An Examination of Late Childhood and Adolescent Growth from Three Communities of Differing Socio-economic Statuses

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Abstract

People in developing countries have nutritional deficiencies for many reasons. These reasons may be and often are complex and difficult to label. Still, they can be put into perspective by studies that compare various factors of human growth. Growth statistics of children from three different communities in Mali, collected by Dr. Katherine Dettwyler in1989 and by Dr. Barbara Cashion in 1976, were studied. The children's ages ranged between eight and sixteen. The data come from three types of locations: a rural village in southern Mali, a lower socio-economic status peri-urban community, and an upper socio-economic status urban community. Studies by Dettwyler in the peri-urban community, from 1981 to 1983, revealed delayed growth during the first three years of life. To determine if these growth deficits were permanent, data was collected from older children in 1989 in the peri-urban community. Growth data from these children were examined to see if their poor nutrition and growth recovered during late childhood and adolescence. These data were then compared to growth data collected by Cashion from the rural and upper socio-economic urban communities. Catch up growth occurred for the peri-urban and urban communities but it did not meet its full potential. The children from the rural community, however, showed very little recovery.

Introduction

Many nutritional problems occur throughout the world. A large percentage of these problems are caused by nutrient deficiencies, especially in protein, in the diets of the resident populations. Unfortunately, many of the undernourished are children. Many statistics from these countries report only mild to moderate malnutrition. The categories under which these children are placed may vary due to different standards of what is adequate nutrition. Also, some severely malnourished children may be hidden in the statistical means. There may be a few that are well-nourished, yet there are still children who are severely malnourished (Dettwyler,1986). Numerous studies have been undertaken to examine the reasons why some children are malnourished. Causes have been categorized under general socio-economic, genetic and cultural factors (Relethford, 1990). Many people believe that the main reason for these nutritional problems is that the people are poor; however in many cases the problem is the result of a combination of several other factors (Dettwyler, 1986). Comparing children living under different economic situations may help us understand the role of economic factors.

Understanding the effects that nutritional deprivation has on selected populations is basic to the comprehension of the main problem facing the developing countries, or those referred to as the Third World. Realizing the mechanics of how such problems start or are allowed to exist aids in the discovery of functional solutions. It is very difficult to change human behavior; moreover rapid change may only bring about resentment and resistance. World problems could be solved much more efficiently if several studies are made to examine the various aspects that may contribute to the problem. Understanding the cultural relations in a society is extremely important because it helps to explain how changes may be made.

One such study of nutritional deficiencies has been made through the studies of various growth patterns of children. Nutritional deprivation affects many aspects of human physiology. One of the most prominant symptoms is poor growth in childhood and a delayed adolescent growth spurt. Normal growth may be seen as a typical slow and steady pattern that follows a decrease in velocity after the rapid fetal growth period. It is interrupted with the onset of the adolescent growth spurt. Fetal growth is very rapid because cells need to divide and proliferate in order to synthesize crucial organs. The adolescent growth spurt in healthy, well-nourished children, begins on average between the ages of 10 to 12 in females and 13 to 15 in males (Tanner, 1962). Females usually enter adolescence about two years ahead of males. At this time growth reaches its peak height velocity. In some children, a slight increase in velocity, called the mid-childhood spurt, occurs between 6 and 8 years (Tanner, 1990). The adolescent growth pattern is important because this spurt of growth yields about about twenty percent of adult size (Hauspie, 1986). Additionally, there are many physiological changes ocurring with the adolescent growth spurt. For example, menarche,the first menstrual period, often occurs in females directly after their peak height velocity. Delayed growth may cause delayed changes in reproductive organs and secondary sex characters, body size and shape, the proportions of fat and muscle, and other important physiological functions (Tanner, 1990).

The tempo of growth appears to be one of the first things that is affected by poor nutrition. Growth deficiencies give the initial warning signs of malnutrition. Growth is affected because the body places higher priority on channeling food resources to fighting diseases and maintaining physical activity. The body tries to maintain a basal metabolism before expending energy on growth. A malnourished child will slow down in growth until his nutrition is improved (Tanner, 1990). Growth restrictions may also be attributed to disease and genetic factors. Disease and malnutrition reinforce one another. A sick child may not feel like eating and therefore not maintain the proper nutrients to fight off the disease. He then becomes more malnourished which lowers his resistance to diseases (Pryor and Crook, 1988).

Delayed growth may be detected by examining the growth patterns and determining if there are any unusual variations from the standard growth curves. The degree of malnutrition is determined by comparing the deficits in growth to various nutritional indices (Crook and Pryor, 1988). Malnutrition may be defined in terms of z-scores. The value of z is the value of the score on the standard normal distribution which is based on large samples of healthy, well-nourished children. Therefore, it tells how many standard deviations the original score is above or below the mean of the standard distribution (Kiess, 1989). Children between 2 and 3 standard deviations below the mean are moderately malnourished and children more than 3 standard deviations below the mean are considered severely malnourished (Dettwyler, 1985). Malnutrition may also be defined in terms of the National Center for Health Statistics (NCHS) percentiles. The NCHS standards contain percentile curves for assessing the physical growth of children. Children falling below the 3rd percentile are considered malnourished (Tanner, 1990).

The human body has a unique ability to grow rapidly after a period of restriction in order to catch up to its genetic potential. The body tries to maintain its genetic path and stay on course throughout its growth period. Yet, there are critical periods when growth ceases and catch up growth may never occur. Certain growth hormones become less sensitive as other hormones become more sensitive, and growth may stop on one part of the body in order to begin at another. Therefore there are time limitations to how much a child can recover. She/He may become stunted if growth has been restricted for a prolonged period of time (Tanner, 1990).

By examining growth data, such as height, weight, head circumference, and arm circumference, the nutritional status of individuals and populations can be compared. Height for age and weight for age statistics during adolescent growth are very important as they are affected greatly by the adolescent growth spurt. They make good indicators because there are many standards for comparisons, and the velocity of growth for height and weight is relatively rapid and constant. However, it is harder to interpret a weight chart than a height chart because weight represents the sum of many different tissues (Forbes, 1986). For example, one child may have little fat and a great deal of muscle, while another may have an abundance of fat. If a nutritional deprivation occurs, weight is lost. In order to maintain normal basal metabolism, an adequate diet is necessary; this prevents important tissues such as fat and muscle from being broken down to supply the body with the necessary nutrients (Dettwyler, 1985). Weight changes are important as an index of starvation or acute malnutrition, yet height is more direct when pointing out chronic growth disorders (Griffiths, 1981). Weight loss may also give an indication of prolonged malnutrition. Charts of a given weight for height can be misleading particularly in a population of tall linear people; however, they may help to establish the ratio of fat to muscle. Weight for height is not a good indicator of growth deficiencies for adolescents since weight for height is extremely variable during puberty.

Head circumference is important because growth of the brain case is related to the growth of the brain (Hauspie,1986). By the age of ten years, 96% of the adult size of the head length, breadth, and circumference is reached. During the adolescent growth spurt there is growth in the tissues of the scalp, and the skull bones increase by about 15% in thickness. It is doubted that the brain itself has an adolescent growth spurt (Tanner, 1990).

Arm circumference is another useful measurement to examine nutritional status. As muscle increases in children, the subcutaneous fat decreases correspondingly; therefore the arm circumference in healthy children, between the ages of 1 and 5, changes very little (Dettwyler, 1985). As the children grow, differences in arm circumference become obvious. Arm circumference can also distiguish acute malnutrition (Crook and Pryor, 1988).

Age is also important because it may give indications to growth spurts and when they occurred. There are many comparisons which may be made from growth data such as male versus female, variation at different ages and between children with different socio-economic status. Also, the statistical variations and extremes should be noted and examined. They could indicate a specific problem area.

Objective

The study I undertook during the 1990-1991 year was to analyze the growth patterns of children in Mali (West Africa). Dr. Katherine Dettwyler, of the Department of Anthropology at Texas A&M, has done extensive research in Mali, and has gathered a great deal of growth data, which was used in this research project. The research was a cross-sectional survey, meaning all the children were measured at the same time rather than measuring the same children more than once over an extended period of time (Relenthford, 1990).

The data were collected in a peri-urban community located across the Niger River from Mali's capital, Bamako. Magnambougou, which has a population of about 15,000, is the community studied (Dettwyler, 1987). Magnambougou has a low socio-economic status. The peri-urban sample included 1,235 children from birth to 18 years. The measurements were taken by Dr. Dettwyler and recorded by a field assistant. Height was measured using a portable length/height measuring board. The younger children were weighed using a hanging scale. This type of scale suspends a child by means of a sling that was attached to the scale. The scale is securely hung from a tree (Griffith, 1981). For the older children and adults, weight was measured using bathroom scales on a hard flat surface. Head and arm circumference were measured using a non-stretchable, plastic-coated tape measure. The equipment was calibrated several times a day.

The comparative data for urban children and rural children came from Dr. Barbara Cashion's 1988 dissertation, Creation of a Local Growth Standard Based Upon Well-Nourished Children and its Application to a Village Sample. The children labeled as "urban" consisted of wealthy upper class children from the capital city, Bamako. The rural sample included children primarily from a school in the village of Siraba, 300 kilometers south of Bamako. Cashion's sample only included children up to the ages of twelve or thirteen years.

Dettwyler's earlier research (1981-1983) suggested that the growth of children during their first three years was delayed. The purpose of analyzing the 1989 data was to determine if the children were able to recover their early childhood growth deficits during later childhood or during their adolescent spurt. I was able to use Cashion's data to compare the Magnambougou data to that of communities of differing socio-economic status.

Background Information

Dr. Katherine Dettwyler's 1985 dissertation showed poor nutrition of Malian infants due to infant feeding practices. Further studies indicated that the malnutrition continues through childhood. Dr. Dettwyler's dissertation explained many reasons for the causes of malnutrition. Children are expected to feed themselves and are not forced to eat. Children are expected to ask for food if they want it. Younger children are not capable of feeding themselves, and may not ask for food especially if they are sick and do not feel like eating. Also, the high protein foods are considered good food and should not be wasted on children who could not appreciate it.

Children eat a great deal of carbohydrate rich foods with little protein. The food needs to be eaten in great quantities in order to receive an adequate amount of protein and energy. However, children become full before they have eaten enough to supply their bodies with the right nutrients. As the children get older many of these dietary practices changed. Children's stomachs grew and they were able to eat enough to maintain the proper amount of nutrients. Older children are more capable of expressing when they are hungry and may get food on their own. They get more protein rich foods in their diet. Also, the children are more resistant to disease because they have survived through most of the severe childhood illnesses (Dettwyler, 1985). Most children who die of diseases such as measles, die before the age of five.

The younger children, after about 6 months, showed a pattern of delayed growth. The children grew at about the fifth percentile on the NCHS, (National Center for Health Statistics), standards. After the introduction of solid foods, many children are susceptible to bacteria and disease which can cause delayed growth and malnutrition. The children can also walk around which increases the susceptibility to disease. The older children's growth data gave indications if the children would catch up in growth after a period of delay. These older children became immune to many diseases, and their bodies were able to use that "excess energy", which would be used in fighting disease, to grow. The nutrients and calories that they do receive go to growth as well as maintaining their basal metabolism. Examining the children from ages 8 to 16 showed if the children resumed their normal growth pattern due to better nutrition. It also gave an indication if the children were able to completely catch up and reach their full growth potential.

Dr. Barbara Cashion's dissertation concluded that the Bamako sample had a delayed adolescent growth spurt which was caused by the limitation of food and essential nutrients. The children were diagnosed with chronic malnutrition. However, the village was considered much better off than most Malian villages. Rainfall was very high and varieties of fruit trees and crops were frequently grown.

Ethnographic Information

Mali, (fig. 1) which is located in west Africa, is one of the poorest nations in the world. Out of a list of 140 countries it places 137th. Fifty percent of children under the age of five die of malnutrition and disease (Cashion, 1988). The Malian economy has traditionally been based on subsistence agriculture. However, the capital city and other peri-urban communities primarily function on a cash economy. Most of the food is purchased at the daily market using cash earned by wage-labor (Dettwyler,1987).

The Malian diet consists of two staples, rice and millet. The meals are composed of a large quantity of millet or rice, is served with a sauce. The most common sauces are made from okra, peanut butter, tomatoes and onions, green leaves, or soumbala (fermented locust beans). Protein from fish or beef is pounded and also added to the sauce (Dettwyler,1987).

Magnambougou is considered a peri-urban community that is at a lower socio-economic level. The population is approximately15,000. People live in compounds without running water or electricity. The houses are made of mud bricks with corrugated iron roofs. The predominant ethnic group in Magnambougou is Bambara, however, there are many other ethnic groups represented. The people of Magnambougou are Moslem, but they do not strictly follow the Moslem teachings. The traditional religious beliefs and practices survive along with the Islamic beliefs. The people have had little or no formal education. They speak Bambara and most can neither read nor write French (Dettwyler, 1987). French is the official language of Mali which is spoken in schools and offices, although there are many people who do not speak French. Eighty percent of the population of Mali speaks Bambara. Bambara is the language of commerce that extends into nearby countries (Cashion, 1988).

Bamako, the capital city has a population of about 1 million. It has many conveniences of any large city. The family household in Bamako includes an extended family that lives in cement or mud homes around a central courtyard. Fresh fruit, meat, and vegetables are purchased daily at the market (Cashion ,1988).

The rural village of Siraba is another community examined. It has a population of about 2000 people. Siraba has many family compounds similar to those of Magnambougou. There is a river nearby that provides fish; moreover, agriculture is very important, and everyone farms to feed their families (Cashion, 1988).

Procedure

I investigated the Magnambougou growth data using various methods. The data was imported into SAS from Data Base 3 + file. SAS allows for a more sophisticated analysis of statistical problems. SAS allows the data to be sorted so that the information can be broken down. The original data consisted of measures of height, weight, head length, head breadth, arm circumference, wrist breadth, head circumference, and the number of permanent and deciduous teeth, on males and females from one to eighteen years of age. In order to look at late childhood and adolescent growth, the younger children were eliminated. I chose to examine the eight to sixteen year olds. The sample sizes of the seventeen and eighteen year olds were too small to give significant results. However, I chose to include the eight and nine year olds so I could compare this data set with another that included children up to the age of twelve only. The sample size information of males and females was examined first to see what data would be significant.

