas specializing in fishing, sisal production, and cattle raising. Although there were body size differences among the samples, there was considerable overlap in mean somatotypes. Endomorphy tended to be lower in boys and girls 6-11 years of age from the subsistence agricultural community, but mesomorphy and ectomorphy were similar. Unfortunately, the study was largely descriptive with little statistical analysis.

Godoy and Barcos (1995) used the Heath-Carter protocol with Chilean girls 4-11 years to address somatotype variation associated with socioeconomic and nutritional status, while Diaz Gamboa and Fuentes Heinrich (1996) compared the somatotypes of Aymara boys and girls, 6-15 years of age, resident at high altitude (3000-4500 meters) in northern Chile. Table 2.2 presents a summary of mean somatotypes from these studies of Latin American children. A question of interest is the applicability of the method on samples of children living under varied nutritional and other environmental conditions.

Correlations between somatotype components and performance in running and jumping activities are generally low to moderate in 7-12 year old boys and girls, with endomorphy and ectomorphy more closely related to running and jumping than mesomorphy (Slaughter et al., 1977, 1980). The most consistent relationship of somatotype and performance is a negative association between endomorphy and running, jumping and agility tasks (Malina, 1975, 1992; Slaughter et al., 1977). Some data indicate a negative correlation between mesomorphy and a moderate distance run, the 600 yard run (Slaughter et al., 1977, 1980). The authors suggested that the negative relationship may be influenced to some extent by fatness as heavier children tend to be higher in mesomorphy. However, the analysis did not control for variation in the other two somatotype components (see above).

Subcutaneous fat is the major aspect of endomorphy in the Heath-Carter protocol and represents 'dead weight' that has no mechanical advantage in performances of activities. Hence, it often hinders the performance of activities that involve the projection or movement of the body through space (Malina, 1992).

Conversely, endomorphy is positively related to performances of static strength, emphasizing the contribution of overall body size to strength. However, relationships between mesomorphy and ectomorphy and performance are not consistent across studies. For example, endomorphy and mesomorphy have a moderately positive correlation with muscular strength while ectomorphy correlates negatively to muscular strength (Malina, 1975). This indicates that overall body size, particularly fat-free mass, is important for strength, which implies that variation in strength is accountable by the amount of muscle mass.

Most studies relating somatotype to performance are limited to correlations between one component and the performance task. As noted earlier, somatotype is defined by the three components together so that treating a component in isolation from the other two may provide limited information. Since the three components are interrelated, it is more appropriate to use second-order partial correlations or multivariate techniques to analyze relationships between the somatotype and performance.

Body Composition

Body composition refers to the partitioning and quantification of the primary tissue components of body mass (Malina and Bouchard, 1991). The two-compartment model, fat-free mass and fat mass, is most commonly used (Beunen et al., 1982; Malina and Bouchard, 1991), although recent developments in methodology permit the use of multi-component modes. Anthropometric dimensions provide an indirect estimate of body composition. Skinfold thicknesses at specific sites are often used as an indication of subcutaneous fat (Malina, 1996) and are good predictors of body fat because the majority of fat is subcutaneous (Norgan, 1991).

Correlations between body composition and performance are generally low to moderate, but vary somewhat across studies. Fat-free mass and measures of muscularity are positively correlated to motor performance (Malina, 1984; Bénéfice and Malina, 1996). Fat mass is negatively associated with performance, especially items that require displacement or projection of the body (Malina, 1975, 1994; Beunen et al., 1983; Thomas and Thomas, 1988; Malina and Bouchard, 1991; Bénéfice and Malina, 1996). Although the performance of sit-ups does not require great displacement of the body, it is also negatively associated with fatness (Riendeau et al., 1958; Cureton et al., 1975; Pate et al., 1989). Static strength, on the other hand, is positively associated with fatness since fatter children and adolescents tend to be taller and heavier (Beunen et al., 1983; Malina and Bouchard, 1991).

Compared to males, females, on average, have a greater proportion of fat mass. Although this is apparent in childhood, the sex difference becomes more defined during adolescence when the fat mass in girls increases at an estimated rate that is almost twice that of boys (Malina and Bouchard, 1991). The sex difference in fatness is often invoked as underlying sex differences in performance.

The fitness of the fattest (obese) and leanest children in several age groups of national samples of Belgian boys and girls was compared (Beunen et al., 1983; Malina et al., 1995). Within each sex and age group, the leanest children performed better, on average, on a variety of motor fitness tests. Static shoulder strength and absolute power output (PWC170, measured in girls only) were exceptions. Absolute values were higher in obese children as being heavier in absolute body mass, regardless of the composition of fat mass and fat-free mass, often results in better performances. However, when adjusted for body weight, the leanest children performed better per unit body mass.

Naidoo (1999) reported that fatness, estimated as the sum of five skinfolds, accounted for 31% of the variation in grip strength per unit mass of 10 year old South African boys. Grip strength per unit of body weight was negatively related to fatness indicating the non-functional contribution of subcutaneous fat to performance, particularly for the fattest boys. Fatness, on the other hand, explained only a small proportion, between 1% to 5%, of the variation in the dash, distance run, push-up, sit and reach, sit-ups, and standing long jump of the 10 year old boys.

In a chronically undernourished population, muscularity and subcutaneous fat have a limited influence on the variance in several motor performances (Bénéfice and Malina, 1996). Muscularity and subcutaneous fat predicted the performances only in 6-10 year old boys, but not in younger and older age groups of boys. However, muscularity and fatness contributed more significantly to the variance in the performances of girls. Among rural Zapotec children in Oaxaca, fatness as estimated from the triceps skinfold was negatively related to the performances in boys but positively related to the performances in girls 6-13 years of age (Malina and Buschang, 1985). In a subsequent analysis of a subsample of the Zapotec boys 9-12 year of age, relative fatness predicted from four skinfolds (triceps, subscapular, midaxillary, and suprailiac) was positively related to grip strength, but had no relationship with running and jumping performances (Malina and Little, 1985). The relatively close relationship between fatness and performance among extremely lean children suggests that there might be a threshold below which fat mass does not exert a negative influence on motor performance, but rather relates positively to performance. Conversely, there may also be a threshold above which excess fat mass exerts a negative influence on performance (Malina and Little, 1985; Bénéfice and Malina, 1996).

Taken together, anthropometric correlates of physical fitness are often analyzed through partial correlational analyses. Few studies have conducted multivariate analyses to explain the variation in performance associated with body segments, lengths, and proportions and body composition. The Heath-Carter somatotype protocol has not been extensively used with Latin American children, particularly those from marginal nutritional and living conditions. Furthermore, the difficulty in keeping the integrity of the three scores that make up somatoype as a composite has limited the exploration of the relationship between somatotype and physical fitness. Physical growth, especially height and weight, of stunted children have been examined to a great extent, while relatively few studies have examined the consequences of stunting on the performance of physical fitness as well as the distribution of subcutaneous fat in stunted and non-stunted children.

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Table 2.1 Summary of studies that used second-order partial correlations between age, height and weight, and physical fitness tasks in children 6-15 years of age.

Study	Sample	Sex	* Range of Correlations	Tests
Seils (1951)	American primary grade children, 6-9 years, from public schools in four communities	Boys (n = 272) Girls (n = 238)	Age: 0.01 to 0.43 Height: - 0.00 to 0.26 Weight: - 0.29 to 0.11	40-yard Dash SLJ Dist Throw
Rarick and Oyster (1964)	American second grade school boys, 7-8 years, from upper to middle suburban community	Boys (n = 48)	Age: 0.17 to 0.32 Height: 0.12 to 0.30 Weight: - 0.27 to - 0.12	30-yard Dash SLJ Dist Throw
Malina and Buschang (1985)	Mexican school children, 6-15 years, from the Valley of Oaxaca	Boys and Girls (n = 332 to 364)	Height: 0.07 to 0.35 Weight: - 0.19 to 0.39	35-yard Dash SLJ, Grip Dist Throw
Rocha Ferreira et al. (1991)	Brazilian school children, 8 years, low SES	Boys (n = 84) Girls (n = 60)	Height: 0.07 to 0.42 Weight: - 0.31 to - 0.19	50 m Dash SLJ, Grip Dist Run
Bénéfice and Malina (1996)	Senegalese children, 5-13 years, from poor farming families in two rural communities	Boys (n = 168) Girls (n = 180)	Age: 0.00 to 0.25 Height: - 0.08 to 0.26 Weight: 0.03 to 0.28	20/33 m Dash SLJ, Grip Dist Throw

*Correlations between age, height, or weight with the fitness items when the other two variables are statistically controlled are shown. Only correlations for tests common to all the studies and similar to items used in the present study are shown. The signs for timed items such as the dash and agility run were inverted as a lower time indicates better performance.
SLJ = Standing Long Jump; Grip = Static Grip Strength; Throw = Distance Throw; Run = Distance Run.

Table 2.2 Mean somatotypes of children 6 to 11 years of age in several Latin American countries.

Study	Sample	Sex	Endomorphy	Mesomorphy	Ectomorphy
Murguia et al. (1990)	Mexican children, 6-11 years, from traditional Indian community and municipalities in Yucatan	Indian: Boys (n = 164)	* 2.0	* 4.6	* 1.7
		Girls (n = 190)	* 2.5	* 4.4	* 1.6
		Sisal: Boys (n = 114)	* 2.3	* 4.0	* 2.2
		Girls (n = 106)	* 2.8	* 3.7	* 2.1
Alexander (1992)	Venezuela school children, 8-11 years, national survey	Boys (n = 1,176)	3.1	4.3	2.4
		Girls (n = 1,202)	3.5	3.8	2.4
Alexander et al. (1993)	Guatemalan school children, 8-11 years, national survey	Boys (n = 1,590)	3.1	4.3	2.7
		Girls (n = 1,755)	3.7	3.9	2.9
Godoy et al. (1994)	Chilean school boys, 6-11 years, medium to high SES	Boys (n = 603)	3.0	4.5	2.7
Godoy and Barcos (1995)	Chilean school girls, 6-11 years low SES	Girls (n = 172)	* 2.6	* 4.2	* 2.2
Diaz Gamboa and Fuentes Heinrich (1996)	Chilean children, 6-11 years, living at high altitude (3000-4500 m)	Boys (n = 62)	* 2.8	* 4.6	* 1.6
		Girls (n = 55)	* 3.7	* 3.8	* 1.8

*Estimated from age-specific means adjusted for sample sizes in each age group. The specific algorithms for calculating endomorphy, mesomorphy, and ectomorphy with the Heath-Carter anthropometric protocol (Carter and Heath, 1990) are described in Chapter 3.

CHAPTER 3

Methods and Procedures

The present study was developed within the activities of the general project: "Secular change in size, strength and motor fitness in the Valley of Oaxaca, Mexico", with Robert M. Malina as the principal investigator (Malina, 1999, 2002). The data were collected in Fall 1999 and Spring 2000, and descriptive analyses of rural and urban children were reported by Peña Reyes (2002). This study extends the analyses to specific issues related to the anthropometric correlates of physical fitness, somatotype, and growth stunting.

Communities Studied

The communities under study, the participants surveyed, and anthropometric and physical fitness data, are briefly described. More detailed information has been previously reported by Peña Reyes (2002).

The state of Oaxaca is in the southern part of Mexico, and the Valley of Oaxaca lies in the center of the state (Figure 3.1). The altitude of the valley floor ranges from 1420 to 1740 m; the valley is surrounded by mountains that reach over 3000 m (Kirkby, 1973). The raised valley floor requires that the issue of altitude affecting the performance of physical fitness tasks, especially cardiovascular endurance, be considered. The potential influences of physiological changes associated with such a moderate altitude are negligible. Altitude appears to affect the threshold level of performance and it seems to be prevalent with training at altitudes above approximately 2,500 meters (Åstrand, 1954).

Performance at high altitude is also affected by level of acclimatization, usually viewed in field studies as duration of residence at a specified altitude. Given the rather moderate altitude of the Valley of Oaxaca and the long term residence of the children at this altitude, the influence of altitude on fitness or performance in the present study is not an issue.

The city of Oaxaca de Juarez is located at the junction of the Y-shaped valley. School children in two communities, one rural and the other urban, in the Valley of Oaxaca comprise the basis for this study. Living conditions in the rural and urban communities in Oaxaca are quite different.

Santo Tomas Malzaltepec is a rural community located about 23 km northwest of the city of Oaxaca. The community is largely based on a tradition of kinship with small-scale family subsistence farming, although a small but increasing number are engaged in other economic activities. In addition, a significant number of adult males have migrated to Mexico City and the United States, and regularly send funds back to the community. There is a health center that is staffed by a public health nurse and a physician who goes to the center daily during the week, except on weekends. Essential utilities such as sewage systems, water availability within each household, and water treatment, though improving in recent years, are generally lacking in the community. The number of paved roads is also limited.

San Juan Chapultepec is an urban community located on the slopes of the hills west of the city of Oaxaca. Most of its population works in the city of Oaxaca. San Juan is an irregular settlement on the edge of the city. Such settlements are called colonias populares in Mexico, although historically, San Juan Chapultepec was an independent community (Graedon, 1976; Murphy and Stepick, 1991). Facilities for health care and sanitation in San Juan are far from the expectations of an urbanized center, but they are in advance of those available in Santo Tomas. San Juan, for example, is within several kilometers of a hospital and related public health facilities.

Both communities were categorized as rural and urban, respectively, based on the census on the national census for Mexico in 2000 (INEGI, 2002). Comparative data for indicators of social, economic, educational and health conditions in Santo Tomas (rural), San Juanito (urban), the city of Oaxaca and the state of Oaxaca are summarized in Table 3.1.

Participants

An initial sample of 708 primary school children (355 boys, 353 girls), 6.01 years to 15.74 years (9.3 $\pm$ 2.0 years), was measured during surveys of the rural and urban communities in the Fall 1999 and early Spring 2000. According to Mexican law, it is mandatory for all children to attend school. Hence, the children represent the total student body in each school at the time of the surveys, except for one child from the urban community. All of the children were apparently healthy and showed no overt signs of being in a diseased state and no obvious physical disabilities. It is possible that several children might have had minor anomalies, but none were immediately apparent. It is likely that children with disabilities or congenital anomalies died before school age. Several cases of Down Syndrome were noted in the mortality records for the 1980s and 1990s, and all deaths occurred before 5 years of age (Malina, field notes).

For the purpose of the present study, the sample was limited to children between the ages of 6.00 to 11.99 years of age, which includes approximately 91% of the initial sample. Numbers of children older than 12.0 years were small in specific age groups within each sex and community. The rural sample thus comprised 329 children, 154 boys and 175 girls with mean ages of 8.8 ± 1.5 years and 9.1 ± 1.7 years, respectively. The urban sample included 318 children, 161 boys and 157 girls with mean ages of 8.8 ± 1.7 years and 9.0 ± 1.7 years. Chronological ages were calculated from date of measurement and birth dates taken from official school enrollment records.

The study was approved by the University Committee for Research Involving Human Subjects at Michigan State University (Appendix A). Local authorities and school officials of each community also approved the project. Parents provided informed consent for their children to participate in the study. Self-assent was also obtained from school children 10 years of age and older. The statement of participation was read to the parents of the children and to the older children, and they were informed that their children or they could participate and/or withdraw from the study at any time.

Anthropometric Variables

Measurements were taken following the protocol described in Lohman et al. (1988; also see Malina 1995). Bilateral dimensions were taken on the left side, which was consistent with the measurements taken in earlier studies done in Oaxaca. Body weight (kg) was measured using a portable scale accurate to 100 grams. The children were measured without shoes, but wore light clothing with all accessories removed. Stature (cm) was measured with a portable field anthropometer with the children standing with arms hanging relaxed at the sides in an erect posture and the eyes in a horizontal plane, with heels placed together without shoes and body weight evenly distributed between both feet. Sitting height (cm) was measured with the portable field anthropometer with the children sitting erect on a table with feet hanging freely and hands positioned on the thighs with palms down. Biacromial and bicristal breadths were measured with the upper end of the anthropometer used as a large sliding caliper, while bicondylar and biepicondylar breadths were measured with a small sliding caliper. Relaxed arm, flexed arm, and calf circumferences were measured with a flexible, non-stretchable tape. The triceps, subscapular, suprailiac and medial calf skinfolds were measured with the Lange skinfold caliper to the nearest 0.5 mm. The weighing scale and all anthropometric equipment (anthropometer, calipers, and tapes) were checked and calibrated daily before measurements were taken. Detailed descriptions of the anthropometric techniques are described in Appendix B.

Derived Variables

The anthropometric dimensions were used to derive several additional variables: (a) the body mass index (BMI, - kg/m^2); (b) estimated leg length (subischial length) – standing height minus sitting height; (c) the sitting height to standing height ratio – sitting height divided by stature multiplied by 100; (d) the sum of four skinfolds (triceps, subscapular, suprailiac and medial calf); and (e) the trunk-extremity ratio – sum of subscapular and suprailiac skinfolds divided by sum of triceps and medial calf skinfolds. Estimated arm and calf muscle circumferences were derived from relaxed arm circumference and the triceps skinfold, and calf circumference and the medial calf skinfold, respectively, using the following formula:

$$\text{Muscle circumference} = C - (\pi S)$$

where C is relaxed arm or calf circumference (cm) and S is the triceps or medial calf skinfold (cm). The derived values provide an estimate of the relative muscularity of the upper arm and lower leg, respectively (Malina, 1995).

Somatotype was estimated with the Heath-Carter anthropometric protocol using the algorithms provided by Carter and Heath (1990, p 374):

1. $\text{Endomorphy} = -0.7182 + 0.1451(X) - 0.00068\,(X^2) + 0.0000014(X^3)$

where X is the sum of the triceps, subscapular, and suprailiac skinfolds and multiplied by 170.18/height in cm.

2. Mesomorphy = [(0.858 x biepicondylar breadth) + (0.601 x bicondylar breadth) + (0.188 x corrected arm circumference) + (0.161 x corrected calf circumference)] – (stature x 0.131) + 4.50

where the corrected arm circumference is flexed arm circumference (cm) minus the triceps skinfold (cm) and the corrected calf circumference is calf circumference (cm) minus the medial calf skinfold (cm).

3. Ectomorphy = HWR x 0.732 – 28.58

where HWR is height (cm) divided by the cube root of weight (kg). If HWR is less than 40.75 but more than 38.25, then Ectomorphy = HWR x 0.463 – 17.63, and if HWR is equal or less than 38.25, a rating of 0.1 is given.

The somatotype of a given child is defined by the three components: endomorphy (first component), mesomorphy (second component), and ectomorphy (third component), respectively.

Physical Fitness

The physical fitness battery included a combination of performance- and health-related tasks (Malina, 1991). Three of the tests were used in earlier studies in the rural community – grip strength, dash, and standing long jump (Malina and Buschang, 1985). The other three, all indicators of health-related fitness (American Alliance for Health, Physical Education, Recreation and Dance, 1980), were selected for their suitability in field conditions, specifically for ease of administration without extensive equipment. All tests were administered during the school day. The tests were demonstrated and explained to the children, and a warm-up, largely stretching, was provided. Detailed descriptions of each fitness test are described in Appendix B.

1. Static strength - Static grip strength of the left and right hands was measured with a Stoelting adjustable dynamometer to the nearest 0.5 kg. Three trials were given with each hand and the best score was retained for each. The children were instructed to exert maximum effort on each attempt.
2. Speed - Running speed was measured as the time elasped in a 35 yard dash (32.3 meters) from a stationary start. Two trials were given and the faster time to the nearest 0.1 second was used. The children ran individually and were instructed to run as fast as they could at the command "go". A rest time between the trials was allowed.

3. Power - Explosive power was measured as the standing long jump. Three trials were given and the furthest distance jumped (cm) was used in the analysis. The children were estimated to jump as far as possible on each attempt.
4. Flexibility - The sit and reach was used to estimate the flexibility of the lower back and upper thigh. Three trials were given and the furthest distance reached (cm) was used. The children were instructed to reach straight out without bouncing.
5. Muscular endurance – Endurance of the abdominal musculature was measured as timed sit-ups, the number completed in 30 seconds. One trial was given. The children were instructed to do as many sit-ups as they could when the cue counting time starts and only stopped when they were told.
6. Cardiovascular endurance – The distance (meters) run and/or walked in 8 minutes for children in grades 1 to 3 and 12 minutes for grades 4 to 6 was used as an indicator of cardiovascular fitness. One trial was given. The children were instructed to run at their own pace for the duration and not to stop moving until the end of the test.