Statistical analyses were then made. I chose to investigate age, sex, height, weight, head circumference, and arm circumference. SAS gave means, standard deviations, maximum and minimum values, and z-scores. These results were then transferred to a graphics program, Quattro-pro, so that the information could be examined readily. Further analyses could be made using SAS. The analyses gave an indication of how the Malian children were growing as compared to Americans.

The data was compared with standards. One of the standards used was the National Center for Health Statistics (NCHS) standards. These standards contain percentile curves for assessing the physical growth of children. The curves are made on accurate measurements from large, nationally representative samples of children in the United States. The 50th percentile corresponds to the mean of the population. The limits of "normality" are included between the 5th and 95th percentiles. These are limits in which 5 in every 100 normal children lie below and above. Because a child is below the 5th percentile does not mean that he has a particular growth problem. However, if the trend shows an individual below the 3rd percentile, there is reason to suspect an abnormality in the growth pattern (Tanner, 1990).

The NCHS gives standards for height and weight (Hamill, 1979). Because it only gives standards for head circumference up to 36 months, another standard was used. This reference data was collected from a sample of 888 white U.S. children form birth to 18 years. It was called the Fels Longitudinal Study, and its participants were from families of a wide range of socio-economic status living in southwestern Ohio (Roche, 1987). Another study from the Manual of Physical Status and Performance in

Childhood gave arm circumference standards (Roche, 1983). Americans' growth rates are considered the standard because they are not affected for the most part by malnutrition and disease. These factors can inhibit growth. Other populations which do not have problems of malnutrition and disease grow very much like the American standards. Thus, the American standards are appropriate because they represent "normal" growth for most populations.

Results

Comparisons were made to contrast specific height, weight, head circumference and arm circumference values with the NCHS percentiles, and other U.S. standards. These comparisons showed where the Malian children fell against the U.S. standards at specific ages. Also, graphs were generated to show how two other Malian populations compared with the children of Magnambougou. The results included the information obtained from the graphs. Trends of growth could be detected by looking at the slopes. The data are presented in tables 1 to 8 and figures 2 through 21.

The first comparisons were of the heights and weights of the children. Comparisons were made for height-for-age using the NCHS standards. The Malian children, both males and females, fell between the fifth and fifitieth percentiles. For all ages, the females height-for-age, (fig. 3), is much closer to the fiftieth percentile than the males, (fig. 4). Between the ages of eight and eleven the males and females appear to be growing at the same rate as the American standards. Additionally, the females grow at a slower rate than the standards from ages 10 to 12. A slight dip occurs in the slope between these ages. However, the females then begin to accelerate and they eventually "catch up" to the fiftieth percentile mark by age sixteen.

The males appear to be heading in the same direction, however they do not accelerate in growth as fast as the females. Figure 4. also shows a decrease in the velocity of growth for the 10 and eleven year olds. The males overall, appear to be staying closer to the fifth percentile while the females approach the standard mean.

The height-for-age z-score graphs gives comparisons of the male versus female growth patterns as well as comparisons to the standard U.S. growth rates. The graphs show the standard distribution as being at the zero line. The Malian children are compared to that line. Most of the children fall below the zero z-score. This indicates that the children are below the standards for specific ages. However, by looking at the slopes of the graphs, the rates of growth can be compared. For example (Fig. 2), the height-for-age z-score graph, shows how the Malian childrens' heights compare with the American standards. Both males and females are shown. The graph indicates that the males and females are both below the normal distribution. The males are actually ahead of the females until age twelve, when the females accelerate at a much greater rate than the males. The females are initially way below the normal distribution, yet they "catch up" to the American standards by about age 16, while the males end up at a half a standard deviation below the mean.

The weight-for-age comparisons gives similar results to the height-for-age data. The males and females fall between the fifth and fiftieth percentiles. However, the females (fig. 5) catch up in weight while the males (fig. 6) actually have a decreasing slope for weight. The females from ages eight to twelve remain close to the fifth percentile. At age twelve, they accelerate in weight and by age sixteen, they catch up to the fiftieth percentile.

The males are actually doing better than the females at ages eight and nine, yet they are still very close to the fifth percentile. They drop even closer to the fifth percentile after age ten. The males do not appear to catch up in weight during adolescence. However the females show remarkable recovery after age twelve.

The weight-for-age z-score (fig. 7) graphs also show how the males and females compare to the American standards. The rates of growth are much easier to see because the standard rate is a straight line. After age twelve, the females accelerate at a rapid pace and appear to catch up to a z-score of "0", or the standard mean.

Upper arm circumference data was also plotted. The females (fig. 8) are again closer to the fiftieth percentile than the males. From ages 10 to 16, the females keep an alternating pattern of increasing and decreasing slopes. However, the overall trend is increasing, and by age sixteen the females have almost caught up to the fiftieth percentile.

The males (fig. 9) at eight and nine years are initially above the fifth percentile. However, they fall below the fifth percentile after age ten. They show no indication of recovery. The males do not show any catch up growth.

The mean arm circumference z-score graph (fig. 10) shows a slightly different result for the females. The females appear to have a catch up growth and look as if their rate of growth accelerates rather rapidly after age twelve. The males show a surprisingly dramatic decceleration of growth beginning from age eight. This z-score graph exemplifies a major difference in growth between males and females. The males appear to be getting skinnier, and the females are catching up to normal standards.

Head circumference was the last measurement examined. The males (fig. 11) follow the fifth percentile very closely. The slope increases slightly until age fourteen, when it takes a large drop and falls below the fifth percentile.

The females (fig. 12) head circumference values look much more promising. The Magnambougou females fall between the fifth and fiftieth percentiles. They appear to be reaching the American mean by age sixteen. The slope varies from one age to the next, but the general trend follows the NCHS standards. The females again look as if they are growing at a better rate than the males. The males show an opposite pattern to the females, and their growth is delayed.

The mean head circumference z-score graph (fig. 13) shows the same patterns to the comparisons made with the NCHS percentiles. The males grow at a faster rate than the Americans but fall after age fourteen. The females growth increases at a rapid pace. Also, the males' pattern is much more consistent than the females. The males do not appear to reach their full growth potential.

After examining the Magnambougou school children specifically, comparisons were then made with other children from different areas of Mali. The "rural" sample included the Siraba children, while the "urban" sample included Cashion's data from Bamako upper class children.

The height-for-age comparisons (figures 14 and 15) show that the urban population follows the Magnambougou slope closely. However, the wealthy urban population does not give any indication that it is growing at a faster rate than the Magnambougou children. The rural children show a different pattern. They follow the fifth percentile and even drop below it.

For height for age, the females (fig. 14) show a dip in the slope for the Bamako children. Overall, these females maintained a steady trend that was very close to the Magnambougou children. The Siraba females consistently follow the fifth percentile, and drop below it at ages 9 and 12.

The males (fig. 15) show a similar pattern to the females. The Bamako males remain close to the Magnambougou line and even fall below it at 9 and 12 years. The rural males follow the fifth percentile and drop below it by age eleven. The probability that the rural children will catch up appears to be very low.

The weight-for-age graphs (figures 16 and 17) show the same type of results as those seen for height-for-age. Yet the rural children are further below the fifth percentile. After age ten the urban children drop in weight. The Magnambougou children follow the urban children very well. The urban males are slightly ahead of the Magnambougou males. The trend suggests that the urban children might catch up as much as the Magnambougou children, while the rural children lag behind.

The females weight for age (fig. 16) gives indications of catch up growth for both the Bamako and Magnambougou children. The Bamako children overlap the Magnambougou line from ages 10 to 12 years. The village females gradually drop below the fifth percentile.

The males weight for age shows a trend for all three communities that follows the fifth percentile. The Bamako males are slightly above the Magnambougou males, who are ahead of the rural village males. The Siraba males fall below the fifth percentile.

For the arm circumference data, the rural females (fig. 18) fall right on the fifth percentile while the Magnambougou females are growing slightly ahead of the urban children.

The rural males (fig. 19) show a large drop in growth after age nine for the arm circumference data. The Magnambougou males and the urban males are also below the fifth percentile after age nine, yet they are much closer to the fifth percentile than the rural males. Arm circumference as well as head circumference shows a great deal of diversity.

The head circumference data (figures 20 and 21) gave varied results between males and females. Looking at the males (fig. 21), the Magnambougou and the urban children remain close to the fifth percentile. While the Magnambougou males accelerate slightly from age ten to age fourteen, the urban children slow down and fall directly along the fifth percentile. However, by age sixteen, the Magnambougou males return to the fifth percentile. The rural children remain behind again. They do show a dramatic drop at age ten where both males and females fall below the fifth percentile and recover by age eleven.

The Magnambougou and urban females (fig. 20) look much different from the males. They are much closer to the fiftieth percentile and give a good indication of catch up growth. The head circumference data show large variations between males and females, yet the urban children and

Magnambougou children still follow very similar paths while the rural children remain considerably behind.

When comparing the slopes of the Malian children to the American standards, the Malian children appear to be growing much faster than the Americans after age 12. The rates are slower between the ages of 8 and 12, which indicates there is some sort of growth restriction. After age 16, the sample size is rather small so the graph does not give a good indication of whether the males eventually "catch up" or if the females fall back again as the graph shows.

Discussion

The Malian children show the phenomenom of catch up growth, however, many do not appear to fully recover. The growth restrictions were probably relieved too late in order for the children to reach their full potential. However, after an earlier period of malnutrition, as indicated by Dettwyler's 1981-1983 research, the childrens' recovery was rather remarkable.

There were many differences between the males' and females' growth. The graphs showed that for the measurements, the females caught up to the American standards while the males either remained at a constant rate, or they actually slowed down in growth. Females are, even in

American standards, ahead of males at an earlier age. The female adolescent growth spurt, on average, begins two years before the males begin their spurt. The average age for the U.S. female adolescent growth spurt is between 10.5 and 13 years. From the height-for-age z-scores (fig. 2) the Magnambougou children's growth spurt appears to begin at age twelve for both males and females (Tanner 1962). The males had a growth spurt as well, but their growth did not equal the females in velocity. Because males' peak height velocity is usually reached two years later than females', the graph may not show the males' catch up growth. The sample sizes for the seventeen and eighteen year olds were too small to include accurate results. The results for the Magnambougou childrens' height-for-age look promising. The childrens' growth deficit is, for the most part, recovered.

The weight-for-age and other measurements showed less recovery, especially for the males. In a population of tall linear people, height may not seem to be affected as greatly as weight, head or arm circumference. However, these people may not have reached their full potential of growth. They may have had an undetected growth deficit. Other measurements are important to look at because they show different patterns that indicate slow growth. Weight-for-age measurements give indications of acute as well as chronic malnutrition, while height-for-age usually shows the long term effects of poor nutrition. The Malian children show patterns of poor growth using all measurements. The growth deficits occurred from restriction in early childhood such as poor nutrition and diseases.

The females' arm circumference comparisons were much better than the males. The females' upper arm circumference (fig. 10) increased its growth rate at an extreme pace while the males dropped to almost two standard deviations below the mean. This dramatic increase in growth was among the females probably due to the intense labor that young Malian females are required to do. They pound millet and carry extremely heavy loads of water and wood as well as many other difficult tasks. The men are required to do very little intensive labor. Also, after adolescence, women have a higher ratio of fat to muscle. Therefore, the women may have gained fat at their adolescent growth spurt.

The head circumference may have indicated longterm delayed growth because growth of the skull is related to growth of the brain (Dettwyler, 1985). By the age of ten years, 96% of the adult size of the head length, breadth, and circumference is reached. Yet growth spurts may be seen at the time of adolescence. The Malian children at adolescence show the females increasing in velocity while the males grow at a slower pace than the Americans.

When looking at the mean z-scores, the Malian children do not appear to fall any lower than 2 standard deviations below the mean for height, weight, arm and head circumference. This indicates moderate malnutrion.

Also, looking at the NCHS percentile comparisons of height, weight, arm and head circumference, the children fall between the fifth and fiftieth percentiles. These results show that they are "adequately" nourished. In this case, the numerical indicators of malnutrition do not give a complete picture when examining an entire population. When measuring individuals, it is easy to determine a specific malnourished child from the standards. However, a large population masks the severe malnourished children. Therefore, if the population falls a great deal under the mean, delayed growth and malnutrition may be suspected.

By examining the adolescents, I was able to identify catch-up growth among the Malian children, indicating recover from the delayed growth spurt. The data indicate that there was a definite increase in the velocity of growth. Thus, the children were on the road to catching up, but did not catch up substantially until adolescence. However, they did not appear to fully recuperate. Also, the females were growing at a much faster pace than the males. Not only did females mature earlier, a female buffering may have occured. In many populations, females seem to be affected less by environmental stress (Tanner, 1990, p171). The males actually slow down in growth for weight, arm circumference, and head circumference. They did show catch up growth in height. The females' growth accelerates greatly after age twelve, and they catch up very close to the American standards.

The data indicates that the change in diet and increased resistance to disease which occurs during late childhood and during adolescence allow the children to return to their normal path of growth. This was quite clear looking at the females. Data from seventeen and eighteen year olds may have shown possible catch up growth for the males because of their delayed maturity.

The comparisons made with Dr. Barbara Cashion's data showed the effect of socio-economic status the nutrition of the area. In most populations throughout the world, wealthier children show improved growth patterns. Also, rural populations show more delayed growth than urban populations. This is due to the fact that cities usually have better availability for health care and food. However, the availability for these things may not mean that the people are getting them, or that they can afford them. Also, if culture has any bearing on the beliefs of feeding practices and health care, those modern technologies may not be desired.

Comparing the Magnambougou children, from a peri-urban community, with upper class children from Bamako indicated that wealth had no measurable impact on growth. The Bamako children follow the Magnambougou children very closely. The slopes overlap quite frequently. For example, looking at the females' weight-for-age, (fig. 16) the Magnambougou females were initially behind the Bamako females, yet by age ten, the Magnambougou children are following the urban children exactly. The males show a similar pattern. Because these children fall between the fifth and fiftieth percentiles there is a strong probability that their nutrition was comparably poor. However, looking at the rural data from Mali, the rural children are doing much worse than Magnambougou or Bamako. These children usually fall on the fifth percentile and frequently below it. Cashion pointed out that the village children did not have enough of all essential nutrients. Growth was stunted by low calories and a strenuous work load, especially in females (Cashion,1988). The economic differences between the village community and the other two communities examined were great enough to make an impact on the amount of food in the area. This lack of food delayed the growth of the children. Whereas the Magnambougou children and the children from Bamako had the same availability of food, its distribution to the children was limited by cultural reasons. Diseases were prevelant in all three communities. Yet, even with a greater availability of health care in Bamako, the urban and peri-urban children had very similar patterns of growth.

The human body has the unique ability to canalize its growth according to its genetic prescription. Whether it reaches its genetic potential is difficult to assess, and reaching the potential may be delayed by many environmental stresses. Mali, being one of the poorest countries in the world, has many stresses that would inhibit the growth of children. If children can survive these initial stresses, they have the ability to get back on track and continue growing, often at a much faster rate than before. Because of the longterm malnutrition during these children's early years, catch up growth will never fully occur. This is due to the desensitization of many important growth hormones. The Magnambougou data exemplified this catch up growth, especially in females.

Many feel that the modern technologies of an urban environment allow better availablity of health care and food. From these results, the Magnambougou data, from children of a lower socio-economic status, almost equalled the Bamako data. Therefore, these technologies did not seem to be distributed nor accepted by the population. Eating habits are very difficult to change, especially when people do not know that nutritious food contributes to health and growth. Older children did have access to those foods, which improved their nutrition and, therefore, their growth. Where there was a lack of food entirely, malnutrition is seen, such as in Siraba. In Mali, the differences in socio-economic statuses between the upper class urban children and the lower class children is not reflected in better growth for the upper class children.

Conclusion

The 1989 data revealed that catch-up growth did occur for the Magnambougou children after a period of prolonged malnutrition. Comparisons with Barbara Cashion's data indicated that the upper socio-economic children grew at similar rates to the lower socio-economic Magnambougou children. However, the rural children from Siraba grew at a much slower rate than the other two communities. Growth studies such as these help determine the degree of malnutrition, and enable researchers to investigate possible solutions.