Static grip strength was measured at the time of anthropometry. The dash and the distance run were conducted on a concrete surface at a designated area within the school compound for the urban children and at the central plaza of the community for the rural children. Markers (plastic cones) were used to mark the boundaries and distance covered for the distance run. The remaining items were also conducted outdoors but in a separate area.

The sum of left and right grip strength was used as the estimate of overall static strength. The distance run was converted to an average running speed expressed as meters per minute (Pate et al., 1989).

Measurement Variability and Reliability

All anthropometric dimensions were collected by a single experienced and qualified individual, while the physical fitness tests were collected with the assistance of trained physical anthropology students enrolled in Escuela Nacional de Antropologia e Historia (ENAH) in Mexico, D.F. Each assistant was assigned to conduct a specific physical fitness test throughout the whole duration of the survey. Intra-observer technical errors of measurement (TEM) for anthropometric dimensions were within acceptable ranges and compares favorably to intra- and inter-examiner estimates in earlier studies in Oaxaca (Buschang, 1980) and in several national health surveys in the United States (Malina, 1995). Replicate measurements for all anthropometric dimensions taken about one month apart in the urban community (n = 36) and about two months apart in the rural community (n = 43). The TEM was calculated for each dimension based on the measurements taken at both occasion were as follows: weight (0.52kg), height (0.32 cm), sitting height (0.40 cm), skeletal breadths (0.09-0.35 cm), arm and calf circumferences (0.21-0.29 cm), and skinfold thicknesses (0.63-0.83 mm) (Peña Reyes, 2002). Using repeated measures analyses with age as the covariate, within day reliabilities for fitness tasks that had more than one trial ranged from 0.85 to 0.95 (Peña Reyes, 2002), indicating high consistency in performances.

Selection and Training of Assistants/Examiners

There were three phases to the selection and training process of the assistants/examiners. First, students enrolled in the physical anthropology department at Escuela Nacional de Antropologia e Historia (ENAH) were identified and interviewed by the field coordinator. Six assistants were selected. Second, a working session was conducted to provide more detailed information about the project and specific training on the field protocols. Third, standardizing sessions were conducted for anthropometry and physical fitness testing. For anthropometry, the specific dimensions were initially described and demonstrated, after which the assistants practiced taking the measurements on each other and subsequently on other adults and children. The administration of the static hand grip strength test was also taught at this time. The assistants were trained in anthropometry in case they had to take the measurements for the children. However, only one person was required to collect all the anthropometric measurements in the present study. For physical fitness, the assistants first familiarized themselves with specific protocols and equipment in the laboratory. The tests were then performed outdoors on a basketball court at ENAH and subsequently administered to a group of children, 8-12 years of age. Before administering the anthropometry and physical fitness protocols on the study sample, the protocols were administered on a group of urban school children in Cuernavaca, Morelos.

Statistical Analyses

The respective analyses for each question were conducted using the SPSS statistical software in the following sequence:

Question 1. Anthropometric correlates of physical fitness in rural and urban children.

a) Sex-specific descriptive statistics were calculated for anthropometric dimensions, derived variables and physical fitness items for each community. Sex-specific multivariate analyses of covariance (MANCOVA) with age as the covariate were used to test urban-rural differences in performance.

b) Second order partial correlations were calculated for each of the physical fitness items in relation to age, stature and body weight for boys and girls separately in each community. Second order partial correlations were used to statistically control for the other two variables so that the discrete effects of age, stature, or weight, on physical fitness could be estimated. The partial correlations were done primarily for comparative reasons since earlier studies, especially those of well-nourished children, have used this approach.

c) Multiple regression was employed first, to estimate the amount of variance in physical fitness variables explained by age, stature, and weight, and second, to estimate the contribution of age, height, weight and other anthropometric dimensions to variation in each physical fitness item. The other anthropometric variables included the BMI; sitting height and estimated leg length (segment lengths); biacromial, bicristal, bicondylar, and biepicondylar breadths (skeletal robustness); estimated arm and calf muscle circumferences (muscularity); and the sum of four skinfolds (fatness).

d) It should be noted that the correlational analyses were conducted for the purpose of comparison with those of earlier studies, while the multivariate analyses conducted in the present study are the primary focus; hence, family error rates in the analyses are not an issue.

Question 2. Heath-Carter somatotypes of rural and urban children.

The analysis of somatotype followed the multivariate statistical procedure recommended by Cressie et al. (1986).

a) Descriptive statistics were initially calculated by age and sex within each community. Subsequently, an ANCOVA was conducted to test the age effects.
b) An overall sex-specific multivariate analysis of covariance (MANCOVA) was conducted for each community with Wilks's lambda as the test statistic and with age as the covariate. The subsequent analyses were conducted only for MANCOVAs that were significant.
c) Community- and sex-specific pairwise comparisons were made using Hotelling's T^2 with a Bonferroni adjusted alpha level to determine which components contributed to the significant urban-rural and sex differences.
d) Forward stepwise discriminant analyses were conducted to determine which somatotype component(s) best discriminated between rural and urban boys and between rural and urban girls.
e) Forward stepwise discriminant analyses were also conducted to determine which somatotype component(s) best discriminated between boys and girls within each community.

Question 3. Relationship between the Heath-Carter somatotype components and physical fitness of rural and urban children.

a) Sex-specific third order partial correlations were used to statistically control for age and the other two somatotype components to examine the association of each somatotype components with each of the physical fitness tasks in the children from each community, e.g., the correlation between endomorphy and standing long jump when age, mesomorphy and ectomorphy were controlled; mesomorphy and standing long jump when age, endomorphy and ectomorphy were controlled; ectomorphy and standing long jump when age, endomorphy and mesomorphy were controlled.

b) Sex- and community-specific multiple regression analysis was used to estimate the variation in each physical fitness task that was contributed by age and each of the somatotype components.

Question 4. Comparison of physical fitness of stunted and non-stunted children in their respective rural and urban communities.

The children were categorized as stunted and non-stunted on the basis of height. Children whose height-for-age z-scores were more than 2.0 standard deviations below age- and sex-specific medians for the United States reference were considered stunted. This is the criterion of the World Health Organization (1997). All other children were considered non-stunted. The most recent Centers for Disease Control and Prevention (2000) growth charts were used to calculate age- and sex-specific z-scores for each child. The prevalence of stunting in the study sample of 6-11 year old children was 28% for both boys and girls in Santo Tomas, and 13% for girls and 16% for boys in San Juan (Table 3.2). The subsequent analyses of stunted and non-stunted children were as follows:

a) Descriptive statistics for the anthropometric and physical fitness variables were calculated for stunted and non-stunted children by sex within each community.

b) Sex-specific multivariate analysis of covariance (MANCOVA) was used to compare the anthropometric and physical fitness characteristics of stunted and non-stunted children within each community.

Question 5. Subcutaneous fat distribution of stunted and non-stunted children.

a) Descriptive statistics for the trunk-extremity ratio were calculated by sex and community for stunted and non-stunted children.
b) Sex-specific analyses of covariance (ANCOVA) were used to compare the trunk-extremity ratio between stunted and non-stunted children within each community.
c) A principal components analysis (Baumgartner et al., 1986; Malina et al., 1995) was also used to evaluate subcutaneous fat distribution in stunted and non-stunted children. The four skinfolds were transformed to natural logarithms and the mean log skinfold was used as the index of subcutaneous fat for the individual. Log values for skinfold thicknesses were then separately regressed on the mean log skinfold thickness for each individual, thus controlling for overall subcutaneous fatness. The residuals were then subjected to principal component analysis. Components with eigen values greater than 1.0 were retained for further analysis (Baumgartner et al., 1986). Component scores of stunted and non-stunted boys and girls within each community were compared with ANCOVA with age as the covariate.

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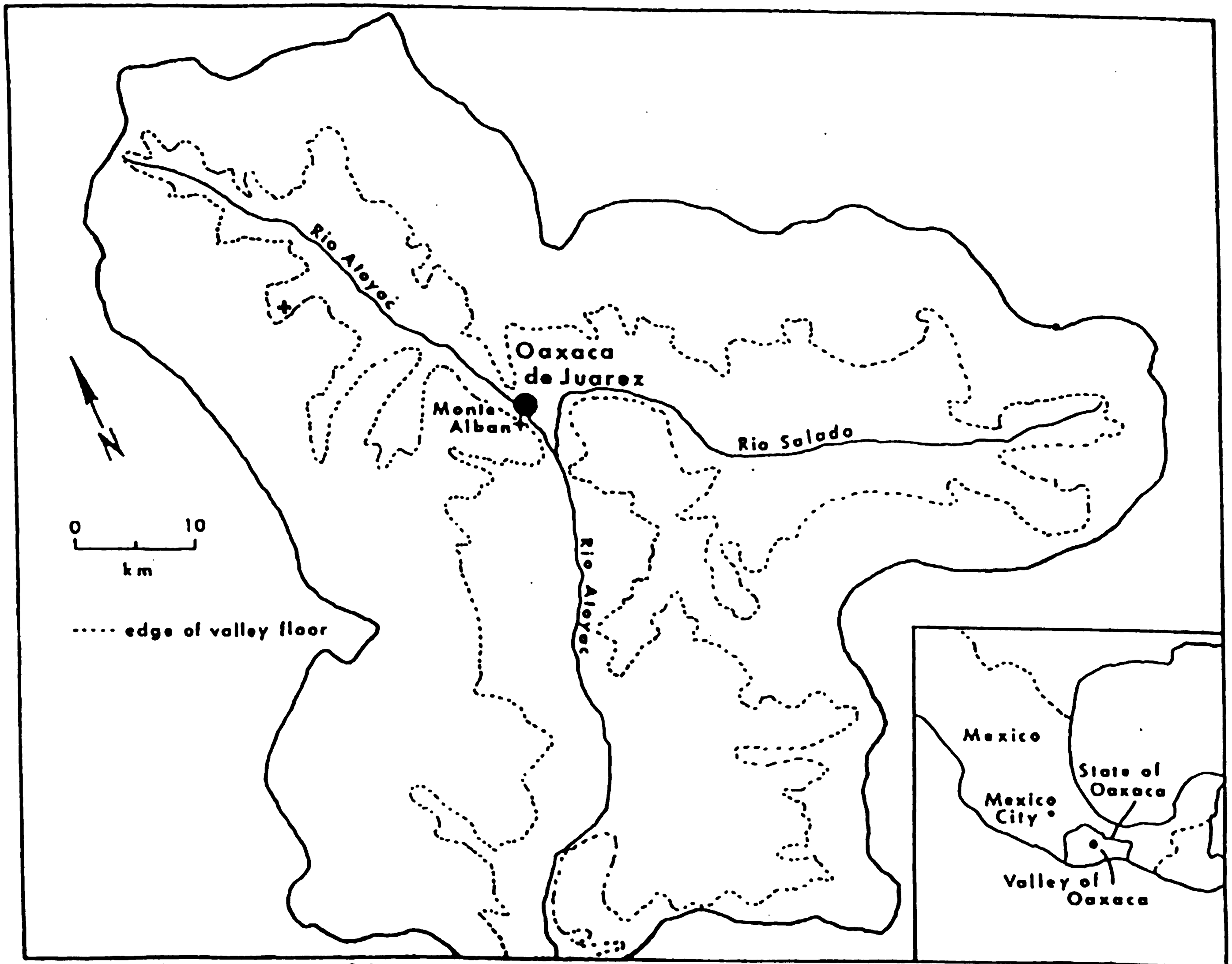

Figure 3.1. Map of the Valley of Oaxaca, indicating the location of the communities Studied; Santo Tomas Malzaltepec (+) and San Juanito Chapultepec (+)

Table 3.1. Indicators of social, economic, educational and health conditions in the rural and urban communities with comparative data for the city of Oaxaca and the state of Oaxaca based on the national census for 2000.

	Santo Tomas (rural)	San Juan (urban)	City of Oaxaca	State of Oaxaca
Total population	1,939	16,279	256,130	3.4 million
Household Characteristics:				
Number of households	422	3,782	60,612	741,005
Sewage connected to street	1%	77%	78%	26%
Sewage to septic tank	14%	5%	6%	20%
No sewage installation	84%	18%	14%	54%
Radio	82%	90%	91%	71%
Television	71%	87%	89%	57%
Refrigerator	29%	61%	72%	37%
Male head of household	85%	73%	70%	77%
Female head of household	15%	27%	30%	22%
Income (% economically active population):				
< 1 minimum wage	15%	15%	12%	20%
1 to 2 minimum wages	16%	29%	25%	24%
2 to 5 minimum wages	15%	34%	28%	18%
No wages	49%	6%	4%	28%
Health and Education:				
Insured population	6%	39%	48%	23%
Uninsured population	93%	59%	50%	76%
Number children/woman	3.1	2.2	1.9	2.1
Literate, 15+ years	91%	91%	94%	78%
Illiterate, 15+ years	9%	9%	5%	20%
Years of schooling	6 yrs	8 yrs	10 yrs	6 yrs
Did not complete primaria	22%	14%	11%	25%

Adapted from INEGI (2002) and Peña Reyes (2002).

Table 3.2. Numbers of stunted and non-stunted children 6-11 years of age by sex within each community.

	Rural		Urban	
	Boys	Girls	Boys	Girls
Stunted	49	43	25	21
Non-Stunted	126	111	132	140
Total	175	154	157	161

CHAPTER 4

Correlates of Physical Fitness in Rural and Urban Children in Southern Mexico

Introduction

Urbanization is assumed to have a positive influence on the growth status of children, which in turn may lead to improvements in physical fitness. This assumption follows from the fact that children residing in urban areas are, in general, taller and heavier than those living in rural areas (Eveleth and Tanner, 1990), and larger body size is positively related to commonly used indicators of fitness in children and adolescents (Malina, 1975, 1994). These observations are derived largely from studies in developed countries of Europe and Asia. Data for the United States indicate negligible rural-urban differences in growth status (Hamill et al., 1972; Meredith, 1979), but urban-rural comparisons of physical fitness are lacking.

The positive effects of urbanization on growth are associated primarily with improved living conditions related to health care and diet. These include, for example, ready availability of a constant food supply, access to potable water and sanitation, and access to health services and quality medical care, educational institutions, and recreational and welfare facilities within the community (Eveleth and Tanner, 1990).

Urban living is not always associated with improved growth status and physical fitness (Cameron et al., 1992; Malina et al., 1981; Meredith, 1979). Rapid urban growth particularly in developing countries is often due to expansions of urban slums and marginal living areas without access to or availability of the health and service infrastructures (Murphy and Stepick, 1991).

Physical fitness and performance of children are related to body size and composition (Malina, 1975, 1994; Malina and Bouchard, 1991; Norgan, 1994).

Although body dimensions and composition are influenced by genotype, reductions in body size and muscle mass are associated with chronic undernutrition. Small body size and reduced muscle mass tend to contribute to lower levels of fitness and performance (Spurr, 1984; Malina and Buschang, 1985; Malina and Little, 1985; Benefice and Malina, 1996).

Undernourished children tend to show reductions in performance or fitness that commensurate with their reduced body size and specifically muscle mass. When performances are expressed per unit height or weight, the performances of well-nourished and undernourished children are reasonably similar, emphasizing the importance of body size per se (Malina et al., 1987; Spurr, 1984). Such a relationship has implications for the functional significance of reduced body dimensions in children with a history of chronic undernutrition. However, the performance and fitness demands of daily activities do not include adjustments for body size. Simply stated, 'bigger is better' for many fitness and performance tasks (Spurr, 1984).

Attempts to explain individual differences in physical fitness and performance have been approached in several ways. Previous studies focused primarily on age, height, and weight (Montoye et al., 1972; Malina, 1975). Some studies include an indicator of biological maturity, specifically skeletal age (Seils, 1951; Rarick and Oyster, 1964; Beunen et al., 1997; Katzmarzyk et al., 1997). Relatively few studies have considered other body dimensions, specifically after controlling for the effects of age, height, and weight, as possible factor(s) contributing to the variation in physical fitness and performance (Malina and Buschang, 1985; Benefice and Malina, 1996).

The present study examined the relationship between anthropometric characteristics and physical fitness of children from a rural and an urban community in Oaxaca in southern Mexico. Both communities have a history of marginal living and nutritional conditions suggesting chronic undernutrition (Malina, 1983; Malina et al., 1980, 1981). The estimated contributions of age and body size to variation in physical fitness are first considered, and then the estimated contributions of age, height, weight, and other anthropometric dimensions to fitness are considered.

Methods and Procedures

The communities, sample, anthropometric procedures and fitness tests were described earlier (Chapter 3). The variables used in the analysis are first listed and the analytical procedures are then described.

Anthropometric variables included the following:

1) Body size: Weight, height, body mass index (BMI);

2) Segment lengths: Sitting height, estimated leg length;

3) Skeletal breadths: Biacromial, bicristal, biepicondylar, bicondylar;

4) Estimated limb musculature: Estimated midarm muscle circumference (EAMC), estimated calf muscle circumference (ECAC);

5) Subcutaneous fatness: Sum of 4 skinfolds - triceps, subscapular, suprailiac and medial calf skinfolds.

Physical fitness variables included the following:

1) Performance-related fitness: 35 yard (32.3 m) dash – running speed, standing long jump (SLJ) – explosive power;

2) Health-related fitness: Sum of right and left grip strength (Sum RL) – static strength, sit-and-reach (SAR) – lower back and upper thigh flexibility, timed sit-ups – abdominal muscular strength and endurance, distance run – cardiovascular endurance.

The analyses proceeded in four stages. First, sex-specific descriptive statistics were calculated for anthropometric dimensions, derived variables and physical fitness items for each community. Second, sex-specific multivariate analyses of covariance (MANCOVA) with age as the covariate were used to test urban-rural differences determined in anthropometric dimensions and fitness. Third, second-order partial correlations were calculated for each physical fitness item in relation to age, stature and body weight for boys and girls separately in each community to allow for comparison with previous studies. Fourth, multiple regression analyses were used to estimate the amount of variance in physical fitness items explained by age, stature, and weight, and then to estimate the contribution of age, height, weight, and other anthropometric dimensions to variation in each fitness item.

Results

Sex-specific age-adjusted means and standard errors for the anthropometric, derived, and physical fitness variables of the rural and urban children are presented in Tables 4.1 to 4.4. Urban children were, on average, significantly taller, heavier, and more muscular than rural children. Body segments of urban children were also broader and longer than rural children. Subcutaneous fatness was significantly greater among urban than rural boys, but did not differ between rural and urban girls. Urban children had, on average, better performances than rural children with the exception of grip strength per unit body weight, the dash and distance run, but statistical significance varied among tasks.

Partial correlations between age, height, and weight and each physical fitness task, after controlling for the other two variables, are presented in Tables 4.5 and 4.6. Overall, the correlations were low to moderate, ranging from - 0.26 to 0.43. After controlling for height and weight, age was positively correlated with performances in both sexes with the exception of the sit and reach in urban girls. Similarly, height was positively related with performances in both sexes except for the sit and reach in boys after controlling for age and weight. In contrast, weight was negatively related with performance except for grip strength in both sexes and the sit and reach in urban boys.

Among physical fitness items, age, height, and weight accounted for a major portion of the variance in strength, 74% to 82% (Tables 4.7 and 4.8). Age and body size accounted for 38% (boys) and 40% (girls) of the variance in the dash for rural children, and 52% (boys) and 57% (girls) in urban children. Age explained most of the variation in running speed. Slightly more of the variation in strength and speed were explained by age and body size in females than in boys.

Approximately 31% to 40% of the variance in the standing long jump was accounted for by age, height and weight. Age contributed most to the variance in power, except in rural girls where weight was the main contributor. Age and body size explained more of the variance in power in boys than in girls.