APPENDIX

FIGURE 1. Mali

Fig.2 Mean Height-for-Age Z-Scores

Magnambougou School

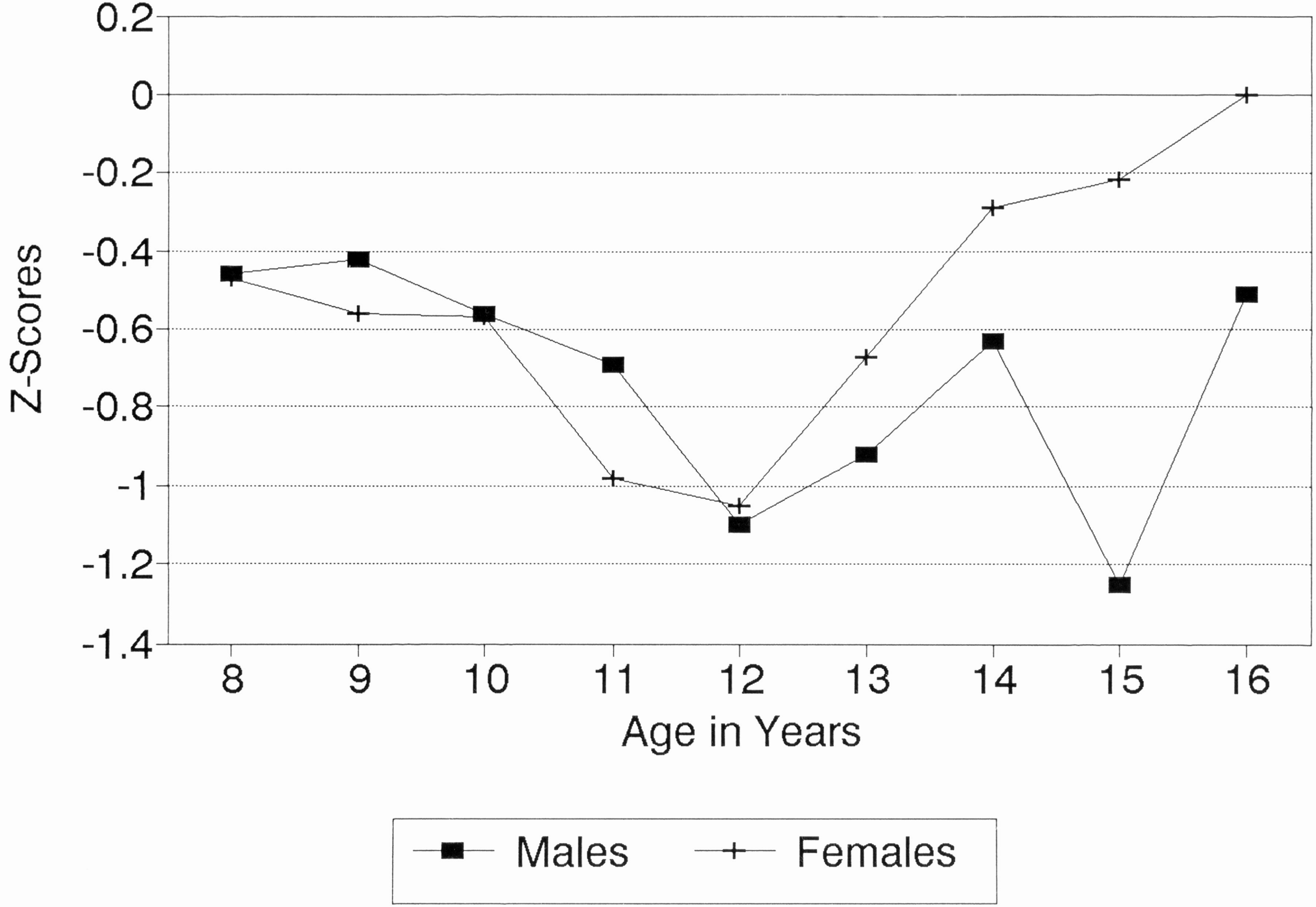


Fig.3 Comparison of Height for Age

Females

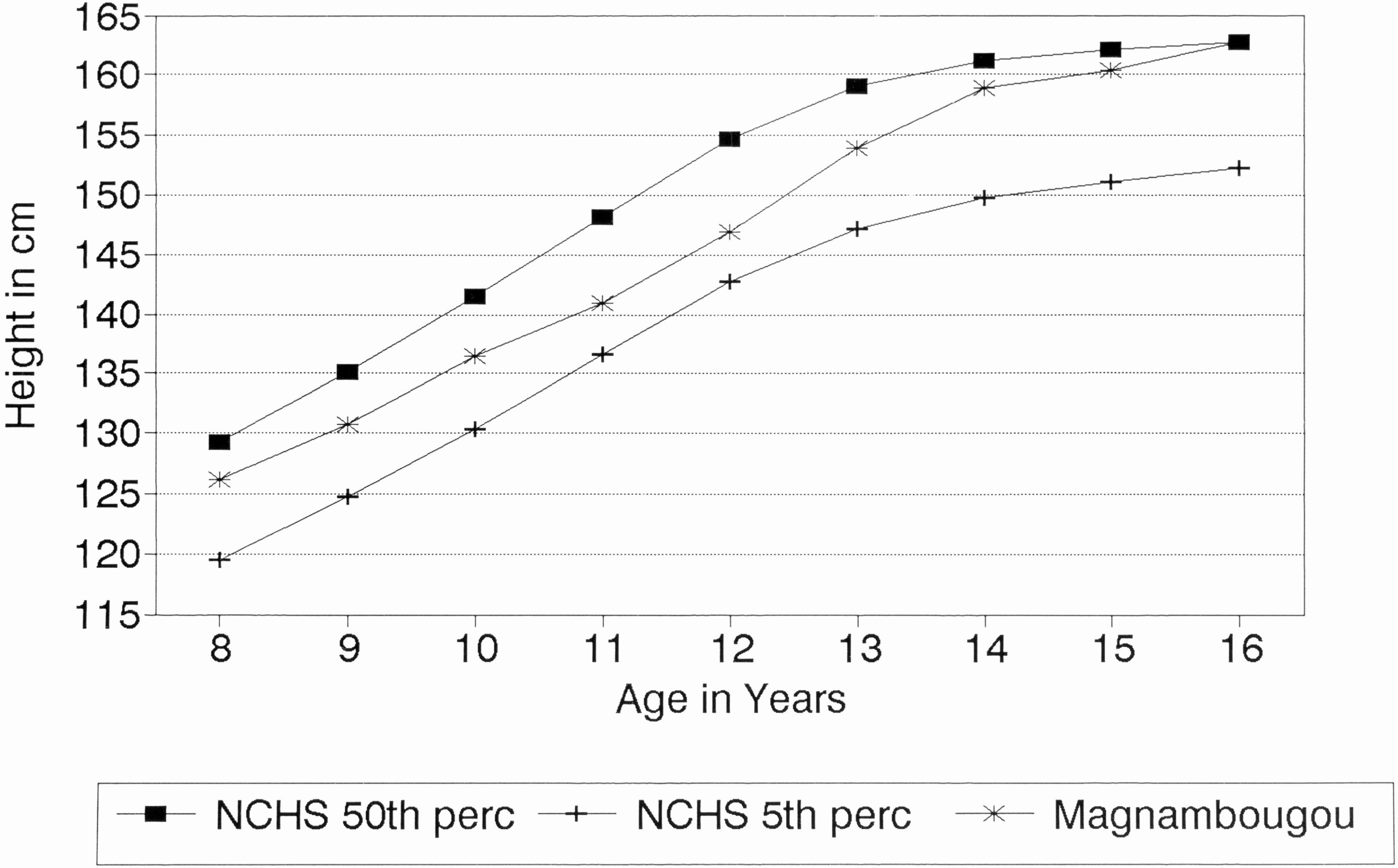


Fig.4 Comparison of Height for Age

Males

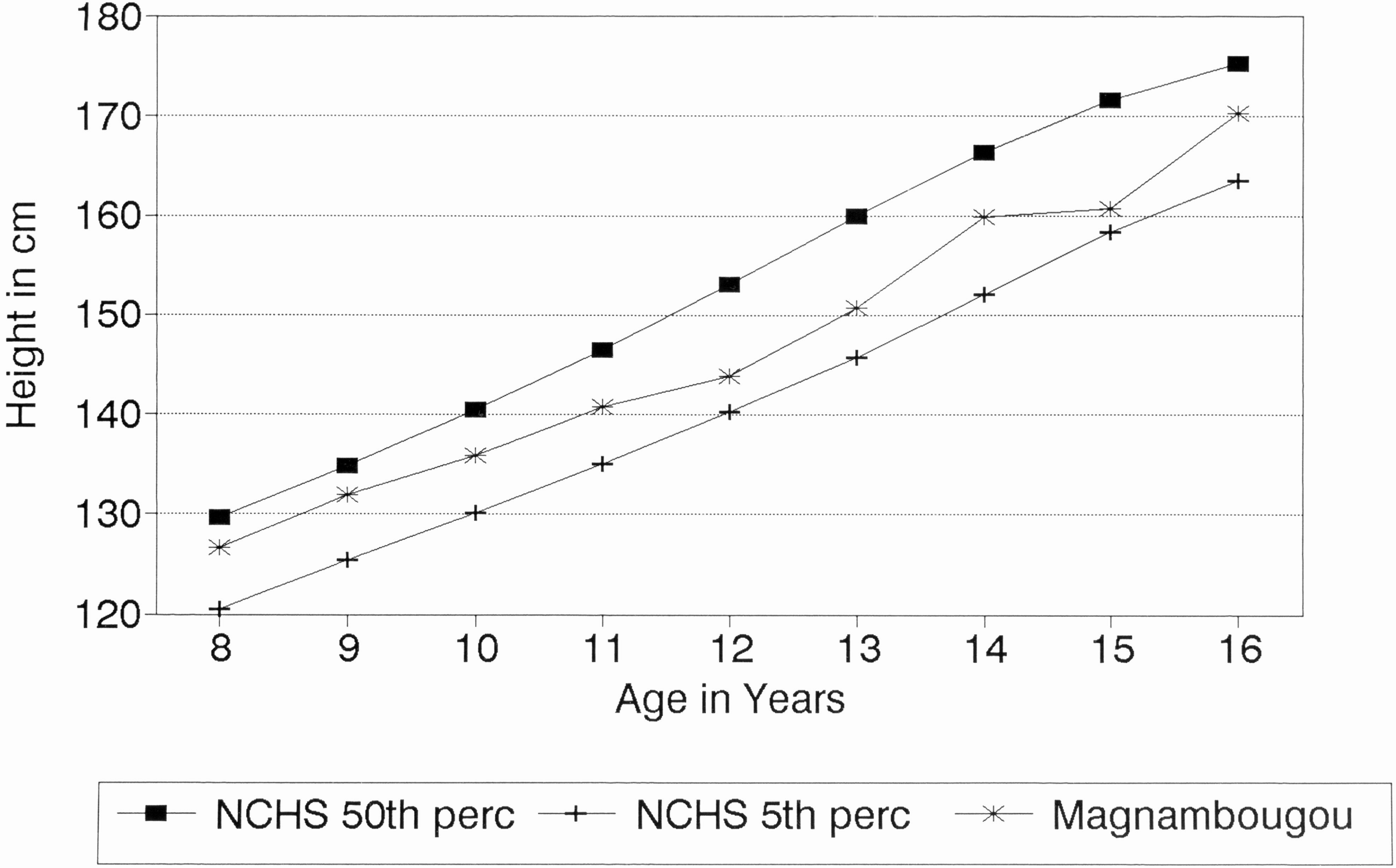


Fig.5 Weight for Age Comparison