Age, height, and weight explained 26% and 23% of the variance in the distance run for urban boys and girls, respectively, but only 9% and 6% of the variance for rural boys and girls. Although height was negatively related to the distance run, it explained the largest portion of the variance for rural children of both sexes and urban boys. Age was the main contributor to the variance in cardiovascular endurance in urban girls.

Age and body size explained more of the variance for sit-ups in boys (24% - rural; 18% - urban) than in girls (9% - rural; 14% - urban). Height contributed most to the variance in sit-ups for rural children, whereas age contributed most for the variance in urban children. In both rural and urban children, weight was negatively related to abdominal endurance. Variation in the sit and reach explained by age and body size was very low, ranging from 1% to 6%.

When age, height, weight, and other anthropometric characteristics were regressed on each physical fitness variable, the increase in explained variance was rather small, ranging from 2% to 14% (Tables 4.9 to 4.12). The increase in the amount of variance explained in fitness was significant in the sum of right and left grip strength across all four samples, while the significance in the variance increased for the other fitness items were variable. The sit and reach (14%) and sit-ups (12%) in urban boys and the distance run (14%) in rural boys were the only fitness items for which other anthropometric dimensions explained an additional 10% or more of the explained variance.

The addition of other anthropometric dimensions to the regression analyses altered the contributions of age, height, and weight to each physical fitness test. A decreasing trend in beta coefficients was observed for several items. Weight was an exception; there was an increasing trend in the coefficients. Beta coefficients indicate the amount of variance contributed by age and specific anthropometric dimensions, and the magnitude of change in performance (positive or negative) associated with an increase or decrease of one standard deviation. Positive beta coefficients suggest improvements, while negative coefficients suggest decrements in performance associated with changes in particular anthropometric variables.

In general, the sum of skinfolds contributed negatively to physical fitness. Across sex and community, a one standard deviation increase in the sum of four skinfolds decreased performances by 0.65 to 0.01 units, except for the dash in urban boys and rural girls, and the distance run in urban girls, where there was a marginal increase. Height accounted for the most variance in strength for rural and urban girls, while weight contributed the most to the variance in strength for rural boys and estimated arm muscle circumference contributed most to the variance in strength for urban boys.

Though negative, variation in the sit and reach was largely explained by leg length in urban boys and rural girls. Biacromial breadth and height were the main contributors to variation in the sit and reach in rural boys and urban girls, respectively. Weight contributed negatively and accounted for most of the variance in sit-ups, except in rural girls, among whom most of the variance was accounted for by biepicondylar breadth.

In boys, age was the main contributor to variation in the standing long jump. Estimated arm muscle circumference contributed a comparable amount of variance in the standing long jump to age in urban boys. The main contributor to the standing long jump in rural girls was weight and the sum of four skinfolds in urban girls. Both weight and the sum of skinfolds contributed negatively to variation in the jump.

Similarly, age was the main contributor to variance in the dash, with the exception of urban boys where weight was the primary factor. The most of the variance in the distance run was explained by weight in urban boys and rural girls, but by height in rural boys and urban girls.

Discussion

Living conditions have an effect on the growth status and physical fitness of children. Results from the present study are consistent with the general perception that "better" living conditions encourage attainment of growth and performance. Children living in the urban community were taller, heavier, and more muscular compared to those from the rural community. Nevertheless, the rural and urban children are, on average, smaller and lighter than children in other urban centers of Mexico (Peña

Reyes et al., 2002). Their heights and weights fall, on average, in the lower percentiles of the new United States growth charts (Centers for Disease Control and Prevention, 2000). Mean heights of urban boys and girls fall at or above the 10th percentiles but approach the 25th percentiles at several ages, whereas mean heights of rural boys and girls fluctuate between the 5th and 10th percentiles. Mean weights of urban children of both sexes tend to be above the 25th percentiles of the reference values. In contrast, mean weights of rural boys and girls are at or below the 25th percentiles. The trends for mean heights and weights suggest elevated weight-for-height in both the urban and rural samples, although the prevalence of overweight is low (Peña Reyes, 2002).

Previous studies on the growth status of children 6-14 years of age from rural and urban communities in Oaxaca in the 1970s also reported that rural children were shorter and lighter, and had reduced muscle mass compared to children resident in urban colonias (Malina et al., 1981). Similar to earlier studies in Africa (Spurgeon et al., 1984; Cameron et al., 1992) and Japan (Matsui and Tamura, 1975), subcutaneous fatness was greater in urban males compare to rural males.

In addition to being larger in body size and estimated musculature, urban children also performed better in fitness tasks, although the differences were not consistently significant. Taller and heavier children tend to perform better on fitness tasks than their shorter and lighter peers (Malina, 1975, 1994; Malina et al., 1987). Body weight is the major contributor to static strength, so a child who is bigger tends to also be stronger. However, although urban children were absolutely stronger, reflecting their larger body size, strength per unit body mass tended to be greater in rural children, which was consistent with earlier studies in Oaxaca (Malina and Buschang, 1985; Malina et al., 1987).

A question of interest is the fitness of the Oaxaca children compared to well-nourished children. Comparable data are not available for Mexico. Data for a mixed-longitudinal sample of Philadelphia children 6-13 years of age tested in the mid-1960s include the standing long jump, the 35-yard dash, and grip strength (Malina, 1968). The jumping and running protocols were the same as in the present study, but a Narragansett dynamometer was used to measure grip strength in the Philadelphia study and an adjustable Stoelting dynomometer was used in the present study. Mean performances of rural and urban Oaxaca children on the standing long jump and 35-yard dash were consistently lower than corresponding age- and sex-specific values for the mixed-longitudinal sample of Philadelphia children. Allowing for differences in type of dynamometer, the grip strength of Oaxaca children was also consistently lower than that of Philadelphia children.

The American Alliance for Health, Physical Education, Recreation and Dance (1980) provide reference values for the distance run (yards) in 9 minutes. Expressing the medians and means as yards per minute and meters per minute, respectively, thus provides an indirect comparison. Allowing for the differences in measurement units, the distance run performance of rural and urban Oaxaca children, estimated as meters per minute, is reasonably similar to the reference. The aerobic performance of the Oaxaca children is perhaps more impressive in the context of their smaller body size, specifically leg length, which is related to stride length. This would suggest better aerobic fitness in the Oaxaca children.

The Fitnessgram (Cooper Institute for Aerobic Research, 1994) scores the sit-and-reach on a pass-fail basis with passing scores of 20 cm in boys and 23 cm in girls 6-11 years of age. Mean values for the sit-and-reach of rural and urban Oaxaca children exceed the passing levels of the Fitnessgram and approximate the medians of the American Alliance for Health, Physical Education, Recreation and Dance (1980) reference. The Fitnessgram also includes modified sit-ups (curl-ups), but it is not a timed test. Children are instructed to perform the curl-ups at a slow and controlled pace of about 20 per minute. Hence, the data are not comparable to values in the present study.

Although the urban and rural children from Oaxaca are smaller and lighter, their health-related physical fitness as reflected in the distance run and sit and reach appears to compare favorably to reference values for taller and heavier American children. In contrast, their performance-related fitness as reflected in grip strength, the standing long jump and dash does not compare as well. These tests are related to body size, and the smaller body size of the Oaxaca children is a disadvantage.

Results of the partial correlations in the present study were similar to those of previous studies of well-nourished (Seils, 1951; Rarick and Oyster, 1964) and low SES and/or undernourished samples (Malina and Buschang, 1985; Rocha Ferreira et al., 1991; Bénéfice and Malina, 1996; see Table 4.13). Age is positively related with performances in both sexes suggesting the notion that neuromuscular maturation and/or experience is an important factor in the performances of children 6-11 years of age (Malina and Bouchard, 1991; Malina, 1994). Height is also largely positively related with performances after controlling for age and weight, while weight is negatively related with performances except for grip strength after age and height were controlled.

Age, height, and weight explained most of the variance in the performances of rural and urban children. Consistent with previous studies, the results of the multiple regression analyses showed body size explained most of the variation in static strength, which was consistent with those of previous studies (Malina and Buschang, 1985; Rocha Ferreira et al., 1991; Bénéfice and Malina, 1996; Katzmarzyk et al., 1997). After static strength, body size also accounted for a major part of the variation in the distance run and sit-ups. Similar to previous studies (Malina and Buschang, 1985), the variation in performance was affected and influenced by absolute body size. However, in the present study, age explained most of the variation in the dash and standing long jump.

Sex differences were also examined in the present study and the variations of several performances were explained by age and body size. More of the variation in strength and speed was explained by age and body size in girls than in boys, whereas more of the variance in power was explained by age and body size in boys than in girls.

With the addition of other anthropometric dimensions to age, height, and weight in the multiple regression analyses, the variance explained in physical fitness increased only marginally. The increase in the variance explained was consistently significant for the sum of right and left grip strength across the four samples while the significance was variable for the other five fitness tasks.

Few of the other anthropometric dimensions added significantly to the variation in performance which was consistent with earlier studies of Mexican (Malina and Buschang, 1985), Brazilian (Rocha Ferreira et al., 1991), and African (Naidoo, 1999) children. These earlier studies, however, used a different analytical approach so that the results may not be directly comparable. Nevertheless, the addition of other anthropometric dimensions to the regression analyses in the present study altered the contributions of age, height, and weight to performances on the physical fitness tasks. This observation suggests overlap or interactions among variables in their estimated contributions to performance.

Among the anthropometric variables considered, several contributed significantly to the proportion of the variance in performance that was accounted for. In general, fatness (sum of four skinfolds) had a consistently negative influence on physical fitness. Of interest, the sum of skinfolds contributed negatively (significantly so in three of the four samples, Tables 4.9-4.12) to static strength after age, height, and weight were statistically controlled. Estimated arm muscle circumference contributed most to the variance in strength, sit-ups, standing long jump, and dash in urban boys, while leg length was the main contributor in the sit and reach. In contrast, there was no consistent pattern in the contributions of other anthropometric variables to the performances of rural boys. Biepicondylar breadth contributed significantly to grip strength, sit-ups, and the standing long jump among rural girls, while there was no consistent pattern in the estimated contributions of other anthropometric variables in urban girls.

In summary, performances in physical fitness tests were influenced by body size. Although variation in performance appeared to be largely influenced by age, height, and weight, there was overlap in the contribution of other anthropometric characteristics to performance. The selective inclusion or exclusion of anthropometric dimensions in such analyses can over- or underestimate the contributions of age, height, and weight to variation in performance.

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Table 4.1. Age-adjusted means and standard errors of anthropometric and derived variables in rural and urban boys 6-11 years of age, and F ratios for the ANCOVAs with age as the covariate.

	Rural (n = 154)		Urban (n = 161)		
Variables	Mean	SE	Mean	SE	F
Age, years	8.8 (± 1.5)		8.8 (± 1.7)		
Weight, kg	25.3	0.4	27.7	0.4	18.31**
Height, cm	123.0	0.4	125.7	0.4	21.74**
BMI, kg/m^2	16.5	0.2	17.2	0.2	8.68**
Sit Ht, cm	66.8	0.2	68.2	0.2	21.36**
Leg Lt, cm	56.2	0.3	57.5	0.3	12.78**
Biacromial, cm	28.1	0.1	29.1	0.1	32.63**
Bicristal, cm	20.1	0.1	21.0	0.1	40.16**
Bicondylar, cm	7.7	0.0	8.0	0.0	19.57**
Biepicondylar, cm	4.9	0.0	5.0	0.0	7.75**
Arm Circ, cm	18.0	0.1	18.7	0.1	12.45**
Calf Circ, cm	24.4	0.2	25.4	0.1	22.00**
EAMC, cm	15.5	0.1	16.1	0.1	10.22**
ECMC, cm	21.9	0.1	22.7	0.1	20.16**
Sum 4 SF, mm	30.7	0.7	33.9	0.7	11.28**

* $p < 0.05$, ** $p < 0.01$ Numbers enclosed in parentheses are standard deviations

Table 4.2. Age-adjusted means and standard errors of anthropometric and derived variables in rural and urban girls 6-11 years of age, and F ratios for the ANCOVAs with age as the covariate.

	Rural (n = 173)		Urban (n = 156)		
Variables	Mean	SE	Mean	SE	F
Age, years	9.1 ($\pm$ 1.7)		9.0 ($\pm$ 1.7)		
Weight, kg	26.2	0.4	28.3	0.4	14.57**
Height, cm	124.2	0.4	127.5	0.5	26.86**
BMI, kg/m^2	16.6	0.2	17.1	0.2	4.42*
Sit Ht, cm	67.3	0.2	68.7	0.2	17.34**
Leg Lt, cm	57.0	0.3	58.8	0.3	23.77**
Biacromial, cm	28.4	0.1	29.2	0.1	23.39**
Bicristal, cm	20.3	0.1	21.4	0.1	48.44**
Bicondylar, cm	7.5	0.0	7.7	0.0	13.36**
Biepicondylar, cm	4.8	0.0	4.9	0.0	5.19*
Arm Circ, cm	18.5	0.1	18.9	0.1	4.27*
Calf Circ, cm	24.6	0.2	25.5	0.2	15.60**
EAMC, cm	15.6	0.1	16.2	0.1	9.44**
ECMC, cm	21.6	0.1	22.6	0.1	26.07**
Sum 4 SF, mm	37.5	0.7	36.7	0.7	0.71

* $p < 0.05$, ** $p < 0.01$ Numbers enclosed in parentheses are standard deviations

Table 4.3. Age-adjusted means and standard errors of physical fitness and derived variables in rural and urban boys 6-11 years of age, and F ratios for the ANCOVAs with age as the covariate.

	Rural (n = 154)		Urban (n = 161)		
Variables	Mean	SE	Mean	SE	F
Sum RL, kg	25.8	0.4	26.9	0.4	3.04
Sum RL/Wt, kg/kg	1.01	0.01	0.97	0.01	5.17*
L Grip/EAMC, kg/cm	0.79	0.01	0.81	0.01	0.70
SAR, cm	26.6	0.4	27.7	0.3	4.90*
Sit-Ups, n	8.9	0.3	12.0	0.3	41.84**
SLJ, cm	96.9	1.4	112.4	1.4	60.67**
Dash, sec	7.16	0.04	7.21	0.04	0.68
Distance Run, m/min	149.6	1.6	139.0	1.5	23.36**

* $p < 0.05$
** $p < 0.01$

Table 4.4. Age-adjusted means and standard errors of physical fitness and derived variables in rural and urban girls 6-11 years of age, and F ratios for the ANCOVAs with age as the covariate.

	Rural (n = 154)		Urban (n = 161)		
Variables	Mean	SE	Mean	SE	F
Sum RL, kg	24.9	0.4	25.1	0.4	0.15
Sum RL/Wt, kg/kg	0.95	0.01	0.89	0.01	11.34**
L Grip/EAMC, kg/cm	0.75	0.01	0.75	0.01	0.01
SAR, cm	27.0	0.3	28.1	0.4	4.75*
Sit-Ups, n	6.9	0.3	10.0	0.4	39.15**
SLJ, cm	82.6	1.3	98.1	1.4	63.22**
Dash, sec	7.72	0.05	7.72	0.05	0.00
Distance Run, m/min	137.5	1.4	135.0	1.5	1.45

* $p < 0.05$
** $p < 0.01$

Table 4.5. Second-order partial correlations among age, body size, and physical fitness items in rural and urban boys 6-11 years of age.

	Age	Height	Weight
Controlling for:	Height and Weight	Age and Weight	Age and Height
Rural (n = 152)			
Sum RL Grip, kg	0.23**	0.33**	0.22**
SAR, cm	0.04	- 0.04	- 0.00
Sit-Ups, n	0.18*	0.25**	- 0.26**
SLJ, cm	0.30**	0.10	- 0.03
Dash[a], sec	0.31**	0.10	- 0.01
Distance Run, m/min	0.19*	0.05	- 0.20*
Urban (n = 161)			
Sum RL Grip, kg	0.12	0.22**	0.40**
SAR, cm	0.07	- 0.05	- 0.09
Sit-Ups, n	0.22**	0.04	- 0.08
SLJ, cm	0.32**	0.03	0.02
Dash[a], sec	0.36**	0.09	- 0.01
Distance Run, m/min	0.23**	0.18*	- 0.33**

* $p < 0.05$, ** $p < 0.01$

[a] Signs were inverted as a lower time equals better performance

Table 4.6. Second-order partial correlations among age, body size, and physical fitness items in rural and urban girls 6-11 years of age.

	Age	Height	Weight
Controlling for:	Height and Weight	Age and Weight	Age and Height
Rural (n = 171)			
Sum RL Grip, kg	0.37**	0.19*	0.42**
SAR, cm	0.15*	0.01	- 0.19*
Sit-Ups, n	0.06	0.16*	- 0.16*
SLJ, cm	0.16*	0.29**	- 0.26**
Dash[a], sec	0.30**	0.20**	- 0.18*
Distance Run, m/min	0.13	0.06	- 0.21**
Urban (n = 152)			
Sum RL Grip, kg	0.17*	0.42**	0.22**
SAR, cm	- 0.09	0.11	0.02
Sit-Ups, n	0.16	0.06	- 0.02
SLJ, cm	0.27**	0.13	- 0.04
Dash[a], sec	0.43**	0.21**	- 0.13
Distance Run, m/min	0.26**	0.12	- 0.15

* $p < 0.05$, ** $p < 0.01$

[a] Signs were inverted as a lower time equals better performance

Table 4.7. Multiple regression of age, height, and weight on physical fitness items in rural and urban boys 6-11 years of age.

				Beta Coefficients		
	n	R^2	F	Age	Height	Weight
Rural						
Sum RL Grip, kg	154	0.75	149.98**	0.21	0.47	0.25
SAR, cm	154	0.01	0.30	0.07	- 0.12	0.00
Sit-Ups, n	154	0.24	16.18**	0.27	0.61	- 0.51
SLJ, cm	154	0.35	26.51**	0.45	0.20	- 0.05
Dash[a], sec	153	0.38	30.57**	0.44	0.22	- 0.01
Distance Run, m/min	152	0.09	4.76**	0.33	0.12	- 0.41
Urban						
Sum RL Grip, kg	161	0.74	149.22**	0.12	0.34	0.45
SAR, cm	161	0.05	2.53	0.15	- 0.14	- 0.19
Sit-Ups, n	161	0.18	11.61**	0.42	0.11	- 0.15
SLJ, cm	161	0.40	34.65**	0.55	0.06	0.03
Dash[a], sec	161	0.52	55.81**	0.56	0.19	- 0.02
Distance Run, m/min	161	0.26	18.48**	0.42	0.46	- 0.61

* $p < 0.05$, ** $p < 0.01$

[a] Signs were inverted as a lower time equals better performance

Table 4.8. Multiple regression of age, height, and weight on physical fitness items in rural and urban girls 6-11 years of age.

	n	R^2	F	Beta Coefficients		
				Age	Height	Weight
Rural						
Sum RL Grip, kg	173	0.82	254.60**	0.30	0.25	0.42
SAR, cm	173	0.06	3.48*	0.28	0.00	- 0.37
Sit-Ups, n	173	0.09	5.24**	0.15	0.40	- 0.33
SLJ, cm	173	0.31	24.71**	0.28	0.66	- 0.46
Dash[a], sec	171	0.40	37.32**	0.49	0.43	- 0.33
Distance Run, m/min	169	0.06	3.26*	0.23	0.16	- 0.43
Urban						
Sum RL Grip, kg	156	0.79	189.16**	0.14	0.49	0.31
SAR, cm	156	0.03	1.49	- 0.14	0.31	- 0.06
Sit-Ups, n	155	0.14	8.08**	0.26	0.16	- 0.03
SLJ, cm	156	0.36	27.99**	0.35	0.32	- 0.06
Dash[a], sec	156	0.57	67.72**	0.55	0.39	- 0.20
Distance Run, m/min	152	0.23	14.66**	0.43	0.33	- 0.38

* $p < 0.05$, ** $p < 0.01$

[a] Signs were inverted as a lower time equals better performance

Table 4.9. Beta coefficients from multiple regressions of age, height, weight and other anthropometric characteristics on physical fitness items in rural boys 6-11 years of age.

Independent Variables	Sum RL Grip	SAR	Sit-Ups	SLJ	Dash[a]	Distance Run
Age	0.17*	0.07	0.24	0.43**	0.40**	0.21
Height, cm	0.12	- 0.14	0.38	0.11	0.09	- 0.64
Weight, kg	0.52*	- 0.03	- 0.63	0.25	- 0.35	0.54
Leg Lt, cm	0.11	- 0.32	0.36	- 0.03	0.08	0.27
Biacromial, cm	0.17	0.51*	0.00	- 0.17	0.21	- 0.05
Bicristal, cm	- 0.04	- 0.18	- 0.07	0.23	0.02	0.07
Bicondylar, cm	0.13	0.13	- 0.08	- 0.18	- 0.22	0.22
Biepicondylar, cm	0.09	0.11	0.27	0.03	0.14	0.06
EAMC, cm	0.03	- 0.17	0.35*	0.09	0.10	- 0.10
ECMC, cm	- 0.20	0.03	- 0.33	- 0.01	0.26	- 0.20
Sum 4 SF, mm	- 0.27	- 0.12	- 0.09	- 0.24	- 0.03	- 0.65**
R^2	0.78	0.08	0.31	0.38	0.42	0.23
Sign. F Δ	0.01	0.21	0.12	0.48	0.41	0.00

* $p < 0.05$
** $p < 0.01$
[a] Signs were inverted as a lower time equals better performance

Table 4.10. Beta coefficients from multiple regressions of age, height, weight, and additional anthropometric characteristics on physical fitness items in urban boys 6-11 years of age.

Independent Variables	Sum RL Grip	SAR	Sit-Ups	SLJ	Dash[a]	Distance Run
Age	0.11	0.14	0.35*	0.57**	0.49**	0.42**
Height, cm	0.25	0.33	0.07	- 0.25	- 0.27	0.47
Weight, kg	0.32	- 0.13	- 1.16**	- 0.29	- 0.54	- 0.50
Leg Lt, cm	0.01	- 0.87**	0.08	0.16	0.31	- 0.09
Biacromial, cm	0.03	0.47*	0.26	0.37*	0.35*	0.06
Bicristal, cm	0.03	0.19	0.15	- 0.13	0.12	- 0.03
Bicondylar, cm	0.07	0.46*	0.54**	0.12	0.23	- 0.02
Biepicondylar, cm	0.12	- 0.23	- 0.43*	- 0.17	- 0.34*	- 0.14
EAMC, cm	0.40**	0.09	0.68**	0.57**	0.47**	0.19
ECMC, cm	- 0.08	- 0.42	- 0.05	- 0.07	0.10	0.08
Sum 4 SF, mm	- 0.37**	- 0.32	- 0.01	- 0.20	0.15	- 0.20
R^2	0.81	0.19	0.30	0.47	0.59	0.28
Significant F Δ	0.00	0.00	0.00	0.01	0.00	0.80

* $p < 0.05$
** $p < 0.01$
[a] Signs were inverted as a lower time equals better performance

Table 4.11. Beta coefficients from multiple regressions of age, height, weight, and additional anthropometric characteristics on physical fitness items in rural girls 6-11 years of age.

Independent Variables	Sum RL Grip	SAR	Sit-Ups	SLJ	Dash[a]	Distance Run
Age	0.23**	0.19	0.16	0.25	0.53**	0.28
Height, cm	0.37*	1.08*	0.13	0.23	0.11	- 0.48
Weight, kg	0.04	0.26	- 0.11	- 0.72*	- 0.21	- 0.53
Leg Lt, cm	0.02	- 1.21**	0.05	0.27	0.22	0.48
Biacromial, cm	0.18*	0.05	- 0.08	- 0.10	0.07	- 0.01
Bicristal, cm	0.02	- 0.18	- 0.15	0.21	- 0.11	- 0.02
Bicondylar, cm	0.04	0.02	0.32	0.20	0.03	- 0.09
Biepicondylar, cm	0.24**	0.21	0.43*	0.35*	0.08	0.22
EAMC, cm	0.07	- 0.13	- 0.32	0.01	- 0.22	- 0.16
ECMC, cm	- 0.06	- 0.24	- 0.01	0.00	0.08	0.40*
Sum 4 SF, mm	- 0.23**	- 0.35	- 0.27	- 0.24	0.03	- 0.10
R^2	0.85	0.14	0.16	0.35	0.42	0.12
Significant F Δ	0.00	0.00	0.09	0.15	0.86	0.16

* $p < 0.05$
** $p < 0.01$
[a] Signs were inverted as a lower time equals better performance

Table 4.12. Beta coefficients from multiple regressions of age, height, weight, and additional anthropometric characteristics on physical fitness items in urban girls 6-11 years of age.

Independent Variables	Sum RL Grip	SAR	Sit-Ups	SLJ	Dash[a]	Distance Run
Age	0.12	- 0.11	0.18	0.33**	0.52**	0.41**
Height, cm	0.43*	0.87*	- 0.15	0.04	0.30	0.06
Weight, kg	0.27	- 0.25	- 0.39	0.35*	- 0.37	0.04
Leg Lt, cm	- 0.10	- 0.52	0.27	0.12	0.17	0.27
Biacromial, cm	0.00	0.06	0.13	- 0.06	- 0.02	0.18
Bicristal, cm	0.08	- 0.23	0.06	- 0.10	- 0.30*	- 0.13
Bicondylar, cm	0.04	0.16	0.04	0.27	- 0.05	- 0.10
Biepicondylar, cm	0.10	- 0.07	- 0.05	- 0.18	0.03	- 0.16
EAMC, cm	0.11	0.29	0.10	0.16	0.15	- 0.15
ECMC, cm	0.07	- 0.03	0.25	- 0.06	0.41**	- 0.09
Sum 4 SF, mm	- 0.23**	- 0.05	- 0.02	- 0.39**	- 0.08	0.01
R^2	0.82	0.09	0.16	0.42	0.62	0.28
Significant F Δ	0.00	0.27	0.88	0.04	0.03	0.35

* $p < 0.05$
** $p < 0.01$
[a] Signs were inverted as a lower time equals better performance

Table 4.13 Summary of studies that used second-order partial correlations between age, height, weight, and physical fitness tasks in children 6-15 years of age.

Study	Sample	Sex	*Range of Correlations	Tests
Present Study	Mexican school children, 6-11 years, from a rural and an urban community in the Valley of Oaxaca	Boys: Rural (n = 152) Urban (n = 161) Girls: Rural (n = 171) Urban (n = 152)	Age: - 0.09 to 0.43 Height: - 0.05 to 0.42 Weight: - 0.33 to 0.42	Dash, SLJ, Grip, SAR, Sit-Ups, Dist Run
Seils (1951)	American primary grade children, 6-9 years, from public schools in four communities	Boys (n = 272) Girls (n = 238)	Age: 0.01 to 0.43 Height: - 0.00 to 0.26 Weight: - 0.29 to 0.11	Dash, SLJ, Throw
Rarick and Oyster (1964)	American second grade school boys, 7-8 years, from upper to middle suburban community	Boys (n = 48)	Age: 0.17 to 0.32 Height: 0.12 to 0.30 Weight: - 0.27 to - 0.12	Dash, SLJ, Throw
Malina and Buschang (1985)	Mexican school children, 6-15 years, from the Valley of Oaxaca	Boys and Girls (n = 332 to 364)	Height: 0.07 to 0.35 Weight: - 0.19 to 0.39	Dash, SLJ Grip, Throw
Rocha Ferreira et al. (1991)	Brazilian school children, 8 years, low SES	Boys (n = 84) Girls (n = 60)	Height: 0.07 to 0.42 Weight: - 0.31 to - 0.19	Dash, SLJ, Grip, Run
Bénéfice and Malina (1996)	Senegalese children, 5-13 years, from poor farming families in two rural communities	Boys (n = 168) Girls (n = 180)	Age: 0.00 to 0.25 Height: - 0.08 to 0.26 Weight: 0.03 to 0.28	Dash, SLJ, Grip, Throw

*Correlations between age, height, or weight with the fitness items when the other two variables are statistically controlled are shown. Only correlations for tests common to all the studies and similar to items used in the present study are shown. The signs for timed items such as the dash and agility run were inverted as a lower time indicates better performance.
SLJ = Standing Long Jump; Grip = Static Grip Strength; Throw = Distance Throw; Run = Distance Run.

CHAPTER 5

Somatotypes of Rural and Urban Children in Southern Mexico

Introduction

Physique refers to the overall shape, form, or configuration of the entire body (Carter and Heath, 1990). It is most often quantified as a somatotype, which is a composite of the contributions of three components: endomorphy (fatness, roundness), mesomorphy (musculoskeletal development), and ectomorphy (linearity).

There are several methods for estimating somatotype (Sheldon et al., 1940, 1954; Parnell, 1958; Carter and Heath, 1990). The most commonly used method at present is the Heath-Carter anthropometric protocol (Carter and Heath, 1990; Malina, 1995), which uses several anthropometric dimensions to estimate the three components of somatotype. Scores for each component ranged from 1 (low) to 7 (high) in the original method of Sheldon et al (1940, 1954) and also in Parnell's (1958) anthropometric approach. In the Heath-Carter anthropometric method, the lowest possible score is 0.1 and the high end of the scale is open-ended (Carter and Heath, 1990).

During childhood, somatotype of boys and girls tend to be generally balanced, 3-4-3 or 3-3-3, but boys tend to be, on average, slightly more mesomorphic and girls tend to be more endomorphic. The sex difference in somatotype is not marked in means, but is especially apparent in the distributions. Although most boys and girls have somatotypes that are balanced, more boys have somatotypes in the mesomorphic pole whereas more girls have somatotypes in the endomorphic pole of the distributions. Considerable overlap characterizes the distributions of somatotypes among and between boys and girls (Carter and Heath, 1990; Malina and Bouchard, 1991).

Studies examining somatotype have largely described and/or compared the physiques of adults in different populations, and especially athletes in a variety of sports (Carter and Heath, 1990). The Heath-Carter anthropometric protocol has also been applied to samples of healthy children and adolescents primarily of European ancestry (Carter and Heath, 1990; Malina and Bouchard, 1991), but has been used to a lesser extent with Latin American children. The protocol was used with school children of both sexes 7-18 years of age in Guatemala (Alexander et al., 1993) and Venezuela (Alexander, 1992), and with boys 6-15 years of age (Godoy et al., 1994) and girls 4-11 years of age (Godoy and Barcos, 1995) in Chile. The studies in Guatemala and Venezuela were done in the context of national physical fitness surveys of school children and the results were presented as descriptive statistics by age and sex. The studies in Chile were limited to boys of medium to high, and to girls of low socioeconomic status (SES) attending school in Santiago. The study of boys focused on age changes in somatotype components in small samples followed longitudinally over one year, while that of girls compared low SES girls relative to nutritional status.

Murguia et al. (1990) applied the Heath-Carter anthropometric protocol to a large sample of children and adolescents of both sexes 5-20 years of age from several different areas of Yucatan, Mexico. The samples were from a traditional Indian community (subsistence maize agriculture) and from three municipalities that were more "modern", specializing in fishing, sisal production, and cattle raising, respectively. Although there were body size differences among the samples, there was considerable overlap in mean somatotypes. Endomorphy tended to be lower in boys and girls 6-11 years of age from the subsistence agricultural community, but mesomorphy and ectomorphy, were similar in the children and adolescents from the four communities (Murguia et al., 1990). Unfortunately, the study was largely descriptive with little statistical analysis.

Diaz Gamboa and Fuentes Heinrich (1996) described the somatotypes of Aymara children, 6-15 years of age, resident at high altitude (3000-4500 meters) in northern Chile. Mean somatotypes indicated balanced endomorphy and mesomorphy and low ectomorphy in girls, and slightly greater mesomorphy than endomorphy and low ectomorphy in boys.

The present study compares Heath-Carter anthropometric somatotypes of rural and urban children 6 to 11 years of age living under marginal health and nutritional conditions in Oaxaca, southern Mexico.

Methods and Procedures

The communities, sample, and anthropometric procedures were described earlier (Chapter 3). The dimensions required by the Heath-Carter anthropometric somatotype protocol included weight (kg), height (cm), bicondylar and biepicondylar breadths (cm), flexed arm and calf circumferences (cm), and the triceps, subscapular, suprailiac and medial calf skinfolds (mm). The algorithms for the Heath-Carter anthropometric protocol were used to derive the three components of somatotype (Carter and Heath, 1990, p 374):

1. **Endomorphy** $= -0.7182 + 0.1451(X) - 0.00068\,(X^2) + 0.0000014(X^3)$

where X is the sum of the triceps, subscapular and suprailiac skinfolds, multiplied by 170.18/height in cm.

2. **Mesomorphy** = [(0.858 x biepicondylar breadth) + (0.601 x bicondylar breadth) + (0.188 x corrected arm circumference) + (0.161 x corrected calf circumference)] – (stature x 0.131) + 4.50

where the corrected arm circumference is flexed arm circumference (cm) minus the triceps skinfold (cm) and the corrected calf circumference is calf circumference (cm) minus the medial calf skinfold (cm).

3. **Ectomorphy** = HWR x 0.732 – 28.58

where HWR is height (cm) divided by the cube root of weight (kg). If HWR is less than 40.75 but more than 38.25, then Ectomorphy = HWR x 0.463 – 17.63; and if HWR is equal or less than 38.25, a rating of 0.1 is given.

Measurement variability for the anthropometry was also described in Chapter 3. The reproducibility of anthropometric somatotypes was estimated in 79 children. Intraclass reliability coefficients were between 0.97 and 0.98, technical errors of measurement varied between 0.16 and 0.23 somatotype units, and coefficients of variation ranged from 4% to 10% (Table 5.1). The differences between means were less than 0.07 units for any somatotype component. Thus, the Heath-Carter anthropometric somatotype was highly reproducible in the sample of rural and urban children. The intraclass coefficients, technical errors of measurements, and coefficients of variation were smaller than reported in the Quebec Family Study (Bouchard, 1985).

The analysis was done in several steps using the multivariate statistical procedure recommended by Cressie et al. (1986). Age-, sex- and community-specific descriptive statistics were initially calculated. Sex-specific multivariate analyses of variance (MANCOVA), with age as the covariate, were calculated to compare differences between rural and urban children. Community-specific multivariate analyses of variance (MANCOVA), with age as the covariate, were calculated to compare sex differences in the rural and urban samples. If a MANCOVA was significant, univariate F-tests were performed to determine which components contributed to the significant difference(s). Sex-specific forward stepwise discriminant analyses were also conducted to determine which somatotype component(s) best discriminated between rural and urban children within each sex, and between the sexes within each community.

Results

Age- and sex-specific means and standard deviations for somatotypes of rural and urban children are presented in Tables 5.2 to 5.5. An ANCOVA indicated no significant age effects on somatotype among the 6-11 year old children except in urban boys (Table 5.3). It appears that the significant age effect was due to elevated endomorphy and mesomorphy, and reduced ectomorphy in 10 year old boys.

Age-adjusted means and standard errors of somatotypes by sex and community are shown in Table 5.6. Rural and urban boys differed significantly in somatotype (p= 0.021); the univariate F-tests indicated that urban boys were significantly more endomorphic than rural boys (p=0.004). In contrast, the MANCOVA for girls was not significant between the communities (p=0.226).

Age-adjusted means and standard errors of somatotypes by sex within each community are shown in Table 5.7. Somatotype differed significantly between boys and girls within each community (p<0.001). girls were more endomorphic (p<0.001) and boys were more mesomorphic (p<0.001), while ectomorphy did not differ.

Results of the forward stepwise discriminant function analyses rural-urban comparisons of somatotype within sex and comparisons of somatotype by sex within each community are presented in Table 5.8. Endomorphy was the best discriminator between rural and urban boys; none of the somatotype components discriminated between rural and urban girls. Within the rural community, endomorphy was the best discriminator between boys and girls followed by mesomorphy. All three somatotype components discriminated between boys and girls in the urban community. Mesomorphy was the best discriminator between urban boys and girls, followed by endomorphy and then ectomorphy.

Discussion

Although there was no significant age-effect in the somatotypes of rural children, mean somatotypes showed a tendency to increase or decrease with age in rural children. In contrast, mean somatotypes fluctuated from age to age in urban children, particularly boys among whom there was a significant age effect (Table 5.2). This appeared to be due to increased endomorphy and mesomorphy, and decreased ectomorphy in the 10 year old boys.

Rural-urban differences in somatotype were apparent among boys but not among girls. Endomorphy discriminated rural and urban boys, while none of the components discriminated between rural and urban girls. Urban boys were more endomorphic than rural boys. The urban-rural differences in endomorphy reflect differences in subcutaneous fatness (Table 4.1) and perhaps in habitual physical activity. Rural boys spend more time daily in moderate and at times vigorous household and agricultural chores (Peña Reyes, 2002).

The lack of an urban-rural difference in the somatotypes of may be related to the lifestyles of girls in both communities. Urban and rural girls do not differ in subcutaneous fatness (Table 4 .2), and girls in both communities spend a good deal of their time in activities related to food preparation and do not differ markedly in physical activity (Peña Reyes, 2002).

A previous study in Yucatan, Mexico, reported that children of both sexes from better living conditions were more endomorphic than those living in traditional subsistence agricultural communities (Murguia et al., 1990). However, the differences in somatotype among the communities were not statistically compared in this study.

It has also been suggested in the nutritional and anthropological literature that the females are more resistant to adverse environmental influences (McCance, 1966; Stinson, 1985). The lifestyle of the children in the rural and urban communities related to diet and physical activity was mentioned earlier, and rural boys were more active than urban boys. Urban boys may also have had chronically excessive energy intake, but data are not available to document this. In contrast, urban and rural girls did not differ in fatness and activity.

It is difficult to speak of environmental influences on the somatotype of children due to lack of data on children and, perhaps due to limitations of the Heath-Carter anthropometric protocol with children. However, studies of adults indicate that extreme environmental circumstances, such as semi-starvation in males (Lasker, 1947), disordered eating in females (Malina, 1992; Malina et al., 2002), or resistance training in males (Tanner, 1952), are needed to significantly modify somatotype. Changes in somatotype with starvation and disordered eating can be reversed with appreciate diet (Lasker, 1947, Malina, 1992), whereas gains in mesomorphy with resistance training return to pre-training values after the training program is stopped (Tanner, 1952).

Within each community, sex differences in somatotype were evident in endomorphy and mesomorphy. Girls in both communities were more endomorphic while boys were more mesomorphic. Endomorphy was the best distinguishing component of somatotype between boys and girls in the rural community followed by mesomorphy. In contrast, all three somatotype components discriminated between the sexes in the urban community, beginning with mesomorphy, then endomorphy and finally ectomorphy.

The results of the present comparison of boys and girls are consistent with somatotype data for European and North American children and adolescents (Malina and Bouchard, 1991). Comparative data for samples of Latin American children 6-11 years of age are summarized in Table 5.9. Data for Latin American children are also generally consistent. There is considerable overlap in mean somatotypes among studies, including the present samples of rural and urban children from Oaxaca.

It should be cautioned, perhaps, that the Heath-Carter anthropometric somatotype method was developed on adults and the samples used to validate the method were largely adult males (Carter and Heath, 1990). The applicability of the method to children, especially in those living under marginal economic and nutritional conditions, needs further study.

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Table 5.1 Reproducibility of anthropometric estimates of somatotype (n = 79).

Variable	Mean	SE	Difference Between Means	Intraclass Coefficient	TE, Somatotype Units	CV, %
Endomorphy	3.52	0.10	0.06	0.97	0.21	6
Mesomorphy	4.32	0.09	0.04	0.98	0.16	4
Ectomorphy	2.31	0.11	0.01	0.97	0.23	10

TE - Technical error = $\sqrt{\Sigma}\,(X1 - X2)^2 / 2N$

CV - Coefficient of variation = (technical error / X) 100

Differences between the means of replicates were not significant.