Females

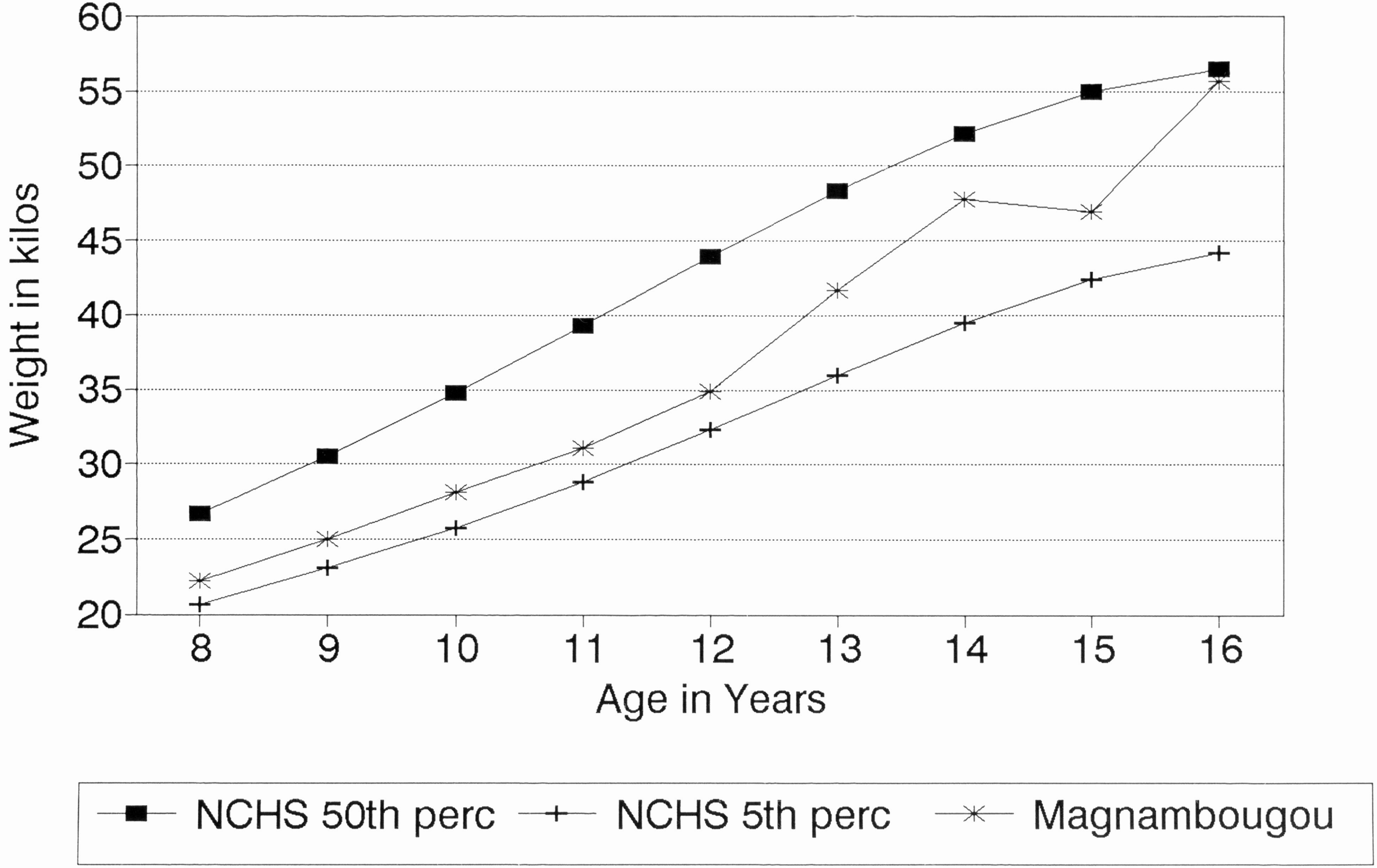


Fig.6 Weight for Age Comparison

Males

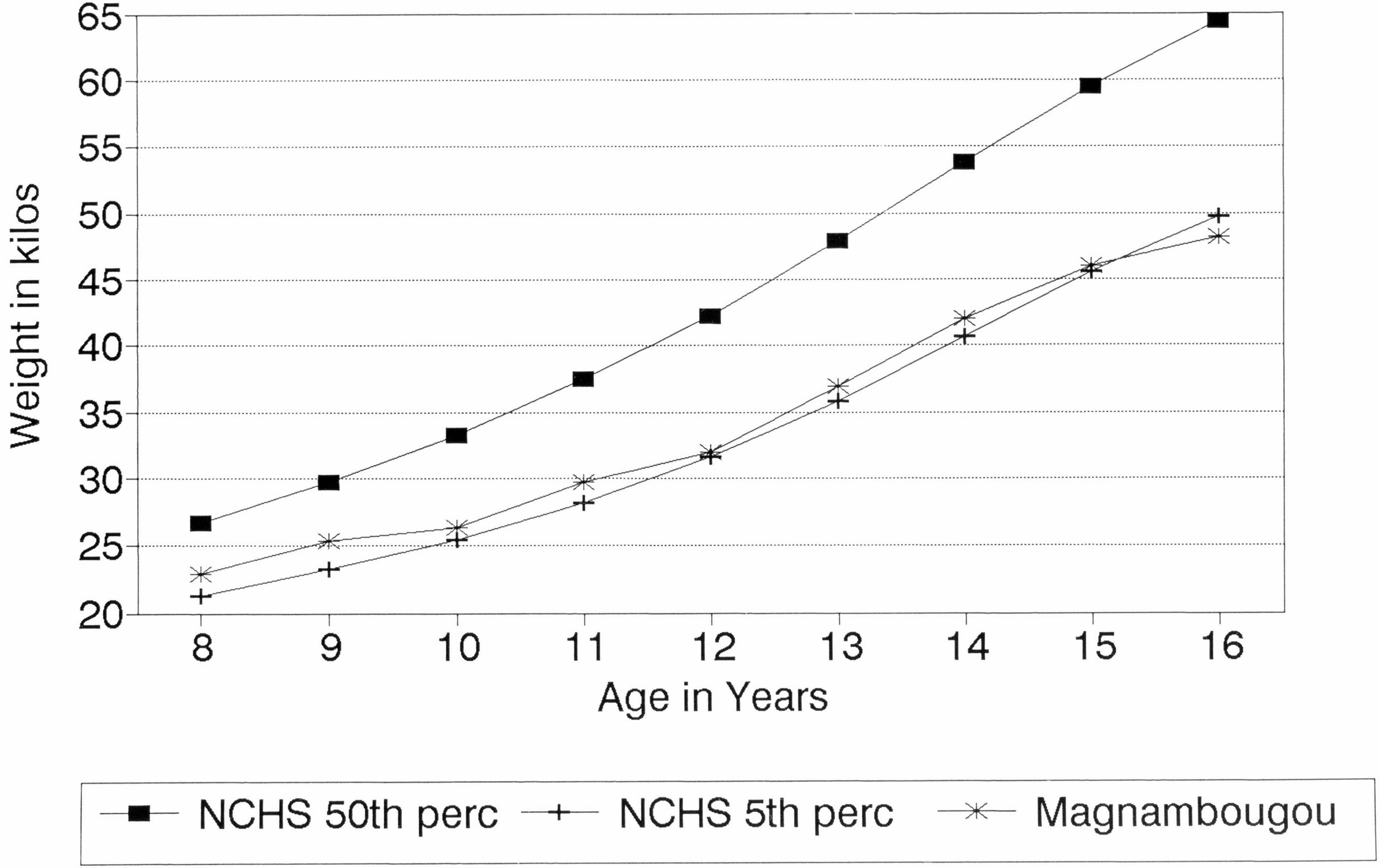


Fig.7 Mean Weight-for-Age Z-Scores

Magnambougou School

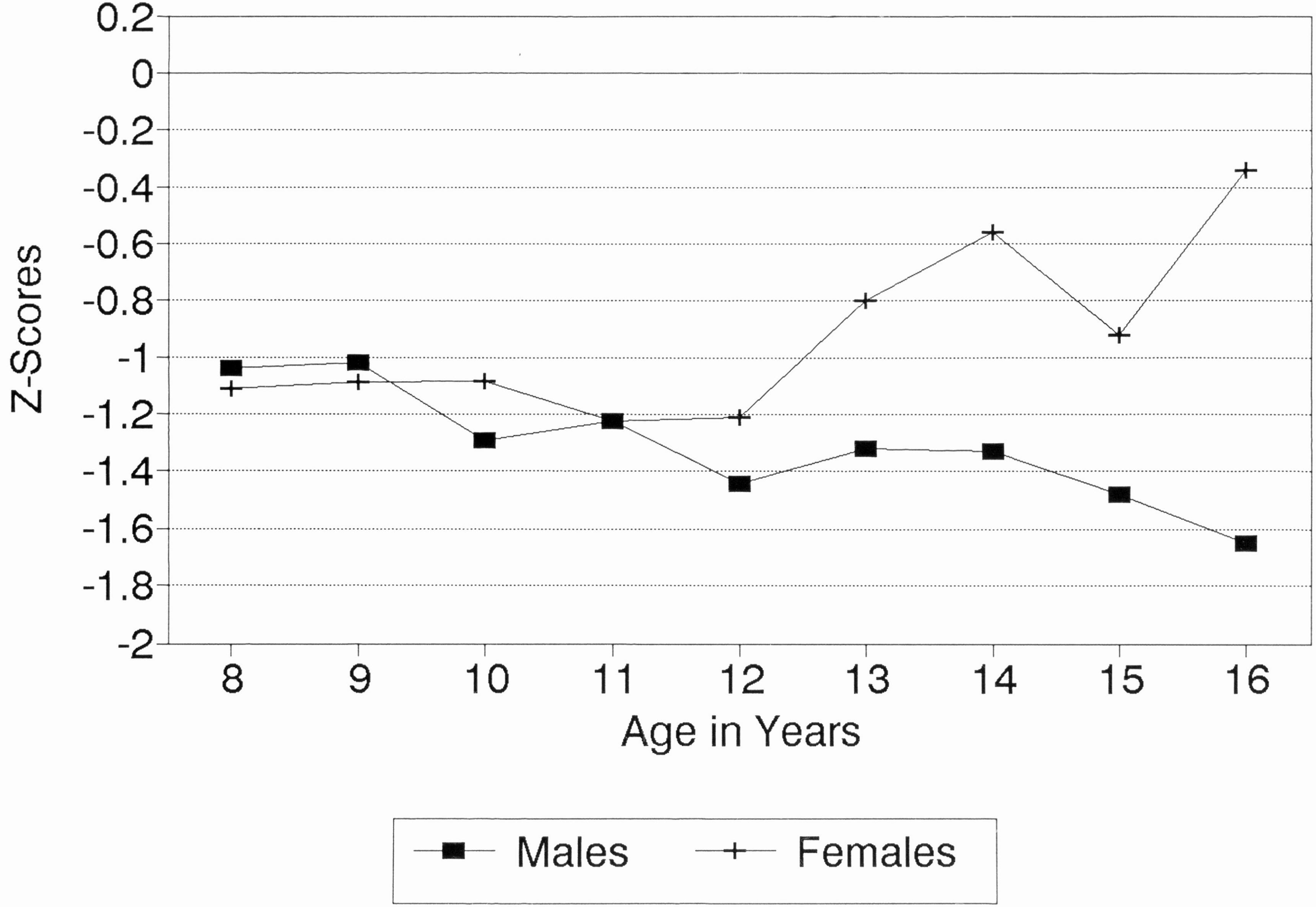


Fig.8 Mean Arm Circumference

Females

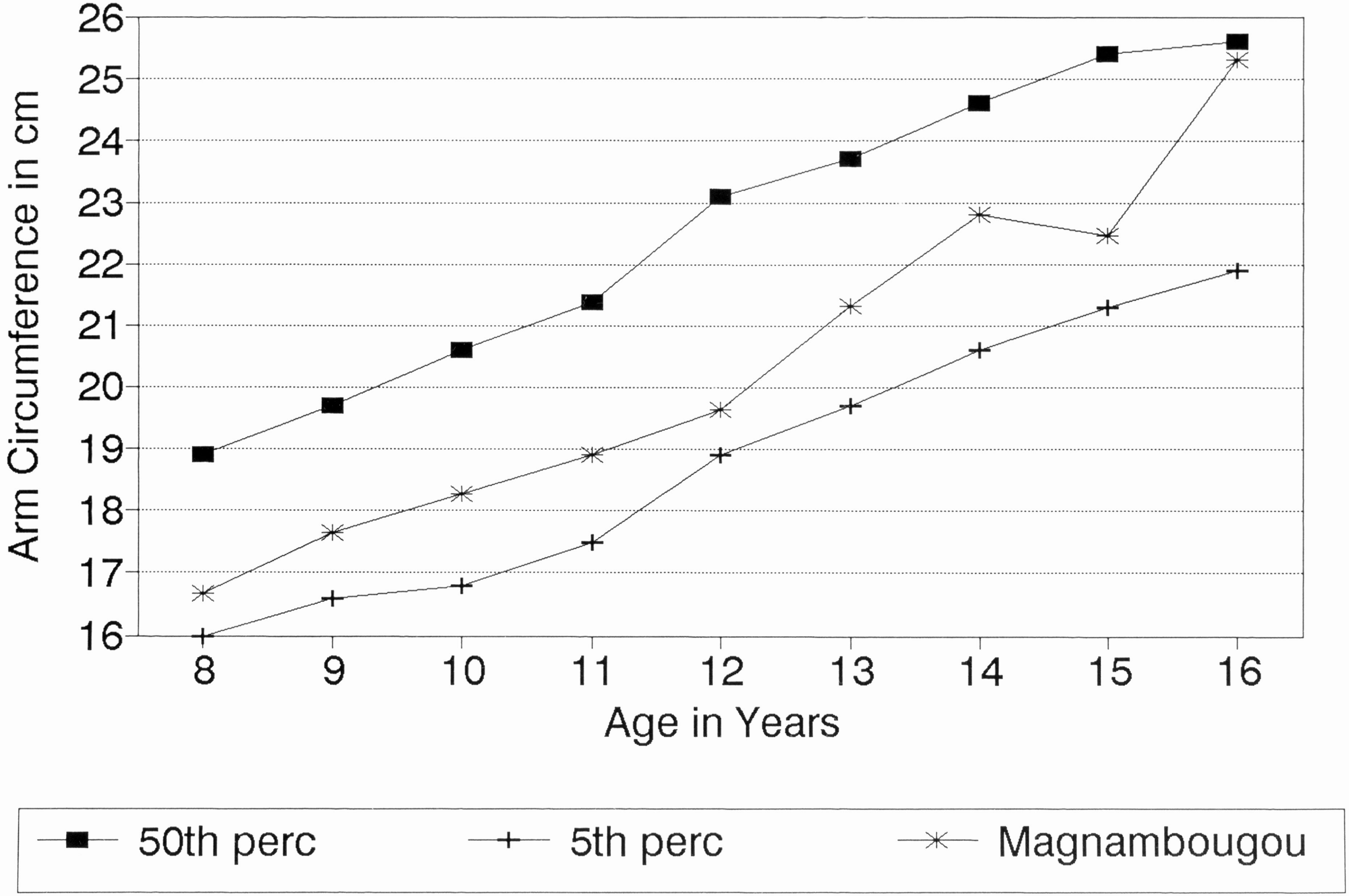
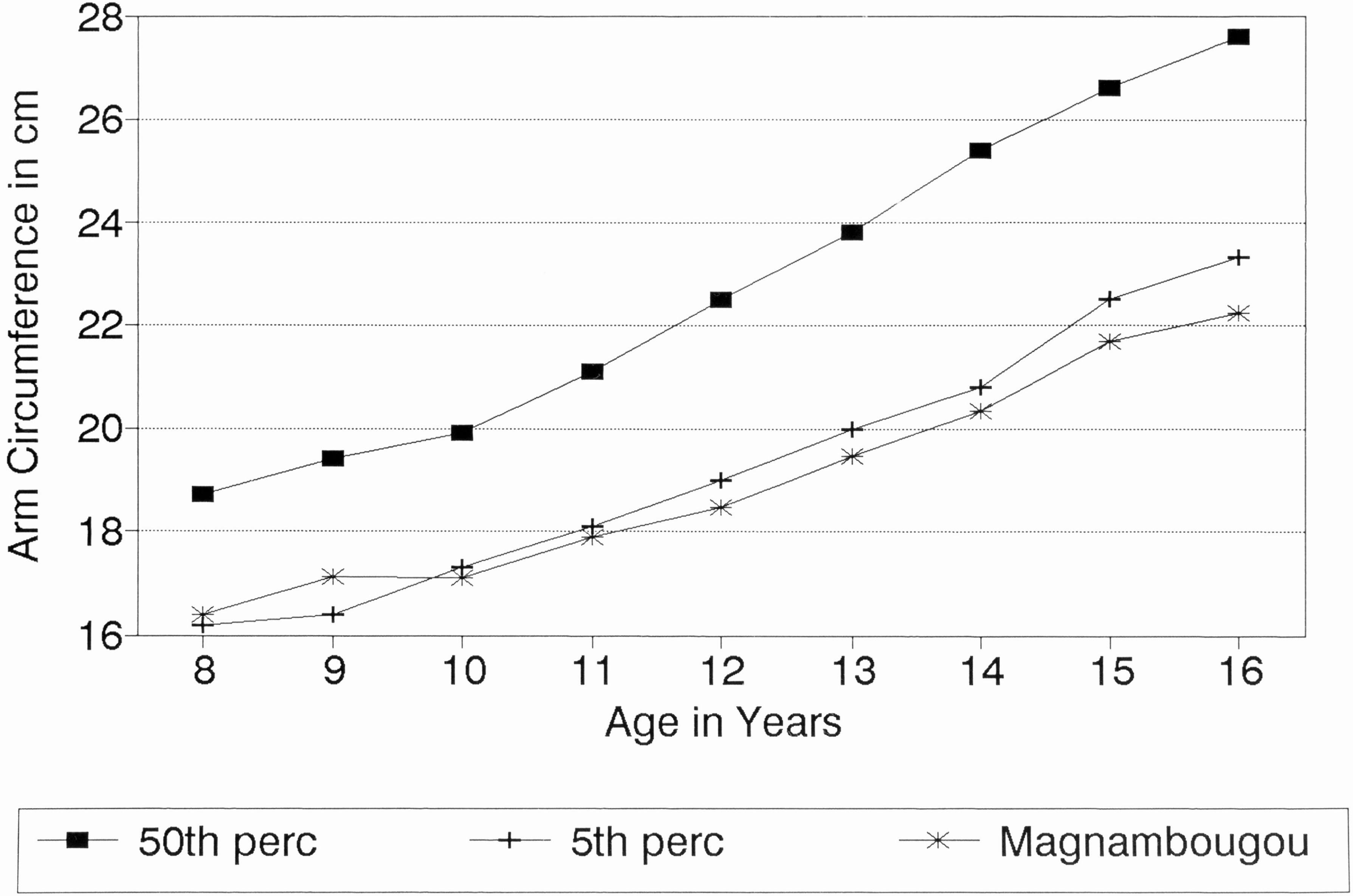


Fig.9 Mean Arm Circumference

Males



Mean Arm Circumference Z-Scores

Fig.10 Magnambougou School

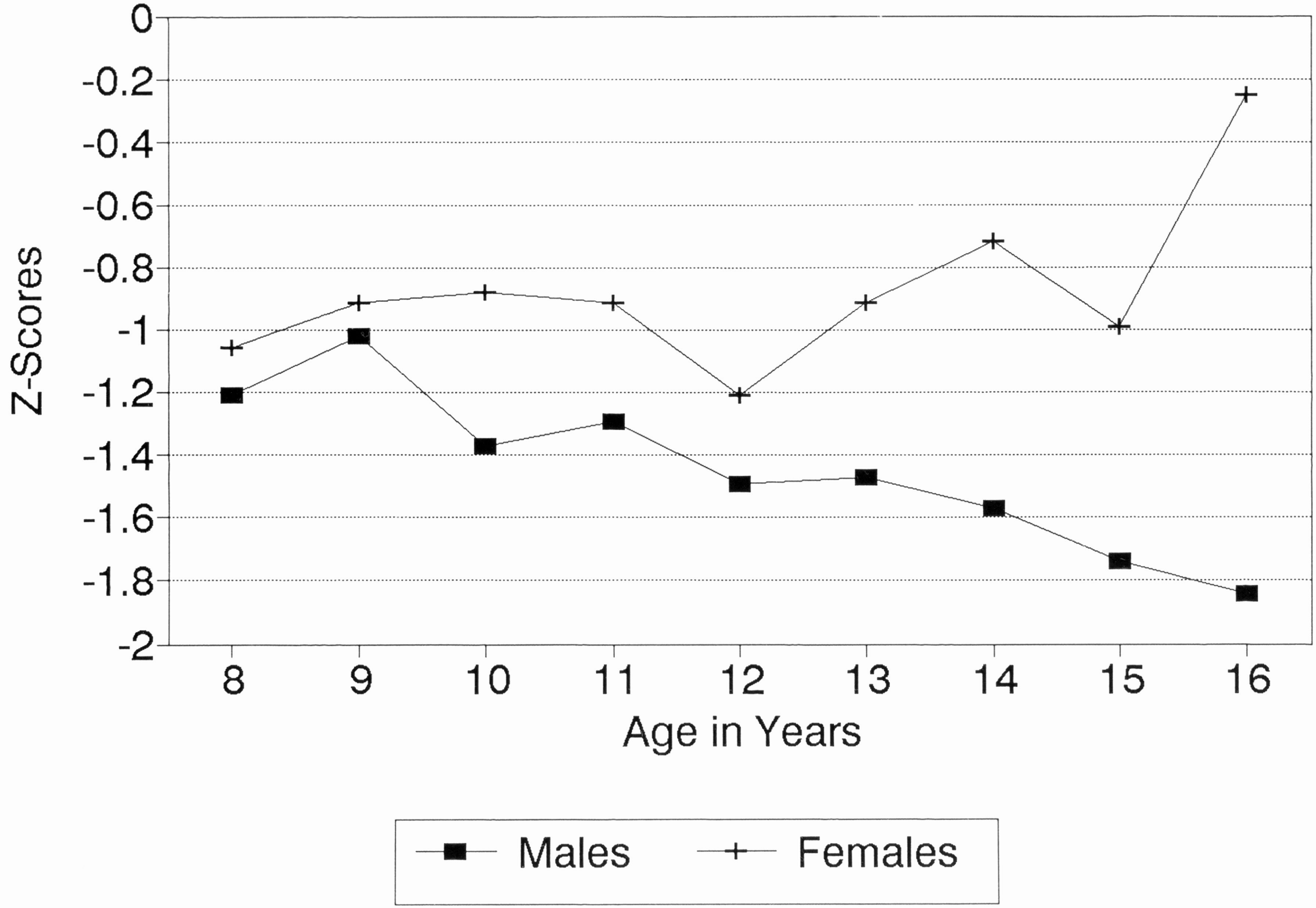


Fig.11 Mean Head Circumference

Males

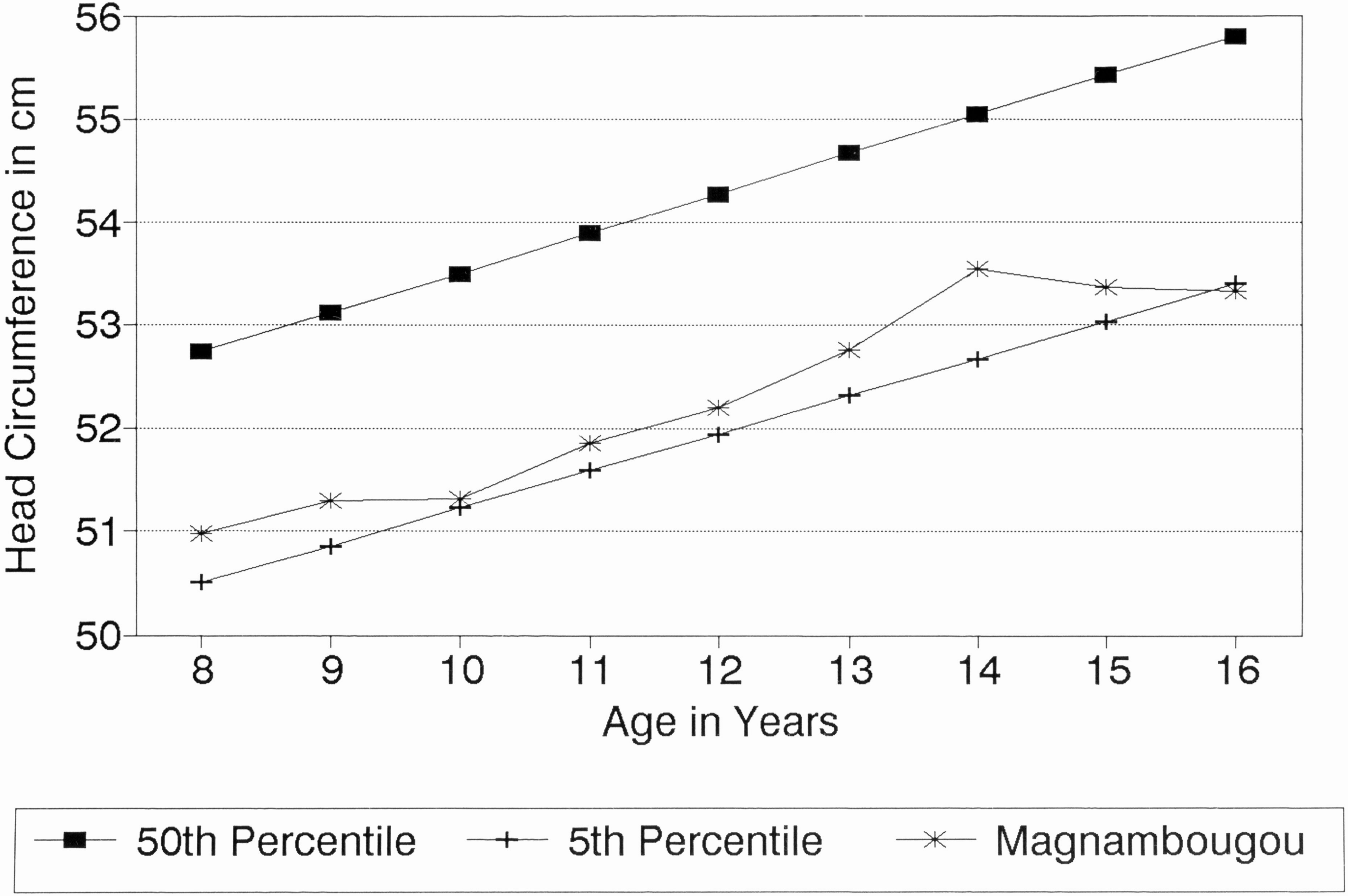
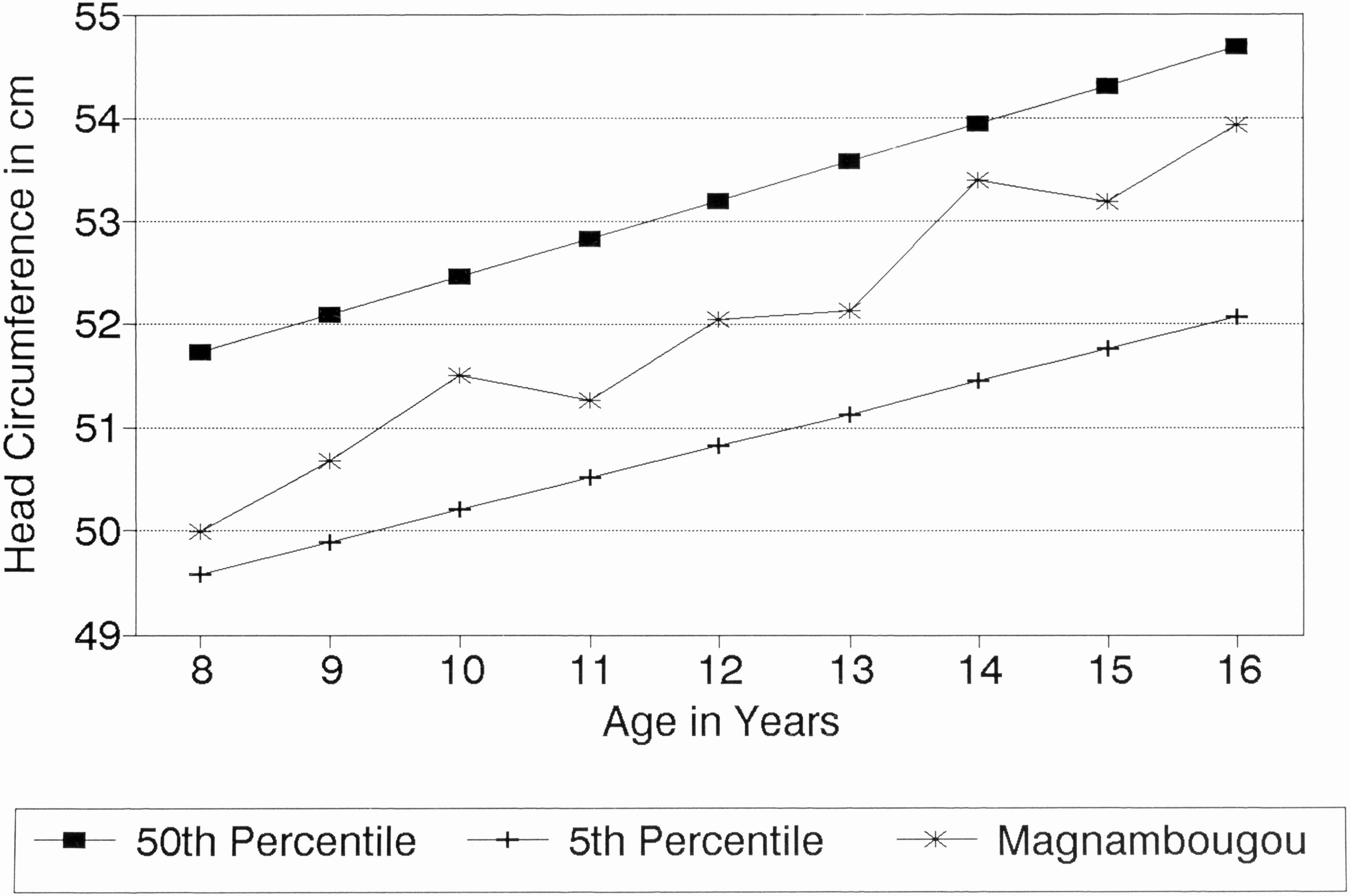