Table 5.2. Means and standard deviations of somatotype in rural boys by age group.

	Endomorphy			Mesomorphy			Ectomorphy		
Age	n	Mean	SD	n	Mean	SD	n	Mean	SD
6	26	3.26	0.85	26	4.74	0.75	26	1.69	0.76
7	26	3.26	0.90	26	4.50	0.79	26	2.03	0.77
8	30	3.14	0.82	30	4.63	0.65	30	2.12	0.76
9	31	3.15	0.96	31	4.38	0.89	31	2.55	0.82
10	26	3.15	0.93	26	4.31	0.66	26	2.59	0.82
11	15	3.06	0.95	15	4.18	0.80	15	2.93	0.89
Analysis of Varaince									
F age		1.18			2.19			1.77	
p		NS			NS			NS	

NS = not significant

Table 5.3. Means and standard deviations of somatotype in urban boys by age group.

	Endomorphy			Mesomorphy			Ectomorphy		
Age	n	Mean	SD	n	Mean	SD	n	Mean	SD
6	30	3.38	0.80	30	5.05	1.00	30	1.68	0.74
7	29	3.12	0.60	29	4.50	0.78	29	2.18	0.92
8	26	3.35	0.89	26	4.36	0.69	26	2.26	0.87
9	25	3.26	0.67	25	4.28	0.82	25	2.64	0.98
10	31	3.99	0.98	31	5.02	1.14	31	1.88	1.14
11	20	3.60	0.65	20	4.29	0.88	20	2.63	0.92
Analysis of Varaince									
F age		2.66			4.04			3.16	
p		*			**			*	

** $p < 0.01$
* $p < 0.05$

Table 5.4. Means and standard deviations of somatotype in rural girls by age group.

	Endomorphy			Mesomorphy			Ectomorphy		
Age	n	Mean	SD	n	Mean	SD	n	Mean	SD
6	29	3.55	0.92	29	4.34	0.59	29	1.90	0.79
7	22	3.44	0.74	22	4.04	0.56	22	2.45	0.81
8	37	3.87	0.92	36	4.29	0.84	37	2.38	1.03
9	24	3.84	1.11	24	4.15	1.13	25	2.33	1.18
10	28	4.04	1.08	28	4.17	1.14	28	2.50	1.18
11	34	4.14	0.74	34	4.03	0.98	34	2.53	0.96
Analysis of Varaince									
F age		0.68			0.43			0.65	
p		NS			NS			NS	

NS = not significant

Table 5.5. Means and standard deviations of somatotype on urban girls by age group.

	Endomorphy			Mesomorphy			Ectomorphy		
Age	n	Mean	SD	n	Mean	SD	n	Mean	SD
6	24	3.72	0.66	23	4.67	0.77	24	1.69	0.91
7	27	3.67	0.77	27	4.09	0.77	27	2.17	1.04
8	23	3.62	0.76	23	4.19	0.78	23	2.28	0.91
9	33	3.77	0.82	33	4.27	0.81	33	2.33	0.99
10	25	3.61	0.71	25	3.88	0.97	25	2.82	1.43
11	25	3.77	0.72	25	3.90	0.94	25	2.74	1.47
Analysis of Varaince									
F age		0.23			1.17			0.39	
p		NS			NS			NS	

NS = not significant

Table 5.6. Age-adjusted means and standard errors, and rural-urban differences in somatotype of children 6-11 years of age.

	Rural			Urban			Rural-Urban Difference		
Sex	n	Mean	SE	n	Mean	SE	Wilks' Lamda	F ratio	p
Boys									
Somatotype	154			161			0.97	3.30	0.021
Endomorphy		3.18	0.07		3.46	0.07		8.36	0.004
Mesomorphy		4.48	0.07		4.62	0.07		2.09	0.149
Ectomorphy		2.28	0.07		2.17	0.07		1.14	0.287
Girls									
Somatotype	173			156			0.99	1.46	0.226
Endomorphy		3.83	0.06		3.70	0.07			
Mesomorphy		4.18	0.07		4.17	0.07			
Ectomorphy		2.35	0.08		2.35	0.09			

Table 5.7. Age-adjusted means and standard errors, and sex differences in somatotype of rural and urban children 6-11 years of age.

	Rural			Urban			Sex Difference		
Sex	n	Mean	SE	n	Mean	SE	Wilks' Lamda	F ratio	p
Rural									
Somatotype	154			173			0.70	46.03	< 0.001
Endomorphy	154	3.18	0.07	173	3.83	0.07		40.12	< 0.001
Mesomorphy	154	4.47	0.07	173	4.19	0.06		9.77	0.002
Ectomorphy	154	2.30	0.07	173	2.33	0.07		0.14	0.705
Urban									
Somatotype	161			156			0.79	27.80	< 0.001
Endomorphy	161	3.46	0.06	156	3.69	0.06		6.74	0.010
Mesomorphy	161	4.61	0.07	156	4.18	0.07		18.39	< 0.001
Ectomorphy	161	2.18	0.08	156	2.33	0.09		1.46	0.227

Table 5.8. Summary of forward stepwise discriminant function analyses for rural-urban and sex differences in somatoype.

	Step 1	Step 2	Step3	Wilks' Lamda	p
Rural-Urban Differences					
Boys	Endomorphy (8.31)			0.97	0.004
Sex Differences					
Rural	Endomorphy (120.46)	Mesomorphy (82.74)		0.97	< 0.001
Urban	Mesomorphy (53.68)	Endomorphy (38.66)	Ectomorphy (6.74)	0.92	< 0.001

Table 5.9. Mean somatotypes of children 6 to 11 years of age in the present study and samples of Latin American children.

Study	Sample	Sex	Endomorphy	Mesomorphy	Ectomorphy
Present Study	Mexican school children, 6-11 years, from a rural and an urban community in the Valley of Oaxaca	Rural: Boys (n = 154)	3.2	4.5	2.3
		Girls (n = 173)	3.8	4.2	2.4
		Urban: Boys (n = 161)	3.5	4.6	2.2
		Girls (n = 156)	3.7	4.2	2.4
Murguia et al. (1990)	Mexican children, 6-11 years, from traditional Indian community and municipalities in Yucatan	Indian: Boys (n = 164)	* 2.0	* 4.6	* 1.7
		Girls (n = 190)	* 2.5	* 4.4	* 1.6
		Sisal: Boys (n = 114)	* 2.3	* 4.0	* 2.2
		Girls (n = 106)	* 2.8	* 3.7	* 2.1
Alexander (1992)	Venezuela school children, 8-11 years, national survey	Boys (n = 1,176)	3.1	4.3	2.4
		Girls (n = 1,202)	3.5	3.8	2.4
Alexander et al. (1993)	Guatemalan school children, 8-11 years, national survey	Boys (n = 1,590)	3.1	4.3	2.7
		Girls (n = 1,755)	3.7	3.9	2.9
Godoy et al. (1994)	Chilean school boys, 6-11 years, medium to high SES	Boys (n = 603)	3.0	4.5	2.7
Godoy and Barcos (1995)	Chilean school girls, 6-11 years low SES	Girls (n = 172)	* 2.6	* 4.2	* 2.2
Diaz Gamboa and Fuentes Heinrich (1996)	Chilean children, 6-11 years, living at high altitude (3000-4500 m)	Boys (n = 62)	* 2.8	* 4.6	* 1.6
		Girls (n = 55)	* 3.7	* 3.8	* 1.8

* Estimated mean after adjusting for sample sizes in each age group. The specific algorithms for the calculation of endomorphy, mesomorphy, and ectomorphy with the Heath-Carter anthropometric protocol (Carter and Heath, 1990) are described in Chapter 3.

CHAPTER 6

Relationship between Somatotype and Physical Fitness in Rural and Urban Mexican Children

Introduction

Physical fitness is influenced by variety of factors including, size, physique, and body composition, among others (Malina and Rarick, 1973; Malina, 1975, 1992). Physique as a factor influencing physical fitness, in particular performance-related fitness, has received considerable attention given the reasonably unique distributions of physiques among athletes in specific sports or in different events within a sport (Carter and Heath, 1990; Malina et al., 2002). In contrast, the relationship between physique and performance in the general population, especially children and adolescents, has received relatively less attention (Malina and Rarick, 1973; Malina, 1975).

Physique refers to the total configuration of the body, and is most often quantified as a somatotype (Sheldon et al., 1940, 1954; Parnell, 1958; Carter and Heath, 1990). Somatotype is a composite based on the contributions of three components - endomorphy, mesomorphy and ectomorphy. At present, the Heath-Carter anthropometric protocol (Carter and Heath, 1990; Malina, 1995) is the most commonly used method to estimate somatotype.

Studies relating physique to performance generally focus on individual components of somatotype. This is a limitation because the three components together define an individual's somatotype. It is necessary to control for variation in the other two components when considering relationships between a component and performance.

Allowing for this limitation of earlier studies, correlations between somatotype components and strength and motor performance tend to be low to moderate in magnitude (Malina, 1975, 1992; Malina and Rarick, 1973). They rarely exceed 0.5; hence, explained variances are low and have limited predictive utility.

Nevertheless, the literature suggests several trends. Correlations between endomorphy and performances requiring projection or movement of the body through space are consistently negative in children and adolescents of both sexes. These include tasks such as the standing long jump, vertical jump, dashes, pull-ups, and distance runs. The excess fatness associated with endomorphy represents dead weight, which must be projected or moved, and thus presents a mechanical disadvantage. In contrast, endomorphy is positively related to measures of static strength, which emphasizes, perhaps, a significant contribution of muscularity to ratings of endomorphy. Mesomorphy contributes variably to strength and motor performance. Correlations tend to be positive and low in both sexes in childhood and adolescence. Ectomorphy is not consistently related to motor performance during childhood, but tends to be negatively related to strength and power tasks in adolescent males. The low negative correlations for strength tasks emphasize the lack of muscular development associated with extreme ectomorphy or linearity of build (Malina 1975, 1992; Malina and Rarick, 1973).

These trends are derived from primarily from samples of well-nourished European and North American children. The situation may be somewhat different for children living under marginal health and nutritional conditions. Chronic undernutrition, for example, is associated with reduced body size and muscularity and altered proportions, specifically proportionally shorter lower extremities.

This study considers the relationship between somatotype and performances on several physical fitness tests in rural and urban children in Oaxaca, southern Mexico. The study used two approaches. First, the relationship between somatotype components and each physical fitness item was correlated while statistically controlling for age and the other two components. Second, the contribution of somatotype to variation in physical fitness was estimated with multivariate techniques.

Methods and Procedures

The communities, sample, anthropometric procedures and fitness tests were described earlier (Chapter 3). Procedures for estimating somatotype with the Heath-Carter protocol and age, sex and rural-urban variation were described earlier (Chapter 5). The physical fitness battery included a combination of performance- and health-related tests:

1. Static strength – Static grip strength of the left and right hands,
2. Running speed – 35 yard (32.3 meters) dash,
3. Power – Standing long jump (SLJ),
4. Flexibility - Sit and reach (SAR),
5. Muscular endurance – Timed sit-ups, number in 30 seconds,
6. Cardiovascular endurance – Distance (meters) run and/or walked in 8 minutes for children in grades 1 to 3 and 12 minutes for grades 4 to 8.

The specific procedures for each test were described in Chapter 3. The sum of left and right grip strength (Sum of RL) was used as the estimate of overall static strength. The distance run was converted to an average running speed expressed as meters per minute (Pate et al., 1989).

Two analyses were done. Sex- and community-specific third order partial correlations between a somatotype component and a fitness task, controlling for age and the other two somatotype components. were initially calculated. Then, sex- and community-specific multiple regression analyses were conducted to estimate the variation in each physical fitness task that was contributed by age and each somatotype component.

Results

Third-order partial correlations between somatotype components and physical fitness variables, controlling for age and the other two components, in rural and urban boys and girls 6-11 years are presented in Tables 6.1 and 6.2. Correlations were generally low and but several were moderate, –0.39 to +0.28. The highest negative correlation, –0.39, was between endomorphy and the distance run in rural boys, whereas the highest positive correlation, 0.28, was between ectomorphy and sit-ups in rural boys. Endomorphy correlated negatively with all fitness items except strength in rural children and the dash in rural girls; the two positive correlations, however, approximated zero (0.03 to 0.10). The three somatotype components were negatively correlated with the distance run except in rural girls. Overall, the partial correlations indicated that each somatotype component was significantly correlated, at most, with only two physical fitness items, but the correlations were moderate at best.

Results of the multiple regression analyses indicated that age and somatotype accounted for 1% to 71% of the variance in the six fitness tasks (Tables 6.3 and 6.4), and there were no consistent urban-rural contrasts by sex. The independent variables contributed proportionally more to the variance in static strength (58% to 71%) compared to the other fitness tests. Contributions of age and somatotype to the variance in other fitness tests were more variable. Age and somatotype accounted for moderate amounts of the variance in the dash, 37% to 56%, and standing long jump, 31% to 41%. Corresponding estimates for the distance run were 26% and 25% of the variance in urban boys and girls, 21% of the variance in rural boys, but only 4% of the variance in rural girls. Age and somatotype accounted for somewhat lesser proportions of the variance in timed sit-ups in urban and rural girls, 14% and 10%, respectively, compared to urban and rural boys, 19% to 28%, respectively. In contrast to the other fitness items, the variance in the sit and reach accounted for by age and somatotype was low in the four groups, 1% to 9%.

Discussion

Partial correlations between somatotype and physical fitness were generally low, with several of moderate magnitude. Endomorphy was consistently and negatively correlated, whereas as mesomorphy and ectomorphy were variably correlated with the fitness items included in this study. The results are reasonably consistent with earlier correlational studies (Malina, 1975, 1992; Malina and Rarick, 1973; Slaughter et al., 1977, 1980). However, the low to moderate correlations between somatotype and static grip strength in the present study (Tables 6.1 and 6.2), especially for endomorphy and mesomorphy, were at variance with the trends suggested in the literature. The highest correlations in the present study were for mesomorphy and strength among urban children, 0.34 in boys and 0.17 in girls, whereas all other correlations were low, -0.02 to 0.10 for endomorphy and -0.02 to 0.15 for ectomorphy.

Results of the multivariate analysis indicated that age and somatotype accounted for 1% to 71% of the variance in the six fitness tasks. Age appeared to be the main contributor to five of the performance items in contrast to Heath-Carter anthropometric somatotype components. Except for a negative influence of endomorphy, there did not appear to be any consistent trends in the contributions of somatotype components to variation in performance in these samples of Mexican children living under marginal nutritional and health conditions. There also were no consistent rural-urban and sex differences in the estimated contributions of age and somatotype to variation in performance. Age and somatotype contributed proportionally most of the variation in static strength (58% to 71%), followed by the dash (37% to 56%) and the standing long jump (31% to 41%). The estimated contributions of age and somatotype to variation in performance were lower and more variable for the distance run (4% to 26%) and sit-ups (10% to 28%), and lowest for the sit and reach (1% to 9%).

Previous studies of somatotype and fitness of children did not include multiple regression analyses; hence, comparisons are not possible. Results of the present study indicated a primary role for age and a lesser role for somatotype in explaining the variance in the health- and performance-related fitness of children 6-11 years of age living under marginal health and nutritional circumstances. The important role for age per se probably reflects the significant contributions of neuromuscular maturation and experience to fitness tasks at these ages.

Data based on questionnaires for fourth, fifth, and sixth grade children suggest a limited scope of activities among both urban and rural children. Urban children appeared to have less regular physical activity in the context of sports and household chores, but a greater variety of activities than rural children. Rural children, in contrast were more regularly involved in household-related activities of moderate intensity and in some instance activities of moderate-to-vigorous intensity, but a reduced scope of activities (Peña Reyes, 2002).

The results may also reflect sampling variation per se, the relatively narrow range of somatotypes in the sample, and/or the small body size of the children compared to other studies based on samples of European and North American children. The small size of the current samples was indicated earlier. The range of variation in somatotypes was relatively reduced compared to studies of well-nourished children. None of the standard deviations for rural boys exceeded 1.0. Age-specific standard deviations for endomorphy ranged from 0.6 to 1.1, and only two of the values exceeded 1.0. Corresponding values for mesomorphy ranged from 0.6 to 1.1, and only four exceeded 1.0. Standard deviations for ectomorphy ranged from 0.7 to 1., and seven exceeded 1.0. Values >1.0 occurred most often among 9-10 year old girls and boys (see Tables 5.2 to 5.5). In contrast, standard deviations for mean components approximate 1.0 to 1.5 somatotype units in samples of North American and European children and adolescents (Carter and Heath, 1990; Malina et al., in press).

The reduced variation in somatotypes, or more specifically, the lack of extreme somatotypes in the present sample of Mexican children, may influence the contributions of physique to performance. It is at the extremes of somatotype that performances on fitness tests may be affected. Endomorphy, mesomorphy and ectomorphy are, respectively, indicators of fatness, musculoskeletal development and linearity. Extreme ectomorphs tend to be deficient in muscle mass and strength, whereas extreme mesomorphs are characterized by muscular development and strength. Extreme endomorphs, on the other hand, have excess fat but also reasonably well development mesomorphy (Malina, 1975, 1992; Malina and Rarick, 1973).

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Table 6.1. Third-order partial correlations of age and somatotype, and physical fitness in rural and urban boys 6-11 years of age.

	Endomorphy	Mesomorphy	Ectomorphy
Controlling for:	Age, Meso, Ecto	Age, Endo, Ecto	Age, Endo, Meso
Rural			
Sum RL Grip, kg	0.10	0.10	0.09
SAR, cm	- 0.08	0.02	- 0.05
Sit-Ups, n	- 0.07	0.18*	0.28**
SLJ, cm	- 0.07	- 0.05	- 0.06
Dash[a], sec	- 0.03	0.06	0.02
Distance Run, m/min	- 0.39**	- 0.08	- 0.17*
Urban			
Sum RL Grip, kg	- 0.02	0.34**	0.15
SAR, cm	- 0.24**	- 0.05	- 0.14
Sit-Ups, n	- 0.13	0.09	0.02
SLJ, cm	- 0.12	0.13	0.03
Dash[a], sec	- 0.11	0.08	- 0.00
Distance Run, m/min	- 0.17*	- 0.10	- 0.05

** Significance at < 0.01
* Significance at < 0.05
[a] Signs were inverted as a lower time equals better performance

Table 6.2. Third-order partial correlations of age and somatotype, and physical fitness in rural and urban girls 6-11 years of age.

	Endomorphy	Mesomorphy	Ectomorphy
Controlling for:	Age, Meso, Ecto	Age, Endo, Ecto	Age, Endo, Meso
Rural			
Sum RL Grip, kg	0.06	0.09	- 0.02
SAR, cm	- 0.24**	- 0.10	- 0.13
Sit-Ups, n	- 0.01	0.11	0.16*
SLJ, cm	- 0.04	0.16*	0.22**
Dash[a], sec	0.03	0.02	0.11
Distance Run, m/min	- 0.09	0.04	0.06
Urban			
Sum RL Grip, kg	- 0.00	0.17*	0.12
SAR, cm	- 0.08	0.05	0.01
Sit-Ups, n	- 0.07	0.00	- 0.04
SLJ, cm	- 0.24**	- 0.08	- 0.15
Dash[a], sec	- 0.07	0.02	0.05
Distance Run, m/min	- 0.05	- 0.19*	- 0.09

** Significance at < 0.01

* Significance at < 0.05

[a] Signs were inverted as a lower time equals better performance

Table 6.3. Multiple regression of physical fitness on age and somatotype in rural and urban boys 6-11 years of age.

	n	R^2	F	Beta Coefficients			
				Age	Endomorphy	Mesomorphy	Ectomorphy
Rural							
Sum RL Grip, kg	154	0.58	50.74**	0.73**	0.09	0.13	0.11
SAR, cm	154	0.01	0.41	0.02	- 0.11	0.02	- 0.12
Sit-Ups, n	154	0.28	14.36**	0.27**	- 0.08	0.30*	0.51**
SLJ, cm	154	0.34	19.55**	0.61**	- 0.08	- 0.07	- 0.10
Dash[a], sec	153	0.37	21.63**	0.60**	- 0.04	0.09	0.04
Distance Run, m/min	152	0.21	9.99**	0.23**	- 0.50**	- 0.14	- 0.32*
Urban							
Sum RL Grip, kg	161	0.63	65.49**	0.74**	- 0.02	0.51**	0.22
SAR, cm	161	0.08	3.30*	0.04	- 0.35**	- 0.11	- 0.32
Sit-Ups, n	161	0.19	9.31**	0.47**	- 0.18	0.19	0.04
SLJ, cm	161	0.41	27.40**	0.68**	- 0.14	0.23	0.06
Dash[a], sec	161	0.52	41.87**	0.76**	- 0.12	0.13	- 0.00
Distance Run, m/min	161	0.26	13.48**	0.45**	- 0.24*	- 0.20	- 0.11

** Significance at < 0.01
* Significance at < 0.05
[a] Signs were inverted as a lower time equals better performance

Table 6.4. Multiple regression of physical fitness on age and somatotype in rural and urban girls 6-11 years of age.