Fig.12 Mean Head Circumference

Females



Mean Head Circumference Z-Scores

Fig.13 Magnambougou School

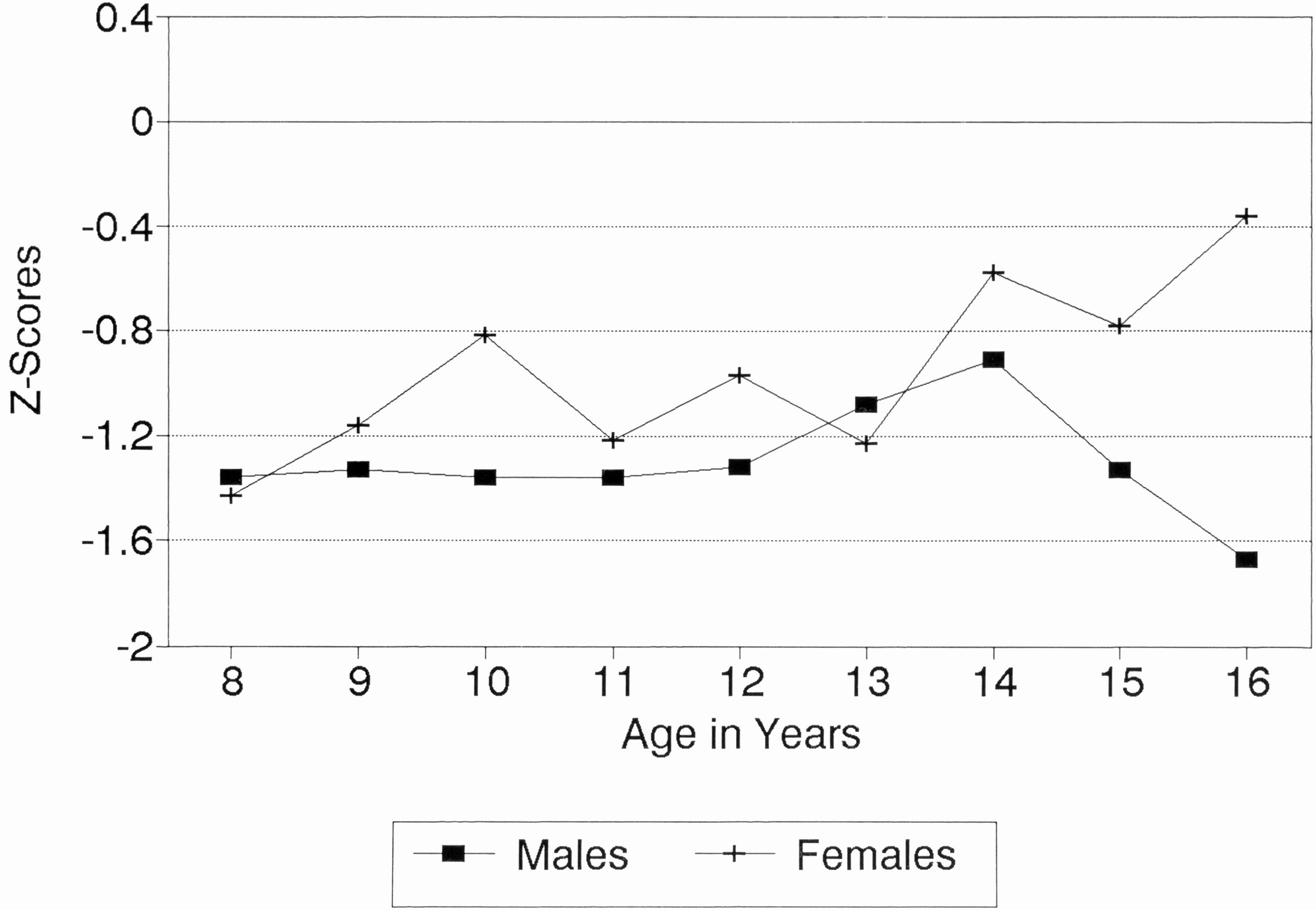


Fig.14 Height for Age Comparison

Females

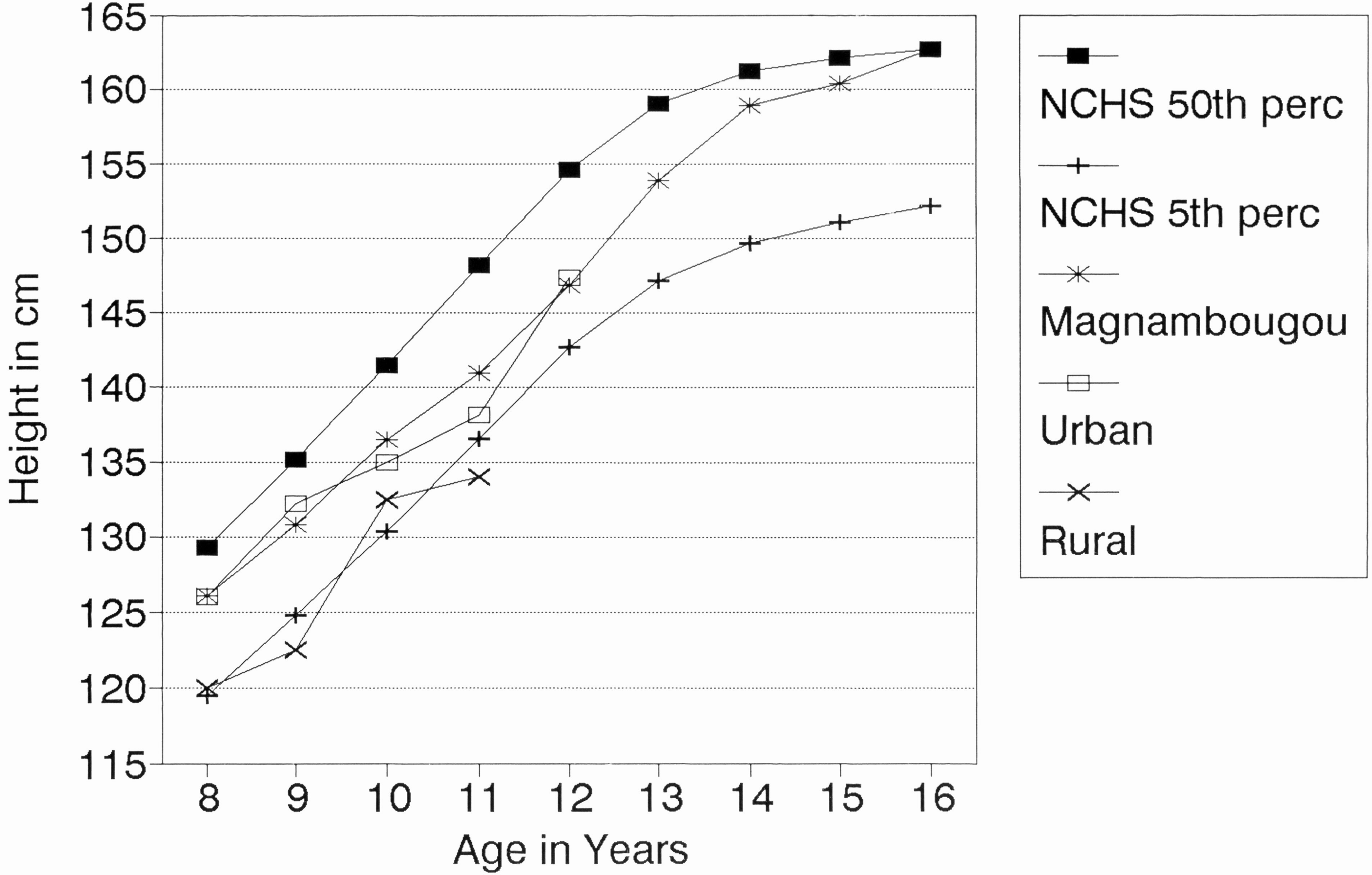


Fig.14 Height for Age Comparison

Females

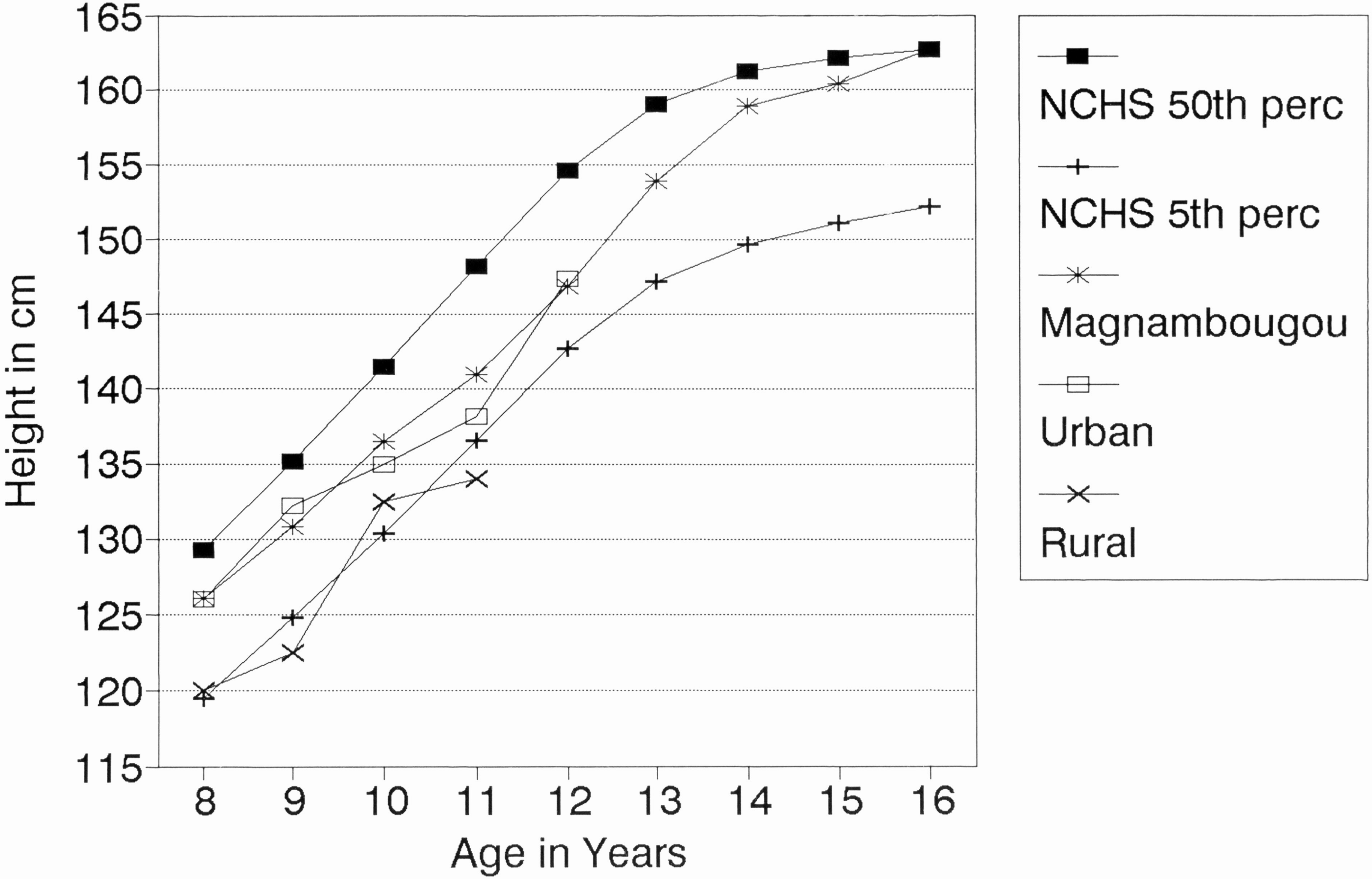


Fig.15 Height for Age Comparison
Males

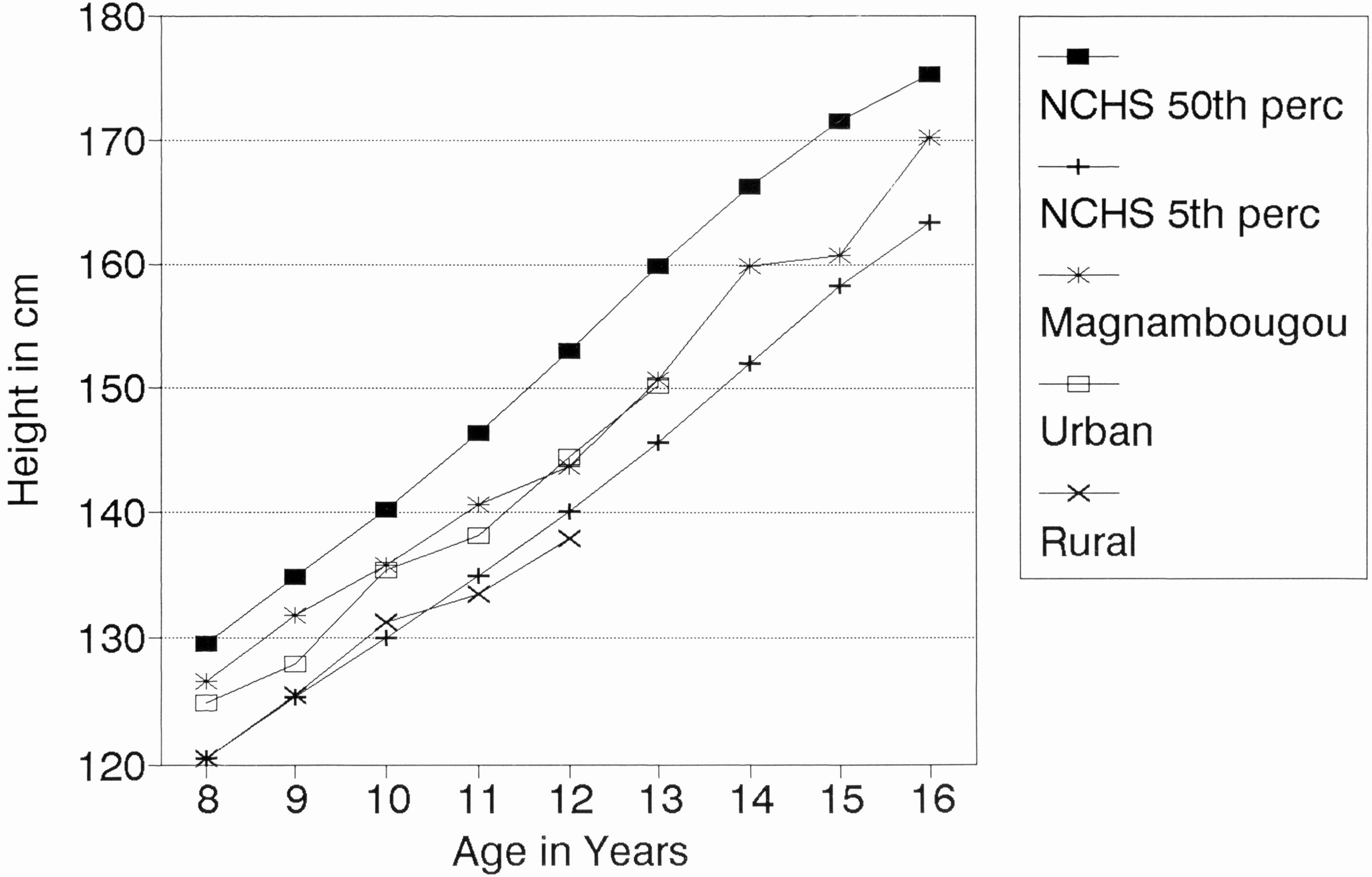


Fig.16 Weight for Age Comparison

Females

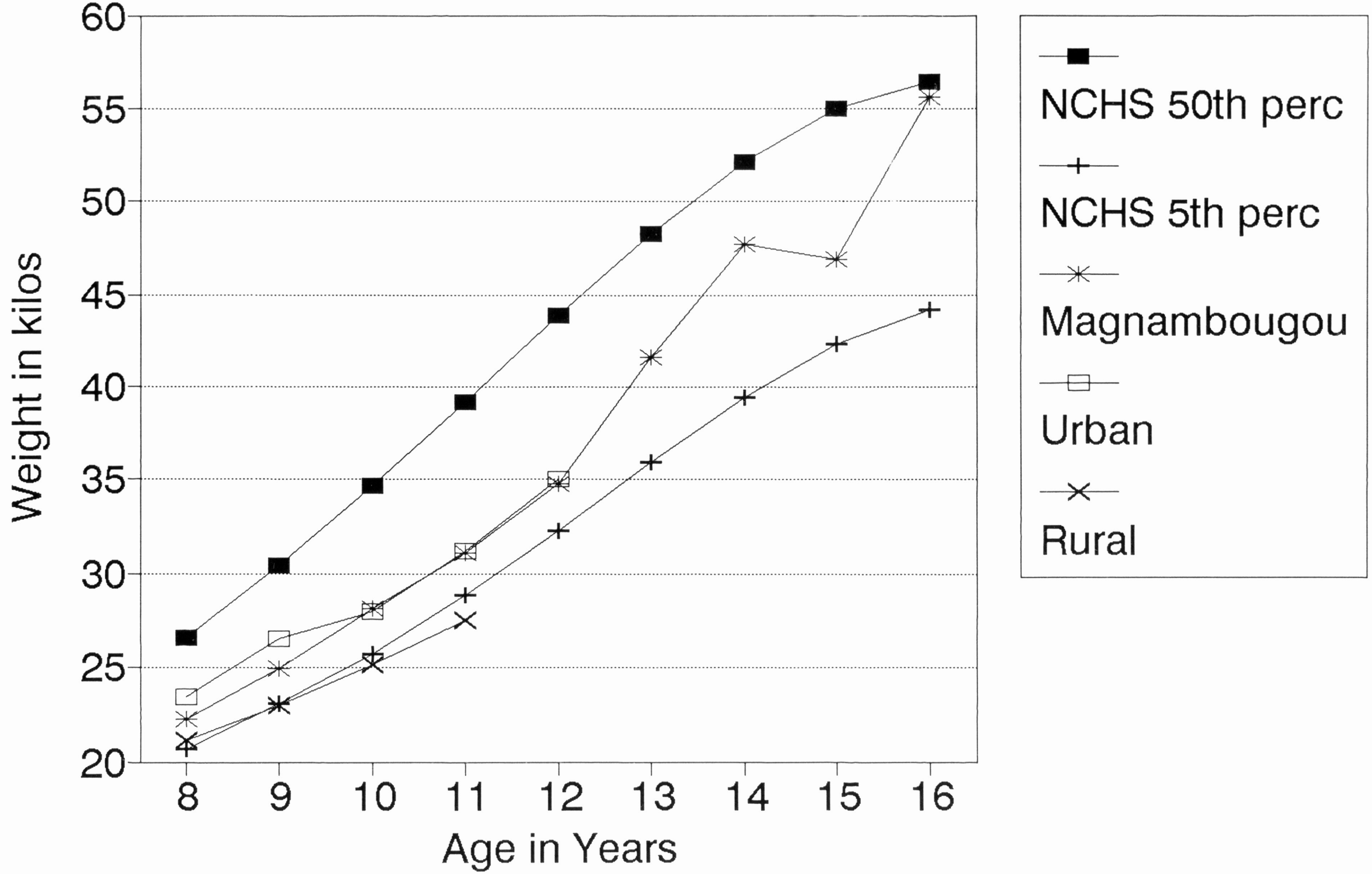


Fig.17 Weight for Age Comparison

Males

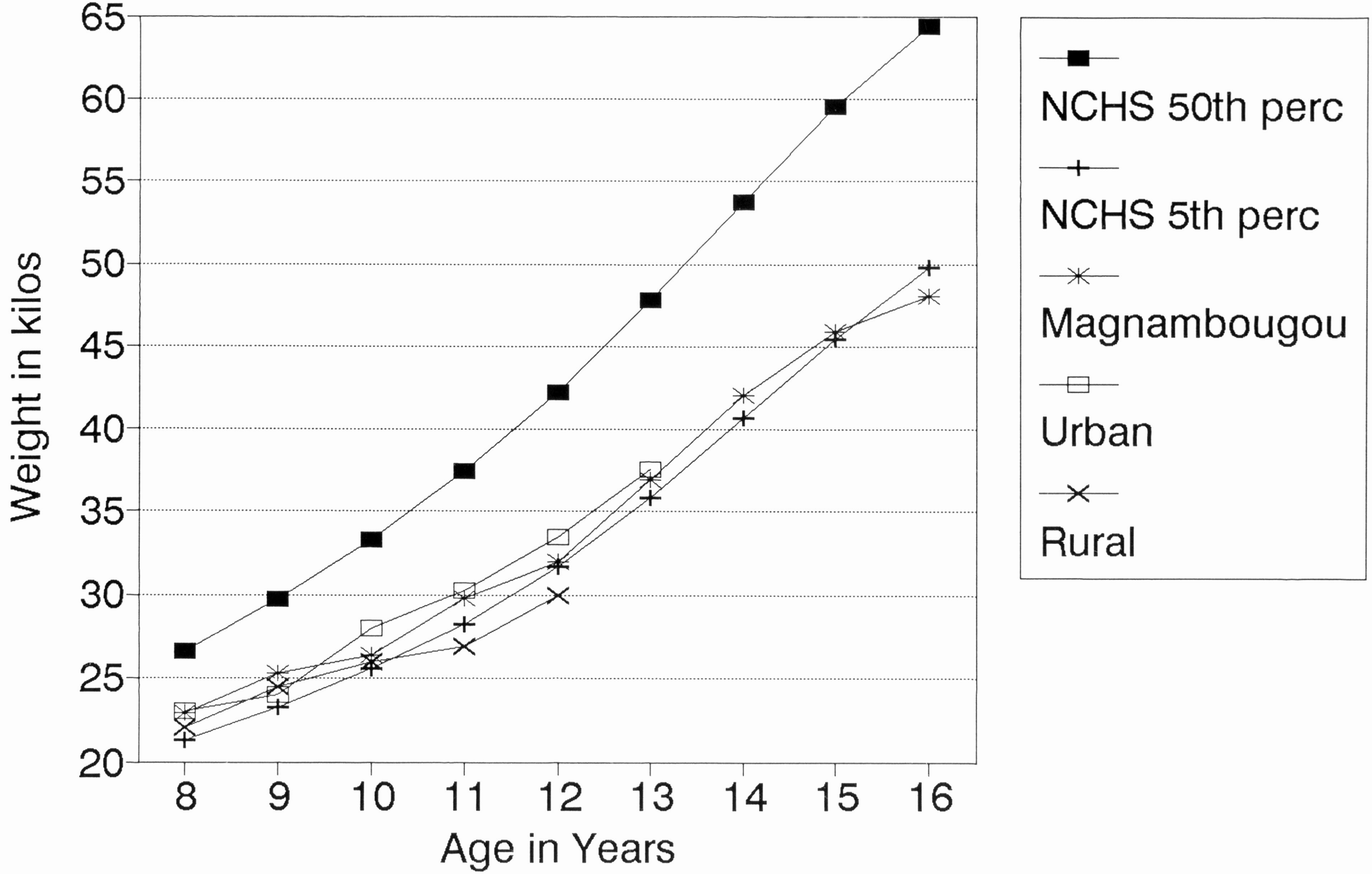