				Beta Coefficients			
	n	R^2	F	Age	Endomorphy	Mesomorphy	Ectomorphy
Rural							
Sum RL Grip, kg	173	0.71	100.91**	0.82**	0.06	0.13	0.01
SAR, cm	173	0.09	3.92**	0.12	- 0.36**	- 0.18	- 0.29
Sit-Ups, n	173	0.10	4.41**	0.21*	- 0.03	0.20	0.32
SLJ, cm	173	0.31	18.39**	0.46**	- 0.07	0.26	0.40**
Dash[a], sec	171	0.40	27.58**	0.57**	0.04	0.02	0.21
Distance Run, m/min	169	0.04	1.50	0.05	- 0.13	0.09	0.14
Urban							
Sum RL Grip, kg	156	0.60	56.20**	0.77**	0.00	0.22*	0.13
SAR, cm	156	0.02	0.59	0.10	- 0.11	0.10	0.04
Sit-Ups, n	155	0.14	5.86**	0.38**	- 0.06	0.04	- 0.03
SLJ, cm	156	0.37	21.74**	0.62**	- 0.23*	- 0.06	- 0.16
Dash[a], sec	156	0.56	47.54**	0.72**	- 0.05	0.07	0.11
Distance Run, m/min	152	0.25	12.18**	0.40**	- 0.05	- 0.31*	- 0.13

** Significance at < 0.01
* Significance at < 0.05
[a] Signs were inverted as a lower time equals better performance

CHAPTER 7

Growth and Physical Fitness of Stunted and Non-Stunted Children in a Rural and an Urban Community in Oaxaca, Mexico

Introduction

Stunting is a concept introduced in the early 1970s by Waterlow (1972, 1973) to indicate retardation of linear growth. The term describes deficits in attained length or height for chronological age compared to an international reference (Waterlow, 1972; World Health Organization [WHO], 2000). The World Health Organization (2000) describes stunting as "...a process of failure to reach linear growth potential as a result of suboptimal health and/or nutritional conditions." Chronic undernutrition and illness early in life, usually the first three years, are primary factors in the etiology of stunting. The prevalence of stunting among children under 5 years of age in developing countries varies from 5% to 65% (de Onís et al., 1993). Stunting is defined as height-for-age that is more than two standard deviations below age- and sex-specific reference values for healthy, well-nourished children (WHO, 2000).

Chronic undernutrition is common in most developing countries where poverty, inequality, and/or economic underdevelopment are prevalent. The growth status of children is very responsive to an environment where the nutritional conditions are marginal, and stunted growth in length/height is a common result. Most studies on stunted populations have considered the retardation of growth per se and/or catch-up growth (Bénéfice et al., 2001a, 2001b; Neumann and Harrison, 1994; Walker et al., 1996). The behavioral, biological, intellectual, and social consequences of chronic mild to moderate undernutrition during childhood have also been investigated on a more or less regular basis (Post and Victora, 2001; Walker and Walker, 1997; Neumann and Harrison, 1994; Martorell et al., 1992), but the consequences of stunting for physical fitness have been studied to a lesser extent (Satyanarayana et al., 1979; Bénéfice et al., 1996).

Stunting is a continuous variable that is a reflection of compromised growth in stature that occurred in early childhood. Although short stature has a generally negative influence on many standard performance tasks (Malina and Buschang, 1985; Malina et al., 1987; Malina and Bouchard, 1991), the effects of stunting per se on physical fitness of school age children has not been systematically evaluated. An exception is the work of Satyanarayana et al. (1979), who considered the effects of stunting at 5 years of age on the physical working capacity of Indian boys during adolescence. The most severely stunted boys were most compromised in working capacity. In contrast, most research on nutritionally at risk populations has been conducted on preschool children, and children who were nutritionally compromised during the first two years of life tend to show deficits in several measures of physical performance (Benefice et al., 1996). Although children below the age of 5 years are more sensitive to unfavorable living and nutritional conditions, children of school age represent a population that has survived the compromised environmental conditions that are generally associated with high morbidity and mortality during the preschool years.

The purpose of this study is to compare the anthropometric and physical fitness characteristics of stunted and non-stunted school children 6-11 years of age resident in an urban and in a rural community in southern Mexico.

Methods and Procedures

The communities, sample, anthropometric procedures and physical fitness tests were described earlier (Chapter 3). The children were classified as stunted and non-stunted on the basis of height. A child whose height-for-age z-score was > 2 standard deviations below the age- and sex-specific median of the United States reference was considered stunted. This is the criterion of the World Health Organization (1997). Other children were considered non-stunted. The new Centers for Disease Control and Prevention (2000) growth charts were used to calculate age- and sex-specific z-scores for each child. The prevalence of stunting in the sample of 6-11 year old children was approximately 28% for both boys and girls in the rural community, and 15% for girls and boys in the urban community (Table 7.1).

Anthropometric variables included the following:

1) Body size: Weight, height, body mass index (BMI);

2) Segment lengths: Sitting height, estimated leg length;

3) Skeletal breadths: Biacromial, bicristal, biepicondylar, bicondylar;

4) Limb circumferences: Relaxed and flexed arm circumference, calf circumference, estimated midarm muscle circumference (EAMC), estimated calf muscle circumference (ECAC);

5) Subcutaneous fatness: Sum of 4 skinfolds - triceps, subscapular, suprailiac and medial calf skinfolds;

6) Proportions: Sitting height/standing height ratio.

Heath-Carter anthropometric somatotypes were also calculated for each child (Carter and Heath, 1990; see Chapter 5).

Physical fitness variables included the following:

1) 35 yard (32.3 m) dash – running speed,

2) Standing long jump (SLJ) – explosive power,

3) Sum of right and left grip strength (Sum RL) – static strength,

4) Sit-and-reach (SAR) – lower back and upper thigh flexibility,

5) Timed sit-ups – abdominal muscular strength and endurance,

6) Distance run (Dist Run) – cardiovascular endurance.

The analyses proceeded in several steps. Descriptive statistics for all variables were initially calculated for stunted and non-stunted children by sex within each community. Sex-specific multivariate analyses of covariance (MANCOVA), with age as the covariate, were used to compare the anthropometric and physical fitness characteristics of stunted and non-stunted children within each community. Sex-specific multivariate analyses of covariance (MANCOVA) were used to compare the somatotypes of stunted and non-stunted children within each community.

Results

Anthropometry. Age-adjusted means and standard errors of anthropometric and derived variables in stunted and non-stunted children by sex in each community are presented in Tables 7.2 to 7.5. All anthropometric characteristics differed significantly between stunted and non-stunted children; stunted children were smaller in all anthropometric dimensions and derived variables. The sitting height/standing height ratio, however, was higher in stunted children (significantly so except urban girls), indicating that the shortness of stunted children was due in large part to proportionally shorter legs.

Somatotype. Within each community and sex, stunted and non-stunted children differed significantly in somatotype (Tables 7.6 and 7.7). However, univariate F-tests for specific components did not differ significantly between stunted and non-stunted children except for endomorphy and ectomorphy in rural boys. Stunted rural boys were significantly less endomorphic and ectomorphic than non-stunted boys. Overall, stunted children of both sexes were slightly higher in mesomorphy, and lower in ectomorphy and endomorphy compared to non-stunted children.

Physical Fitness. Community- and sex-specific age-adjusted means and standard errors for the physical fitness characteristics of stunted and non-stunted children are summarized in Tables 7.8 to 7.11. Only absolute strength (sum of right and left grip) and left grip strength per unit estimated arm muscle circumference differed significantly between stunted and non-stunted children of both sexes within each community. The only other significant differences between stunted and non-stunted children were the dash in rural males and the standing long jump in rural girls; non-stunted children performed better. Although the differences were not significant, stunted rural children had somewhat better average performances on the distance run expressed as meters per minute compared to non-stunted rural children, but corresponding means for stunted and non-stunted urban children were virtually identical. Otherwise, mean performances of stunted children on the sit and reach and timed sit-ups were comparable to those of non-stunted children.

Discussion

Anthropometric characteristics were consistently larger in the non-stunted compared to stunted children. The sitting height to standing height ratio, however, was higher in stunted children indicating that growth of the lower extremities (leg length) was specifically compromised. Bénéfice et al. (2001a, 2001b) reported similar observations in stunted (malnourished) Senegalese girls. Undernourished children and adults, who were not necessarily stunted, also were shorter and lighter, and had reduced muscle mass compared to well-nourished age and sex peers (Spurr, 1984; Bénéfice et al., 1996, 1999; Hoffman et al., 2000).

Absolute body size and nutritional status are related to physical performance (Spurr, 1984; Malina and Buschang, 1985). However, in the present study, non-stunted children performed better than stunted children only in absolute strength (sum of right and left grip) and strength per unit estimated midarm muscle circumference. The former reflects the influence of overall small body size, while the latter suggests changes in muscle mass associated with growth stunting. The reduced strength per unit arm muscle in stunted children may, perhaps, reflect qualitative changes in muscle tissue associated with undernutrition early in life. Interestingly, strength per unit body mass did not differ between stunted and unstunted children, which further implicates subtle changes in muscle tissue. Performances in the dash of rural males and the standing long jump of rural females also favored the non-stunted children, and may also possibly reflect changes in muscle mass per se and qualitative changes in muscle tissue associated with early undernutrition.

Otherwise, the performances of stunted and non-stunted children on the other fitness tests did not consistently differ. There were negligible differences in the sit and reach (flexibility) and timed sit-ups (abdominal muscular strength and endurance). On the other hand, stunted children in the rural community were, on average, better in the distance run (meters per minute) than non-stunted children, whereas stunted and non-stunted children in the urban community did not differ in the distance run.

Heath-Carter anthropometric somatotypes differed between stunted and non-stunted children. Stunted children of both sexes, urban and rural, had somatotypes that were, on average, slightly more mesomorphic and less endomorphic and ectomorphic compared to non-stunted children. Although stunted children were, on average smaller in the body dimensions used to estimate the Heath-Carter somatotype, they were obviously shorter (as per the criterion of stunting) but had disproportionally shorter in estimated leg length compared to non-stunted children. Although the shortness relates to the definition of stunting, the short stature may influence the estimated somatotype. Each component of the Heath-Carter anthropometric protocol involves an adjustment for height. Unfortunately, comparative somatotype data for other samples of stunted and non-stunted children are not available to verify this suggestion.

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Table 7.1. Prevalence of stunting in 6-11 year old children in the rural and urban communities.

	Rural		Urban	
	Males	Females	Males	Females
Stunted	49	43	25	21
Non-Stunted	126	111	132	140
Total	175	154	157	161

Table 7.2. Age-adjusted means and standard errors of anthropometric and derived variables of stunted and non-stunted rural boys 6-11 years of age.

	Stunted (n = 43)		Non-Stunted (n =111)		
Variables	Mean	SE	Mean	SE	p
Weight, kg	21.9	0.5	26.6	0.3	< 0.01
Height, cm	116.6	0.5	125.5	0.3	< 0.01
BMI, kg/m^2	16.0	0.2	16.8	0.2	< 0.05
Sit Ht, cm	64.0	0.3	67.9	0.2	< 0.01
Leg Lt, cm	52.7	0.4	57.6	0.2	< 0.01
Sit Ht / Ht, %	54.9	0.2	54.2	0.1	< 0.01
Biacromial, cm	26.7	0.2	28.6	0.1	< 0.01
Bicristal, cm	19.0	0.2	20.5	0.1	< 0.01
Bicondylar, cm	7.4	0.1	7.9	0.0	< 0.01
Biepicondylar, cm	4.6	0.0	5.0	0.0	< 0.01
Arm Circ, cm	17.1	0.2	18.3	0.1	< 0.01
Calf Circ, cm	23.2	0.2	24.8	0.1	< 0.01
EAMC, cm	14.9	0.2	15.8	0.1	< 0.01
ECMC, cm	21.0	0.2	22.2	0.1	< 0.01
Sum 4 SF, mm	26.8	1.2	32.2	0.8	< 0.01

Table 7.3. Age-adjusted means and standard errors of anthropometric and derived variables of stunted and non-stunted rural girls 6-11 years of age.

	Stunted (n = 49)		Non-Stunted (n = 124)		
Variables	Mean	SE	Mean	SE	p
Weight, kg	22.5	0.6	27.6	0.4	< 0.01
Height, cm	117.7	0.5	126.9	0.3	< 0.01
BMI, kg/m^2	16.1	0.3	16.9	0.2	< 0.05
Sit Ht, cm	64.6	0.3	68.4	0.2	< 0.01
Leg Lt, cm	53.1	0.4	58.5	0.2	< 0.01
Sit Ht / Ht, %	54.9	0.2	53.9	0.1	< 0.01
Biacromial, cm	27.1	0.2	28.9	0.1	< 0.01
Bicristal, cm	19.3	0.2	20.8	0.1	< 0.01
Bicondylar, cm	7.2	0.1	7.6	0.0	< 0.01
Biepicondylar, cm	4.6	0.0	4.9	0.0	< 0.01
Arm Circ, cm	17.6	0.2	18.8	0.2	< 0.01
Calf Circ, cm	23.4	0.3	25.1	0.2	< 0.01
EAMC, cm	14.9	0.2	15.9	0.1	< 0.01
ECMC, cm	20.5	0.2	22.1	0.2	< 0.01
Sum 4 SF, mm	34.7	1.4	38.6	0.9	< 0.05

Table 7.4. Age-adjusted means and standard errors of anthropometric and derived variables of stunted and non-stunted urban boys 6-11 years of age.

	Stunted (n = 21)		Non-Stunted (n = 140)		
Variables	Mean	SE	Mean	SE	p
Weight, kg	22.5	1.1	28.5	0.4	< 0.01
Height, cm	117.4	0.8	127.0	0.3	< 0.01
BMI, kg/m^2	16.3	0.5	17.4	0.2	< 0.05
Sit Ht, cm	65.0	0.5	68.7	0.2	< 0.01
Leg Lt, cm	52.4	0.5	58.3	0.2	< 0.01
Sit Ht / Ht, %	55.3	0.3	54.2	0.1	< 0.01
Biacromial, cm	27.5	0.3	29.3	0.1	< 0.01
Bicristal, cm	19.8	0.3	21.2	0.1	< 0.01
Bicondylar, cm	7.6	0.1	8.0	0.0	< 0.01
Biepicondylar, cm	4.7	0.1	5.1	0.0	< 0.01
Arm Circ, cm	17.3	0.4	18.9	0.2	< 0.01
Calf Circ, cm	23.8	0.4	25.6	0.2	< 0.01
EAMC, cm	15.0	0.4	16.3	0.1	< 0.01
ECMC, cm	21.4	0.4	22.9	0.1	< 0.01
Sum 4 SF, mm	29.2	1.7	34.6	0.7	< 0.01

Table 7.5. Age-adjusted means and standard errors of anthropometric and derived variables of stunted and non-stunted urban girls 6-11 years of age.

	Stunted (n = 25)		Non-Stunted (n = 131)		
Variables	Mean	SE	Mean	SE	p
Weight, kg	23.2	1.0	29.2	0.4	< 0.01
Height, cm	118.7	0.9	129.1	0.4	< 0.01
BMI, kg/m^2	16.3	0.4	17.3	0.2	< 0.05
Sit Ht, cm	64.3	0.6	69.5	0.3	< 0.01
Leg Lt, cm	54.4	0.6	59.6	0.2	< 0.01
Sit Ht / Ht, %	54.2	0.3	53.9	0.1	NS
Biacromial, cm	27.7	0.3	29.5	0.1	< 0.01
Bicristal, cm	20.0	0.3	21.6	0.1	< 0.01
Bicondylar, cm	7.3	0.1	7.8	0.0	< 0.01
Biepicondylar, cm	4.6	0.1	5.0	0.0	< 0.01
Arm Circ, cm	17.7	0.3	19.1	0.1	< 0.01
Calf Circ, cm	23.8	0.4	25.8	0.2	< 0.01
EAMC, cm	15.1	0.3	16.3	0.1	< 0.01
ECMC, cm	21.1	0.3	22.8	0.1	< 0.01
Sum 4 SF, mm	32.5	1.4	37.5	0.6	< 0.01

Table 7.6. Age-adjusted means and standard errors of somatotype in stunted and non-stunted rural and urban boys 6-11 years of age.

	Stunted			Non-Stunted			Stunting Status Difference		
Village	n	Mean	SE	n	Mean	SE	Wilk's Lamda	F ratio	p
Rural									
Somatotype							0.82	11.00	0.000
Endomorphy	43	2.91	0.13	111	3.28	0.08		5.41	0.021
Mesomorphy	43	4.59	0.12	111	4.44	0.07		1.14	0.288
Ectomorphy	43	2.04	0.12	111	2.37	0.08		5.46	0.021
Urban									
Somatotype							0.90	5.54	0.001
Endomorphy	21	3.20	0.18	140	3.49	0.07		2.33	0.129
Mesomorphy	21	4.70	0.21	140	4.61	0.08		0.16	0.689
Ectomorphy	21	1.92	0.21	140	2.21	0.08		1.55	0.215

Table 7.7. Age-adjusted means and standard errors of somatotype in stunted and non-stunted rural and urban girls 6-11 years of age.

	Stunted			Non-Stunted			Stunting Status Difference		
Village	n	Mean	SE	n	Mean	SE	Wilk's Lamda	F ratio	p
Rural									
Somatotype							0.91	5.83	0.001
Endomorphy	49	3.72	0.13	124	3.88	0.08		1.15	0.286
Mesomorphy	49	4.33	0.13	124	4.11	0.08		2.07	0.152
Ectomorphy	49	2.13	0.14	124	2.44	0.09		3.46	0.065
Urban									
Somatotype							0.91	4.99	0.003
Endomorphy	25	3.50	0.15	131	3.73	0.07		2.07	0.153
Mesomorphy	25	4.28	0.17	131	4.15	0.07		0.51	0.479
Ectomorphy	25	2.04	0.23	131	2.41	0.10		2.20	0.140

Table 7.8. Age-adjusted means and standard errors of physical fitness and derived variables of stunted and non-stunted rural boys 6-11 years of age.

	Stunted (n = 43)		Non-Stunted (n = 109)		
Variables	Mean	SE	Mean	SE	p
Sum RL, kg	21.6	0.6	27.5	0.4	< 0.01
Sum RL/Wt, kg/kg	0.98	0.02	1.02	0.02	NS
L Grip/EAMC, kg/cm	0.69	0.02	0.83	0.01	< 0.01
SAR, cm	26.7	0.7	26.5	0.4	NS
Sit-Ups, n	8.9	0.6	8.9	0.4	NS
SLJ, cm	96.1	2.7	97.3	1.7	NS
Dash, sec	7.30	0.08	7.10	0.05	< 0.05
Distance Run, m/min	152.7	2.8	148.4	1.7	NS

NS = not significant

Table 7.9. Age-adjusted means and standard errors of physical fitness and derived variables of stunted and non-stunted rural girls 6-11 years of age.

	Stunted (n = 43)		Non-Stunted (n = 109)		
Variables	Mean	SE	Mean	SE	p
Sum RL, kg	21.4	0.6	26.3	0.3	< 0.01
Sum RL/Wt, kg/kg	0.95	0.02	0.95	0.01	NS
L Grip/EAMC, kg/cm	0.67	0.02	0.78	0.01	< 0.01
SAR, cm	27.3	0.6	26.9	0.4	NS
Sit-Ups, n	6.7	0.6	7.0	0.4	NS
SLJ, cm	77.9	2.6	84.5	1.6	< 0.05
Dash, sec	7.73	0.09	7.71	0.06	NS
Distance Run, m/min	141.6	2.9	136.0	1.8	NS

NS = not significant

Table 7.10. Age-adjusted means and standard errors of physical fitness and derived variables of stunted and non-stunted urban boys 6-11 years of age.

	Stunted (n = 43)		Non-Stunted (n = 109)		
Variables	Mean	SE	Mean	SE	p
Sum RL, kg	21.5	1.2	27.6	0.5	< 0.01
Sum RL/Wt, kg/kg	0.95	0.04	0.97	0.01	NS
L Grip/EAMC, kg/cm	0.69	0.03	0.82	0.01	< 0.01
SAR, cm	28.3	1.0	27.6	0.4	NS
Sit-Ups, n	11.6	1.0	12.1	0.4	NS
SLJ, cm	109.3	3.8	112.8	1.5	NS
Dash, sec	7.36	0.11	7.19	0.04	NS
Distance Run, m/min	139.4	4.5	138.9	1.7	NS

NS = not significant

Table 7.11. Age-adjusted means and standard errors of physical fitness and derived variables of stunted and non-stunted urban girls 6-11 years of age.

	Stunted (n = 43)		Non-Stunted (n = 109)		
Variables	Mean	SE	Mean	SE	p
Sum RL, kg	20.3	0.9	26.0	0.4	< 0.01
Sum RL/Wt, kg/kg	0.87	0.03	0.90	0.01	NS
L Grip/EAMC, kg/cm	0.64	0.03	0.76	0.01	< 0.01
SAR, cm	27.2	1.0	28.2	0.4	NS
Sit-Ups, n	8.8	0.9	10.2	0.4	NS
SLJ, cm	94.9	3.4	98.7	1.5	NS
Dash, sec	7.93	0.13	7.68	0.05	NS
Distance Run, m/min	137.5	3.5	134.5	1.5	NS

NS = not significant

CHAPTER 8

Subcutaneous Fat Distribution in Stunted and Non-Stunted Children from Oaxaca, Mexico

Introduction

It is common to discuss obesity and its comorbidities in developed or industrialized countries. However, the prevalence of overweight and obesity is increasing in developing countries where previously undernourished populations are undergoing rapid economic development, rural-to-urban migration, and nutritional changes associated with development and western influences (Popkin et al., 1996, 2001; Schroeder et al., 1999). There appears to be a paradox in developing countries. The presence of chronic undernutrition, especially among preschool children, is apparently continuing in the face of an increasing prevalence of overweight and obesity, specifically in adolescents and adults. A rapid increase in the prevalence of "diet-related" diseases in developing countries, in turn, has implications for costs of public health care that are comparable in magnitude to the costs associated with chronic undernutrition (Popkin et al., 2001).

Changes in the distribution of subcutaneous adipose tissue occur during puberty and the adolescent growth spurt (Malina and Bouchard, 1988, 1991; Malina, 1996). Boys tend to accumulate more subcutaneous fat on the trunk relative to the extremities during puberty, which is due in part to a decrease in the thickness of extremity skinfolds at this time. In contrast, girls gain proportionally similar amounts in both trunk and extremity skinfold thicknesses during puberty. There is also ethnic variation in the relative distribution of subcutaneous fat (Mueller, 1988; Malina et al., 1995; Malina 1996). Compared to individuals of European ancestry, those of African, Asian, and Mexican ancestry tend to have proportionally more subcutaneous fat on the trunk than on the extremities.

It has been suggested that growth stunting during infancy and early childhood may influence subcutaneous fat distribution in adolescence and adulthood. Data are presently limited to adolescent Senegalese girls (Bénéfice et al., 2001a, 2001b) and Guatemalan adults (Schroeder et al., 1999) who were stunted in early childhood. Senegalese adolescent girls who were classified as stunted between 6 and 18 months of age had proportionally thicker trunk skinfolds than those who were not stunted (Bénéfice et al., 2001a, 2001b). Guatemalan young adults who were stunted by 36 months of age had a proportionally greater accumulation of subcutaneous fat on the upper (higher waist-hip ratios) body compared to those who were not stunted (Schroeder et al., 1999).

Bénéfice et al. (2001a) suggested that the trend to accumulate proportionally more subcutaneous fat on the trunk "...may represent transitory changes in fatness under the influence of hormonal stimulation during puberty" (p. 57). Sawaya et al. (1998) proposed that hormonal changes as a consequence of early malnutrition may be a major contributory factor to greater than expected weight gain in mildly stunted girls, 7-11 years of age, from a shanty town (favela) in São Paulo, Brazil. The authors suggested a specific role for high-fat diets.

Corresponding data on the relative fat distribution of stunted children during childhood are apparently not available. The present study thus compares the subcutaneous fatness and relative subcutaneous fat distribution of stunted and non-stunted rural and urban Mexican children, 6-11 years of age.

Methods and Procedures

The communities, sample, and anthropometric procedures were described earlier (Chapter 3). A child whose height-for-age z-score was > 2 standard deviations below age- and sex-specific medians of the United States reference (Centers for Disease Control and Prevention, 2000) was considered stunted. Other children were considered non-stunted. The prevalence of stunting in the sample of 6-11 year old children was approximately 28% for both boys and girls in the rural community, and 15% for girls and boys in the urban community (see Table 7.1).

Anthropometric variables included the present analysis were as follows:

1) Body size: Weight, height, body mass index (BMI);
2) Subcutaneous fatness: Triceps, subscapular, suprailiac and medial calf skinfolds; sum of the four skinfolds; provided an estimate of overall subcutaneous fatness.
3) Relative subcutaneous fat distribution: Trunk-Extremity Ratio (TER) - ratio of the sum of two trunk skinfolds (subscapular and suprailiac) to the sum of two extremity skinfolds (triceps and medial calf).

The analyses proceeded in three steps. Descriptive statistics were initially calculated for all variables. Sex-specific multivariate analyses of covariance (MANCOVA), with age as the covariate, were used to compare the size and fatness characteristics of stunted and non-stunted children within each community.

Principal components analysis (PCA), as described by Baumgartner et al. (1986) and Malina et al. (1995), was also used to evaluate relative subcutaneous fat distribution. The PCA was used to reduce the number of variables and possibly attain a smaller set of variable components that might suggest a trend in the evaluation of relative fat distribution (Rencher, 1995). The four skinfolds were transformed to natural logarithms and the mean log skinfold was used as the index of subcutaneous fat for the individual. Log values for skinfold thicknesses were then separately regressed on the mean log skinfold thickness for each individual, thus controlling for overall subcutaneous fatness. The residuals were subjected to the principal components analysis. The resulting components provided an indication of relative subcutaneous fat distribution. Components with eigen values greater than 1.0 were retained for further analysis. Component scores of stunted and non-stunted boys and girls within each community were compared with analyses of covariance (ANCOVA), with age as the covariate.

Results

Age-adjusted means and standard errors of the body size and fatness characteristics of stunted and non-stunted children by sex within each community are presented in Tables 8.1 and 8.2. Within each community, non-stunted children were significantly larger in body size and skinfold thicknesses than stunted children with the exception of the triceps and medial calf skinfolds in rural girls. On the other hand, the TER did not significantly differ between stunted and non-stunted children except in rural girls. Mean ratios were quite similar in stunted and non-stunted boys in each community, but were higher in non-stunted than in stunted girls in each community. Note, however, that the standard errors for the TER in stunted children of both sexes were considerably larger than corresponding errors in non-stunted children.

Results of the principal components analysis are summarized in Table 8.3. Two components with eigen values greater than 1.0 resulted and accounted for approximately 60% of the variance. The first principal component contrasted the two trunk skinfolds (negative loadings) with the two extremity skinfolds (positive loadings), suggesting a trunk-extremity component, which accounted for 32.2% of the variation in fat distribution in the sample. The first component highlights high extremity fatness and low trunk fatness. The second principal component had positive loadings for all four skinfold and accounted for about 25% of the variance in fat distribution of the sample. The two trunk skinfolds had moderately high positive and similar loadings, and the two extremity skinfolds had low, positive loadings. It also suggested a trunk-extremity contrast with an emphasis on trunk compared to extremity fatness.

Sex-specific age-adjusted means and standard errors for scores on the two principal components in rural and urban, stunted and non-stunted children, respectively, are presented in Table 8.4. Mean component scores did not differ significantly between stunted and non-stunted children by sex within each community.

Discussion

Stunted children, both rural and urban, were shorter (as expected) and lighter, and had a lower BMI and thinner skinfold thicknesses than non-stunted children in both sexes. The TER, however, did not differ significantly between stunted and non-stunted children, except among rural girls. The TER was, on average, higher in non-stunted boys and girls, both urban and rural, which suggests proportionally more subcutaneous fat on the trunk in non-stunted children. This contrasts observations based on skinfolds in Senegalese adolescent girls (Bénéfice et al., 2001a, 2001b) and on the waist-hip ratio in Guatemalan young adults (Schroeder et al., 1999) who were stunted in growth before three years of age.

The variability in results among the three studies of samples who were stunted may be due to several factors. The present study was based on a largely prepubertal sample 6-11 years of age. Only two 11 year old girls, one urban and one rural, were post-menarcheal. In well-nourished samples, individual and in particular sex differences in relative fat distribution become established during adolescence (Malina, 1996). It is also possible that the proportionally greater accumulation of subcutaneous fat on the trunk in stunted children occurs during adolescence as suggested by Bénéfice et al. (2001a).

Another factor may be the indicators of relative subcutaneous fat distribution used in the three studies. The present study was based on four skinfold thicknesses, two on the trunk and two on the extremities, a trunk-extremity skinfold ratio, and principal components analysis. The study of Senegalese adolescents also used skinfolds, but the same skinfolds were not measured at all ages in the mixed-longitudinal sample (Bénéfice et al., 2001a, 2001b), and a different analytical strategy was used. The study of Guatemalan young adults was based on the waist-hip ratio (Schroeder et al., 1999). The validity of the waist-hip ratio as an indicator of relative subcutaneous fat distribution has not been established, particularly in adolescents. It may be more of an indicator of primarily abdominal fatness in adults in contrast to fatness on the upper (subscapular) and lateral (suprailiac) aspects of the trunk. Further, the waist-hip ratio is not the appropriate indicator of relative subcutaneous fat distribution in children and adolescents (Johnston, 1992; Sarria, 1992), and some of the subjects in the Guatemalan study were in fact late adolescents.

Results of the present study and corresponding studies of Senegalese adolescents and Guatemalan young adults emphasize the need for further study of the potential effects of early growth stunting on relative subcutaneous fat distribution. Studies utilizing more clinically relevant indicators of fat distribution, e.g., magnetic resonance imaging and computerized axial tomography, in stunted and non-stunted children are warranted.

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Table 8.1. Age-adjusted means and standard errors of body size and indicators of fatness and relative subcutaneous fat distribution of stunted and non-stunted boys, 6-11 years of age, within each community.

		Stunted		Non-Stunted		
	Variables	Mean	SE	Mean	SE	p
Rural						
	Weight, kg	21.9	0.5	26.6	0.3	< 0.01
	Height, cm	116.6	0.5	125.5	0.3	< 0.01
	BMI, kg/m^2	16.0	0.2	16.8	0.2	< 0.05
	Triceps, mm	6.9	0.3	8.1	0.2	< 0.01
	Subscapular, mm	5.7	0.3	7.0	0.2	< 0.01
	Suprailiac, mm	7.2	0.5	8.9	0.3	< 0.01
	Medial Calf, mm	7.0	0.3	8.3	0.2	< 0.01
	Sum 4 SF, mm	26.8	1.2	32.2	0.8	< 0.01
	TER, %	93.0	3.1	97.0	1.9	NS
Urban						
	Weight, kg	22.5	1.1	28.5	0.4	< 0.01
	Height, cm	117.4	0.8	127.0	0.3	< 0.01
	BMI, kg/m^2	16.3	0.5	17.4	0.2	< 0.05
	Triceps, mm	7.2	0.4	8.5	0.2	< 0.01
	Subscapular, mm	6.1	0.6	7.4	0.2	< 0.05
	Suprailiac, mm	8.5	0.6	10.0	0.2	< 0.05
	Medial Calf, mm	7.5	0.4	8.7	0.2	< 0.05
	Sum 4 SF, mm	29.2	1.7	34.6	0.7	< 0.01
	TER, %	99.7	4.6	100.5	1.8	NS

Based on MANCOVA with age as the covariate. Sum 4 SF = Sum of 4 Skinfolds (Triceps, Subscapular, Suprailiac, Medical Calf), TER = Trunk-Extremity Ratio
NS = Not Significant

Table 8.2. Age-adjusted means and standard errors of body size and indicators of fatness and relative subcutaneous fat distribution of stunted and non-stunted girls, 6-11 years of age, within each community.

	Variables	Stunted Mean	Stunted SE	Non-Stunted Mean	Non-Stunted SE	p
Rural						
	Weight, kg	22.5	0.6	27.6	0.4	< 0.01
	Height, cm	117.7	0.5	126.9	0.3	< 0.01
	BMI, kg/m^2	16.1	0.3	16.9	0.2	< 0.05
	Triceps, mm	8.7	0.3	9.3	0.2	NS
	Subscapular, mm	7.5	0.4	8.8	0.3	< 0.05
	Suprailiac, mm	9.4	0.4	10.7	0.3	< 0.05
	Medial Calf, mm	9.1	0.4	9.8	0.2	NS
	Sum 4 SF, mm	34.7	1.4	38.6	0.9	< 0.05
	TER, %	93.3	2.7	101.6	1.7	< 0.05
Urban						
	Weight, kg	23.2	1.0	29.2	0.4	< 0.01
	Height, cm	118.7	0.9	129.1	0.4	< 0.01
	BMI, kg/m^2	16.3	0.4	17.3	0.2	< 0.05
	Triceps, mm	8.2	0.3	8.8	0.1	< 0.05
	Subscapular, mm	7.0	0.5	8.6	0.2	< 0.01
	Suprailiac, mm	8.9	0.5	10.4	0.2	< 0.01
	Medial Calf, mm	8.5	0.4	9.6	0.2	< 0.01
	Sum 4 SF, mm	32.5	1.4	37.5	0.6	< 0.01
	TER, %	94.8	3.9	102.8	1.7	NS

Based on MANCOVA with age as the covariate. Sum 4 SF = Sum of 4 Skinfolds (Triceps, Subscapular, Suprailiac, Medical Calf), TER = Trunk-Extremity Ratio
NS = Not Significant

Table 8.3. Summary of the principal components analysis: Loadings on the four skinfolds on each principal component.

	Principal Components	
Skinfold	PC1	PC2
Triceps	0.748	0.281
Subscapular	- 0.278	0.684
Suprailiac	- 0.216	0.701
Medial Calf	0.777	0.169
Eigen Value	1.287	1.066
Variance, %	32.2	26.7

Table 8.4. Age-adjusted means and standard errors of scores on the two principal components for stunted and non-stunted rural and urban children by sex.

	PC1				PC2			
	Stunted		Non-Stunted		Stunted		Non-Stunted	
	M	SE	M	SE	M	SE	M	SE
Males								
Rural	- 0.0030	0.15	0.0012	0.09	- 0.0009	0.16	0.0004	0.10
Urban	- 0.0892	0.21	0.0133	0.08	- 0.0388	0.22	0.0058	0.09
Females								
Rural	0.0252	0.12	- 0.0099	0.08	0.0088	0.13	- 0.0035	0.87
Urban	- 0.0160	0.20	0.0031	0.09	- 0.0090	0.20	0.0017	0.09

CHAPTER 9

General Summary, Discussion and Conclusions

The present study examined the anthropometric and physique characteristics of rural and urban children as correlates of health- and performance-related physical fitness. It also considered the anthropometric, physique, fatness, and fitness characteristics of stunted and non-stunted children in the rural and urban communities. In this chapter, the results are discussed in light of the questions/hypotheses and findings of previous studies.

Setting and Methods

The setting of the study was two communities, one rural and the other urban, in the Valley of Oaxaca in southern Mexico. Both communities were categorized as rural and urban, respectively, based on the census on the national census for Mexico in 2000.

The rural community is located about 23 km northwest of the city of Oaxaca. It is a subsistence agriculture community in which a major segment of the population speaks an indigenous language, Zapotec. The community has a health center that is regularly staffed by a public health nurse and a physician. Essential utilities such as sewage systems, water availability within each household, and water treatment, though improved in recent years, are generally limited.

The urban community is located on the slopes of the hills west of the city of Oaxaca. It is an irregular settlement on the edge of the city (colonias populares), although historically it was an independent community (Murphy and Stepick, 1991).

Most of its population works in the city of Oaxaca. Facilities for health care and sanitation are far from expectations of an urbanized center, but are in advance of those available in the rural community.

The sample included children 6.00 to 11.99 years of age. Chronological ages were calculated from date of measurement and birth dates taken from official school enrollment records. The rural sample comprised 329 children, 154 boys and 175 girls, and the urban sample included 318 children, 161 boys and 157 girls.

Anthropometric dimensions included weight, height, sitting height, four skeletal breadths, three limb circumferences and four skinfold thicknesses. Derived variables included the body mass index, estimated leg length, the sitting height to standing height ratio, the sum of four skinfolds, the ratio of trunk to extremity skinfold thicknesses, and estimated arm and calf muscle circumferences. Heath-Carter anthropometric somatotypes were also derived.

The physical fitness battery included a combination of performance-related tests, 35 yard (32.3 meter) dash, standing long jump, and health-related tests: sum of right and left grip strength, sit and reach, timed sit-ups, distance run.

Discussion

The subsequent discussion is set in the context of the specific questions and hypotheses of the study.

Question 1. What is the contribution of anthropometric dimensions to variation in the performance of rural and urban children on physical fitness tasks?

This question examined the contribution of age, height, and weight, and of other anthropometric indicators to variation in health- and performance-related physical fitness. Based on multiple regression analyses, the variance explained by age, height and weight ranged from 74% to 82% for strength, 38% to 57% for the dash, 31% to 40% for the jump, 6% to 26% for the distance run, 9% to 24% for timed sit-ups and 1% to 6% of the sit and reach. The addition of other anthropometric variables to the regression analyses increased the explained variance in fitness tests only marginally, 2% to 14%. The addition of other anthropometric dimensions to the analyses also altered the contributions of age, height and weight to the explained variance in the fitness tests, which suggests overlap or interactions among variables in their contributions to performance. The results are generally consistent with previous studies of children in Mexico (Malina and Buschang, 1985), Brazil (Rocha Ferreira et al., 1991), and Africa (Naidoo, 1999) children, although different analytical procedures were used.

Results of the analyses did not support the hypotheses:

a) It was hypothesized that estimated arm muscle circumference would explain a significant portion of the variation in static strength. The anthropometric dimensions that significantly contributed to static strength were variable across the four samples of children. The main significant contributor was the sum of skinfolds except in rural boys. Estimated arm muscle circumference contributed significantly only to the variation in the static strength of urban boys.

b) It was hypothesized that estimated calf muscle circumference and estimated leg length would explain a significant portion of the variance in the 35 yard dash. Age was the main significant contributor of variation in running speed across all the four samples of children, and calf muscle contributed significantly only to the variance in the dash in urban girls.

c) It was hypothesized that arm and calf muscle circumferences would explain a significant portion of the variance in the standing long jump. Estimated arm and calf muscle circumferences contributed significantly to the variation of explosive power only in urban boys. Age was the main contributor to the variance in the jump except in rural girls.

d) It was hypothesized that estimated leg length would explain a significant portion of the variation in the sit and reach. Estimated leg length did contribute significantly to the variation in the sit and reach in urban boys and rural girls, but none of the anthropometric dimensions consistently contributed to the explained variance in flexibility.

e) It was hypothesized that the two estimates of muscularity, arm and calf muscle circumferences, would explain a significant portion of the variance in timed sit-ups. Estimated arm muscle circumference contributed significantly to the variance in the abdominal muscular endurance of boys, whereas estimated calf muscle circumference did not contributed significantly to the explained variance in the four samples.

f) It was hypothesized that the sum of four skinfolds would explain a significant proportion of the variance in the distance run. The sum of skinfolds contributed to the variation in the distance run only in rural boys. The primary contributor to variation in the distance run in urban boys and girls was age.

There was substantial overlap in the estimated contributions of anthropometric characteristics to the six fitness tests. The hypotheses were thus not supported.

Question 2. Do the somatotypes of rural and urban children 6 to 11 years of age living under marginal health and nutritional conditions in Oaxaca, Mexico, differ?

It was hypothesized that rural and urban children 6-11 years of age do not significantly differ Heath-Carter anthropometric somatotypes. Results of the analysis generally supported the hypothesis. Urban boys were significantly more endomorphic than rural boys, whereas urban and rural girls did not differ in somatotype. This may reflect differences in lifestyle. Rural boys were more active than urban boys. Urban boys may also have had chronically excessive energy intake, but data are not available to document this. In contrast, urban and rural girls did not differ in fatness and activity (Peña Reyes, 2002). A previous study in Yucatan, Mexico, reported that children of both sexes from better living conditions were more endomorphic than those living in traditional, indigenous, subsistence agricultural communities (Murguia et al., 1990).

It is difficult to speak of environmental influences on the somatotype of children due to lack of data on children and, perhaps due to limitations of the Heath-Carter anthropometric protocol with children. Studies of adults indicate that extreme environmental circumstances, such as semi-starvation in males (Lasker, 1947), disordered eating in females (Malina, 1992; Malina et al., 2002), or resistance training in males (Tanner, 1952), are needed to significantly modify somatotype. Changes in somatotype associated with starvation and disordered eating can be reversed with an appropriate diet (Lasker, 1947, Malina, 1992), whereas gains in mesomorphy with resistance training return to pre-training values after the training program is stopped (Tanner, 1952).

A possible explanation may be the suggestion in the anthropological literature that females are generally more resistant to environmental influences than males (McCance, 1966; Stinson, 1985). In the present case, environmental influences related to the accumulation of subcutaneous fat may be relevant, i.e., chronically excessive energy intake and/or chronically low levels of physical activity. Most activities of girls in both the rural and urban communities revolve about food preparation and are of low to moderate intensity. On the other hand, rural boys engage in regular moderate to vigorous activity associated with household and agricultural chores, whereas urban boys do not have such responsibilities (Peña Reyes, 2002).

Question 3. What is the relationship between somatotype and the health- and performance-related physical fitness of rural and urban children?

It was hypothesized that after controlling for age and the other two somatotype components, endomorphy has a negative relationship to cardiovascular endurance (distance run); mesomorphy has a positive relationship to measures of strength, speed, power, and muscular endurance; and ectomorphy has a positive relationship to flexibility. The hypothesis was generally supported in the partial correlation analysis. Endomorphy was consistently and negatively correlated, whereas as mesomorphy and ectomorphy were variably correlated with the fitness items included in the study. The results are reasonably consistent with earlier correlational studies (Malina, 1975, 1992; Malina and Rarick, 1973; Slaughter et al., 1977, 1980). There also were no consistent rural-urban contrasts in the correlations.

Age and somatotype contributed proportionally more to the variation in static strength, dash, and standing long jump, with smaller contributions to three of the health-related fitness items, sit and reach, timed sit-ups, and distance run. Endomorphy generally had a negative contribution to fitness, while the contributions of mesomorphy and ectomorphy were variable. Previous studies of somatotype and fitness of children did not use multiple regression analyses; hence, comparisons are not possible. Results of the present study, however, suggest a primary role for age and a lesser role for somatotype in explaining the variance in the health- and performance-related fitness of children 6-11 years of age. The important role for age per se probably reflects the significant contributions of neuromuscular maturation and experience to age-related improvement in fitness tasks and perhaps the increase in body size. On the other hand, there are relatively small changes in somatotype during childhood (Carter and Heath, 1990; Malina and Bouchard, 1991), and in the present study there was no age effect in three of the four samples.

The results may also reflect sampling variation per se, the small body size of the children compared reference data for well-nourished children, and/or the relatively narrow range of somatotypes in the sample compared to other studies based on samples of European and North American children. The current samples were, on average, consistently below the 25th percentiles of the United States reference data and were consistently smaller than samples of urban school children in other areas of Mexico. The range of variation in somatotypes was relatively reduced compared to studies of well-nourished children. The reduced variation in somatotypes in the sample of rural and urban children, more specifically, the lack of extreme somatotypes, may influence the correlation and regression analyses, and in turn estimates of the contribution of somatotype to performance. In studies of well-nourished children, the influence of somatotype on performance is more apparent at the extremes of the distributions, e.g., extreme ectomorphs are deficient in muscle mass and strength (Malina and Rarick, 1973; Malina, 1975). The issue needs further consideration in other samples from developing countries.

Question 4. How do growth stunted and non-stunted children within each community compare in body proportions, relative muscularity, subcutaneous fatness, relative subcutaneous fat distribution, and physical fitness?

Growth stunting is defined as a height more than two standard deviations below the age- and sex-specific reference for well-nourished children. A z-score was calculated for each child relative to the Centers for Disease Control and Prevention (2000) growth charts for the United States. Children with height-for-age z-scores below –2.0 were classified as stunted. About 28% of the rural school children (49 boys, 43 girls) and 15% of the urban school children (25 boys, 21 girls), 6-11 years of age, were stunted. All other children were classified as non-stunted, 126 and 111 rural boys and girls, respectively, and 132 and 140 urban boys and girls, respectively.

Three hypotheses were generated from the literature on stunting:

a) Stunted and non-stunted children 6-11 years of age do not in differ relative muscularity and subcutaneous fatness, but do differ in relative body proportions related to sitting height and leg length. This hypothesis was partially supported. Stunted children had proportionally shorter legs than non-stunted children, i.e., the sitting height to standing height ratio was higher. However, stunted children, both rural and urban, were significantly smaller in all anthropometric dimensions and derived indicators compared to non-stunted children. In the context of the hypothesis, stunted children were less muscular and had less subcutaneous fat than non-stunted children. Bénéfice et al. (2001a, 2001b) reported similar observations in adolescent Senegalese girls who were stunted in early childhood. Undernourished adults and children, who were not necessarily stunted, are, on average, shorter and lighter, and have reduced muscle mass compared to well-nourished age and sex peers (Spurr, 1984; Bénéfice et al., 1996, 1999; Hoffman et al., 2000).

b) Non-stunted children 6-11 years of age perform better in tests of health- and performance-related physical fitness compared to stunted children. This hypothesis was also partially supported. Non-stunted children performed significantly better than stunted children only in absolute grip strength and in grip strength per unit estimated arm muscle circumference. These observations reflect the small body size and reduced muscle mass of stunted children also suggest changes in muscle mass associated with stunting. The reduced strength per unit arm muscle in stunted children may reflect, perhaps, qualitative changes in muscle tissue associated with undernutrition early in life. Otherwise, non-stunted children of both sexes did not perform significantly better than stunted children on the other fitness tests. Results were variable for the dash and standing long jump. Of interest, three indicators of health-related physical fitness, the sit and reach (flexibility), timed sit-ups (abdominal muscular strength and endurance), and distance run (cardiovascular endurance) did not differ significantly between stunted and non-stunted children in all of the comparisons.

c) Stunted children 6-11 years of age have a proportionally greater accumulation of subcutaneous fat on the trunk than on the extremities compared to non-stunted children. Subcutaneous fat distribution was estimated as the ratio of the sum of the two trunk skinfold thicknesses (subscapular + suprailiac) to the sum of the two extremity skinfold thicknesses (triceps + medial calf) (TER), and scores on two factors based on principal components analysis of the four skinfolds. Two components that contrasted trunk and extremity skinfolds were identified, i.e., had eigen values >1.0.

Although stunted children, both rural and urban, had a lower BMI and thinner skinfold thicknesses than non-stunted children, the TER was not significantly different, except among rural girls. Scores on the two principal components also did not differ significantly between stunted and non-stunted children. Hence, relative subcutaneous fat distribution did not differ between stunted and non-stunted children, and the hypothesis was rejected. The results contrast observations based on skinfolds in Senegalese adolescent girls (Bénéfice et al., 2001a, 2001b) and on the waist-hip ratio in Guatemalan young adults (Schroeder et al., 1999), who were stunted in growth during early childhood. The variability in results among studies may be related to several factors. The present study was based on a sample of largely prepubertal children 6-11 years of age. Only two 11 year old girls, one urban and one rural, were post-menarcheal. The proportionally greater accumulation of subcutaneous fat on the trunk in stunted children may occur during adolescence and into adulthood (Bénéfice et al., 2001a). Another factor may be the anthropometric indicators of relative subcutaneous fat distribution used in the three studies. The present study was based on four skinfold thicknesses, two on the trunk and two on the extremities. The study of Senegalese adolescents also used skinfolds, but the same skinfolds were not measured at all ages in the mixed-longitudinal sample (Bénéfice et al., 2001a, 2001b), and a different analytical strategy was used. The study of Guatemalan young adults was based on the waist-hip ratio (Schroeder et al., 1999). The validity of the waist-hip ratio as an indicator of relative subcutaneous fat distribution has not been established. It may be more of an indicator of primarily abdominal fatness in contrast to fatness on the upper (subscapular) and lateral (suprailiac) aspects of the trunk. Further, the waist-hip ratio is not the appropriate indicator of relative subcutaneous fat distribution in children and adolescents (Johnston, 1992; Sarria, 1992), and some of the subjects in the Guatemalan study were in fact late adolescents.

Conclusions

Based on the results of the present study, several conclusions are warranted. First, the anthropometric correlates of physical fitness do not differ between urban and rural children of both sexes 6-11 years of age. Age, height and weight account for a large proportion of the variance in the six fitness tasks. The addition of other dimensions to the regression analysis adds relatively little to the explained variance, but alters the estimated contributions of age, height and weight.

Second, rural and urban girls 6-11 years of age do not differ in somatotype, but urban boys are more endomorphic than rural boys, perhaps reflecting lifestyle differences associated with habitual physical activity and diet.

Third, the contribution of somatotype to the explained variance in the six fitness tasks does not differ between rural and urban children.

Fourth, stunted children 6-11 years of age are smaller in anthropometric dimensions, but have proportionally shorter legs than stunted children of the same age.

Fifth, non-stunted children are absolutely stronger and have greater strength per unit estimated arm muscle than stunted children.

Sixth, stunted and non-stunted children do not differ in tests of performance- and health-related fitness, with the exception of static strength.

Seventh, stunted and non-stunted children 6-11 years of age do not differ in relative subcutaneous fat distribution.

Recommendations

The following are recommended for further study:

First, expansion of the performance protocol to include the movement patterns associated with each task. For example, field observations suggest that many children appeared to perform the standing long jump with a seemingly immature movement pattern. Such an approach may afford insights into how marginal health and nutritional conditions influence the development of specific movement patterns. This suggestion also implies that future study should be extended into the preschool ages.

Second, validation of the Heath-Carter anthropometric somatotype protocol to other samples of children living under marginal health and nutritional conditions in different cultural groups, i.e., cross-culturally.

Third, results of studies of children in different cultural contexts suggest that age, height and weight are primary factors affecting performances on a variety of tasks among children 6-11 years of age. There is a need for further study of the contributions of age, height and weight, and other anthropometric characteristics to variation in performance, such as models incorporating interaction terms, or preliminary factor analysis to reduce the number of specific anthropometric.

Fourth, given the difference between stunted and non-stunted children in absolute strength and strength per unit estimated arm muscle mass, there is a need to consider changes in muscle tissue associated with growth stunting early in life. The use of non-invasive imaging techniques may provide some insights.

Fifth, changes in relative fat distribution associated with growth stunting need further study. If factors that regulate fat distribution are altered by chronic undernutrition and specifically growth stunting in early childhood, when do the changes in fat distribution occur? The use of non-invasive imaging techniques should provide valuable insights into the study of relative fat distribution associated with growth stunting.

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APPENDIX A

MICHIGAN STATE
UNIVERSITY

March 29, 2002

TO: Robert MALINA
128 IM Sports Circle

RE: **IRB # 98-118** CATEGORY: 2-8 EXPEDITED
RENEWAL APPROVAL DATE: March 29, 2002

TITLE: SECULAR CHANGE IN SIZE, STRENGTH AND MOTOR FITNESS IN THE VALLEY OF OAXACA, MEXICO

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete and I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the **UCRIHS APPROVED THIS PROJECT'S RENEWAL.**

RENEWALS: UCRIHS approval is valid for one calendar year, beginning with the approval date shown above. Projects continuing beyond one year must be renewed with the green renewal form. A maximum of four such expedited renewal are possible. Investigators wishing to continue a project beyond that time need to submit it again for complete review.
REVISIONS: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please use the green renewal form. To revise an approved protocol at any other time during the year, send your written request to the UCRIHS Chair, requesting revised approval and referencing the project's IRB# and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.
PROBLEMS/CHANGES: Should either of the following arise during the course of the work, notify UCRIHS promptly: 1) problems (unexpected side effects, complaints, etc.) involving human subjects or 2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of further assistance, please contact us at 517 355-2180 or via email: UCRIHS@pilot.msu.edu.

Sincerely,

Ashir Kumar, M.D.
UCRIHS Chair

AK: bd

cc: Swee Kheng Tan
128 IM Sports Circle

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APPENDIX B

Protocols for Anthropometry and Fitness Testing

(Adapted from Peña Reyes, 2002)

Anthropometry

1) Body mass (weight) was measured in kilograms using a portable scale and recorded to the nearest 100 grams. Weight was measured without shoes, but the children wore light clothing with all accessories removed (sweaters, sweatshirts, jackets, etc.).
2) Stature (standing height) was measured with the child standing erect posture, without shoes and with body weight evenly distributed between both feet. The heels were placed together and the arms were hanging relaxed at the sides. Height is the distance from the floor to the top of the head positioned in the Frankfort horizontal plane. Measurements were recorded to the nearest 0.1 centimeter (cm).
3) Sitting height corresponds to the distance from the table (sitting surface) to the highest point at the top of the head (vertex). The individual sat erect on the table with the knees hanging freely and the hands positioned on the thighs. Sitting height was measured to the nearest 0.1 cm.
4) Skeletal Breadths: Four skeletal breadths were measured to the nearest 0.1 cm.
   a) Biacromial breadth was measured as the distance between the left and right acromial processes of the scapulae with

application of firm pressure. The measurement was taken from the rear.

b) Bicristal breadth was measured as the distance between the most lateral points of iliac crests with application of firm pressure. The measurement was taken from the rear.

c) Bicondylar breadth was measured as the distance across the most medial and most lateral points of the femoral condyles. The individual was seated with the knee flexed at 90°.

d) Biepicondylar breadth was measured as the distance between the epicondyles of the humerus with the elbow flexed at 90°.

5) Limb Circumferences: Three limb circumferences were measured and recorded to the nearest 0.1 cm.

a) Relaxed arm circumference was measured at the level midway between the olecranon and acromial processes with the arm handing loosely at the side. The tape was placed in the horizontal position in contact with the skin but without compression of the underlying soft tissues.

b) Flexed arm circumference was taken at the same level as relaxed arm circumference, but the arm was flexed to a right angle at the elbow.

c) Calf circumference was measured as the maximum circumference of the calf with the subject in a standing position and body weight evenly distributed between both legs. The measuring tape was placed in a horizontal plane in contact with the skin but without compressing the soft tissues.

6) Skinfolds: Four skinfolds were measured to the nearest 0.5 mm using a Lange skinfold caliper (as was used in the earlier studies in Oaxaca). A double fold of skin and underlying soft tissue was raised with the thumb and index finger of the left hand about one cm above the specific site for each fold and the caliper was applied to the site.
   a) Triceps skinfold was measured on the back of the arm over the triceps muscle at the same level as relaxed arm circumference.
   b) Subscapular skinfold was measured on the back immediately beneath the inferior angle of the scapula following the natural cleavage line of the skin.
   c) Suprailiac skinfold was measured immediately above the iliac crest in the midaxillary line.
   d) Calf skinfold was measured on the medial aspects of the calf at the same level as calf circumference.

Physical Fitness

Physical fitness items included a combination of motor-and-health-related tasks. Four tasks were used in an earlier study in Santo Tomas – right and left grip strength, 35- yard dash, and standing long jump. Three additional health-related fitness tests were added.

1) Static grip strength of the right and left hand was measured with a Stoelting adjustable dynamometer. The subject held the dynamometer in the line with the forearm at the level of the thigh. Children were instructed to squeeze the dynamometer as vigorously as possible so as to exert maximum force. Three trials were administerd for each hand, the protocol alternating trials between hands. The best trial with each hand was retained for the analysis (Malina and Buschang, 1985).
2) The 35-yard dash (32.3 meters), an indicator of running speed, was measured as the time elapsed from the starting signal to crossing the finish line. The children ran on a flat concrete surface on the respective school grounds. The elapsed time was recorded to the 0.1 second. Two trials were administered, and the better of the two was retained for the analysis. A sufficient rest period between trials was included in the protocol (Malina and Buschang, 1985).
3) The standing long jump, a measure of power, was measured as the distance from the take-off line to the point where the heels touched the ground. The distance was measured to the nearest cm. Three trials were administered and the best of the three was retained for the analysis (Malina and Buschang, 1985).
4) The sit-and-reach, an indicator of lower back and upper thigh flexibility, was measured as follows. Subjects were permitted to

warm-up before the test by performing slow stretching movements. The subject removed his/her shoes and was seated at the test apparatus with the legs fully extended. The heels were approximately shoulder width apart and the feet were flat against the end board of the apparatus. The subjects were instructed to extend the arms forward as far as possible with the hands placed on top of each other. The subject leaned forward extending the finger tips, with palms facing downward, as far along the ruler as possible without jerking or bouncing. This effort pushed a sliding marker along the scale. The child stretched forward along the top of the box four times. On the fourth attempt, he/she held the stretch for at least one second. The score was the farthest point reached on the last stretch, which was recorded to the nearest centimeter (Safrit, 1995). Three trials were recorded and the best of the three was retained for the analysis.

5) Sit-ups, a measure of abdominal strength and endurance, were measured as follows. The subject was in a supine position with the knees bent at right angles and the feet approximately shoulder width apart. The hands were placed at the side of the head with the fingers over the ears and with the elbows pointed toward knees. The hands and elbows had to be maintained in this position for the entire duration of the test. The participant's ankles were held throughout the test by the appraiser to ensure that heels were in

constant contact with the mat. The subject was required to sit up, touch the knees with the elbows, and return to the starting positions (shoulder touching the mat). Each subject performed as many sit-ups as possible within 30 seconds. Subjects were permitted to pause for rest whenever necessary. Clear instructions were given. Bouncing was not allowed and the subject's buttocks had to remain in contact with the mat. In curling down after the sit up, the lower back had to be in contact with the mat before the upper back and shoulders touched. One trial was given.

6) The 12 minute run/walk was used as a measure of cardiovascular fitness. The subjects ran or walked for 12 minutes in an area at the urban school or the central plaza of the rural community, which was previously laid out with posts marking the limits and distance covered. The number of laps ran was counted by the research assistants. A warm-up and cool-down was provided done before and after the test, respectively. Participants ran in groups of about five. The distance ran was recorded to the nearest meter by the research assistants. After testing several first grade children, it was noted that younger children had a difficult time trying to complete the 12 minutes walk/run. Therefore, the test was modified for children in the younger ages, corresponding to children at the 1^{st} to 3^{rd}grades. The walk/run time was reduced from 12 to 8 minutes. Only one trial was administered and the

children were verbally encouraged throughout the test to complete the task.

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