Fig.18 Mean Arm Circumference

Females

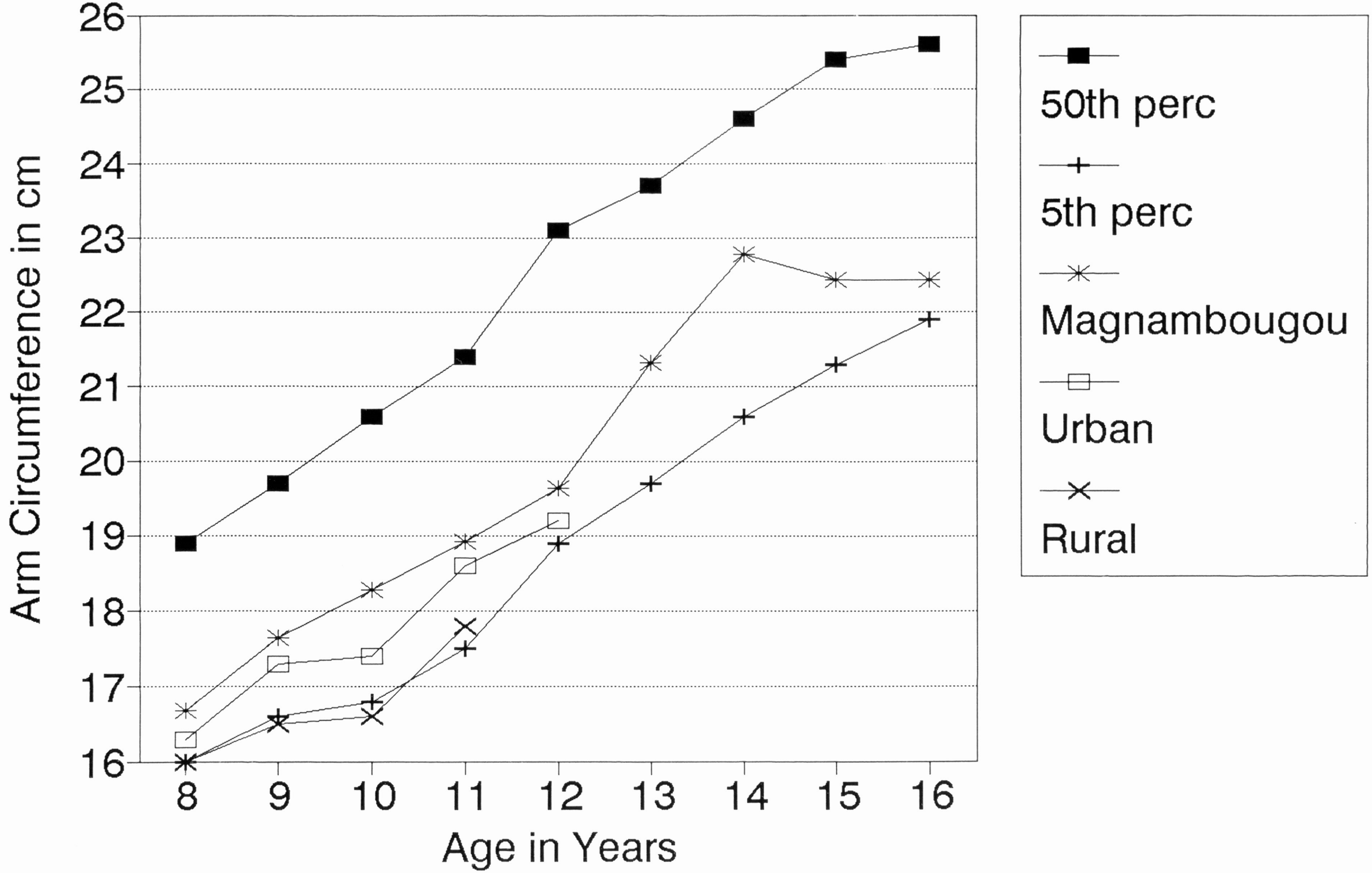


Fig.19 Mean Arm Circumference

Males

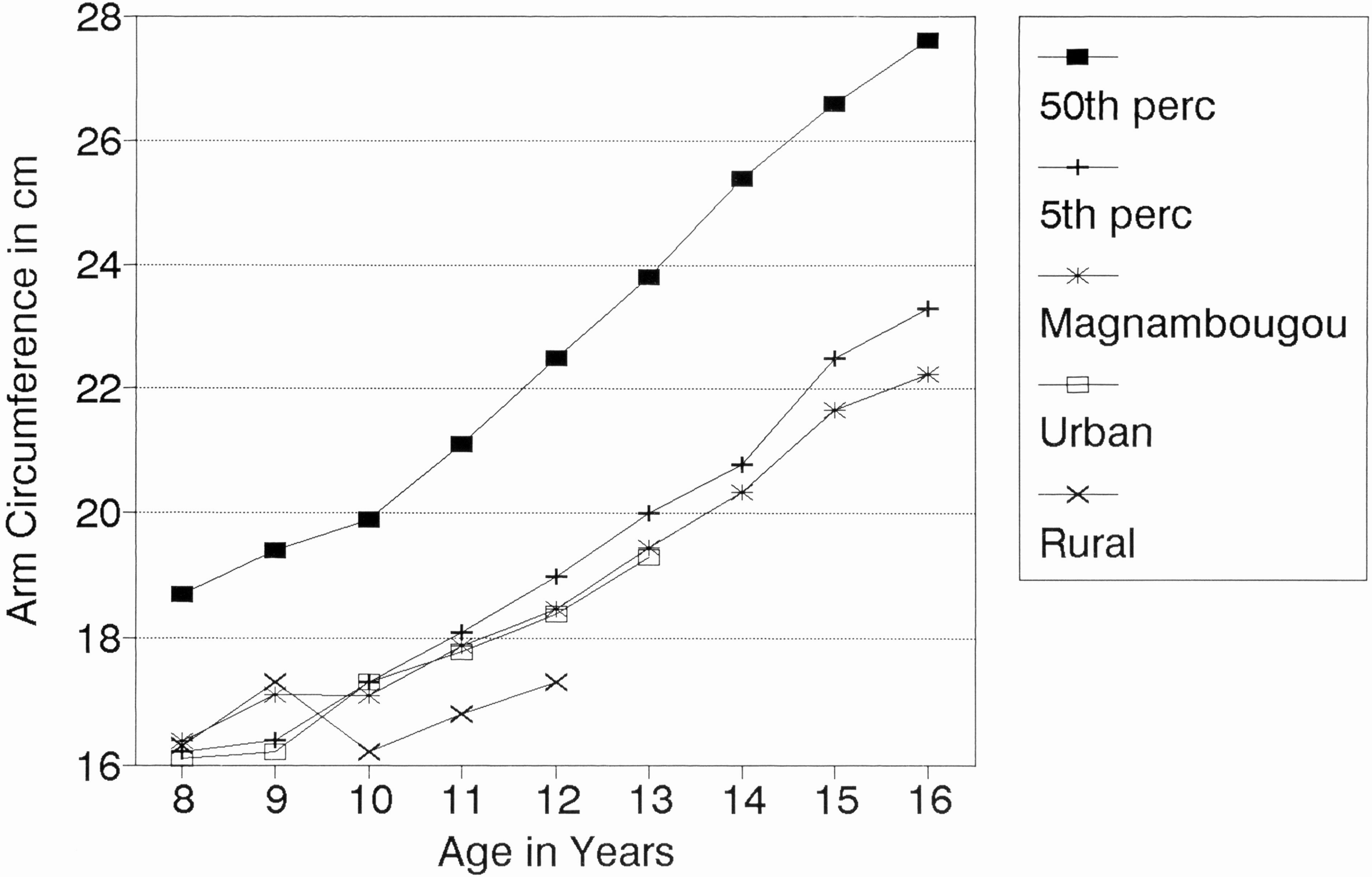


Fig.20 Mean Head Circumference

Females

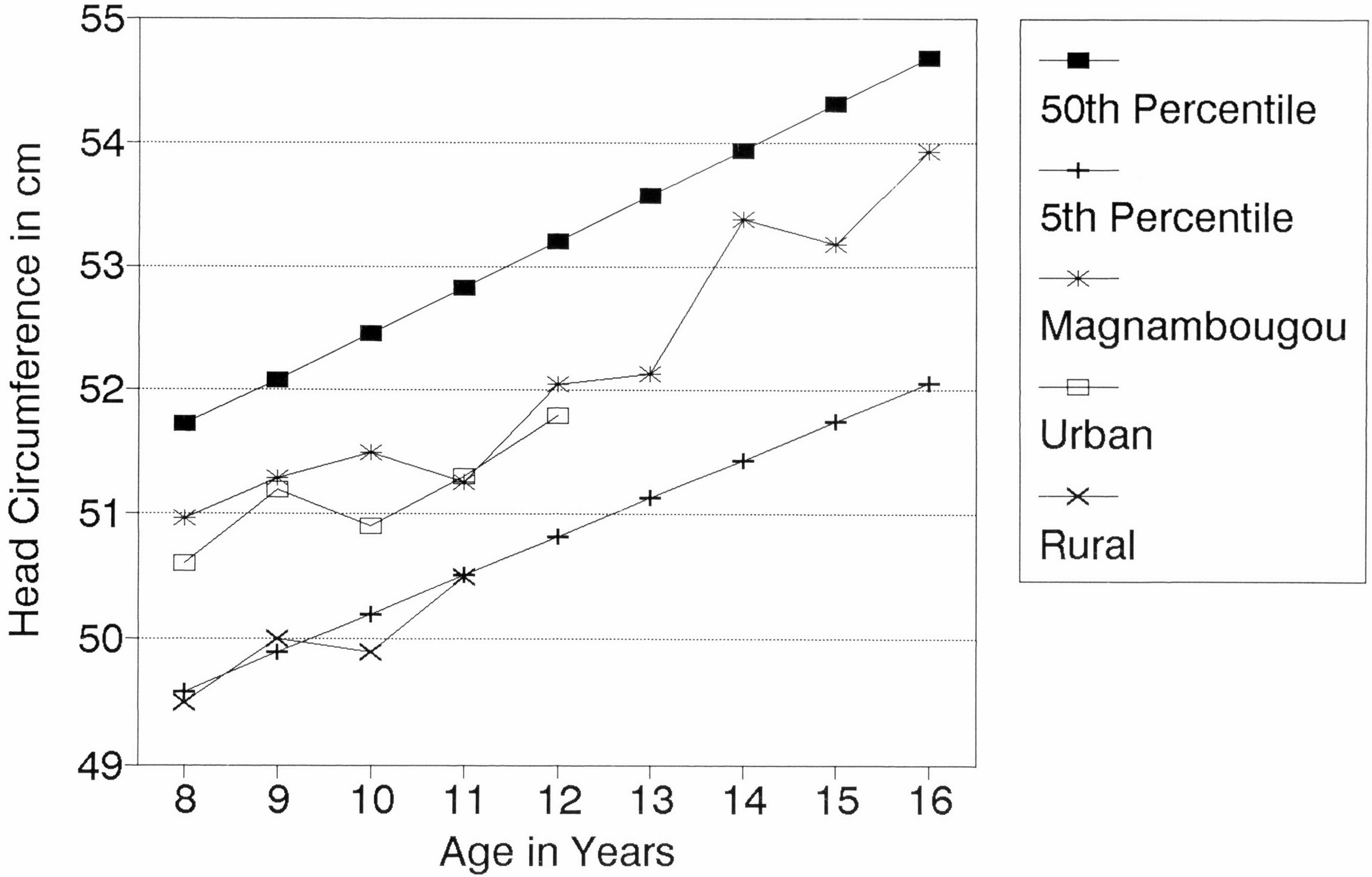


Fig.21 Mean Head Circumference

Males

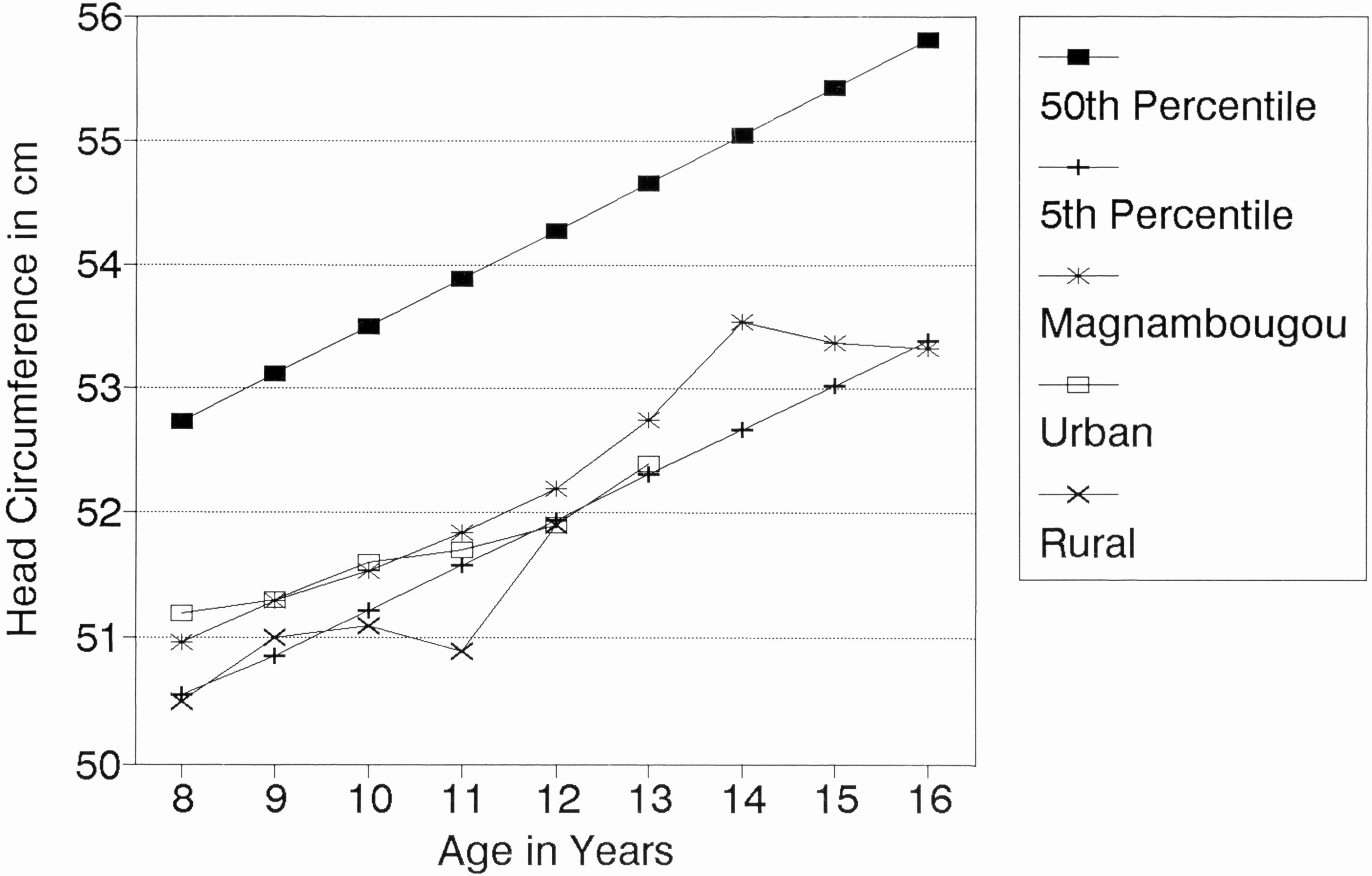


Table 1. Height-for-age (cm) Females

Age	Magnambougou	50th Perc	5th Perc	Urban	Rural
8	126.09	129.3	119.5	126.0	120.0
9	130.78	135.2	124.8	126.0	122.5
10	136.50	141.5	130.4	132.2	132.5
11	140.97	148.2	136.6	135.0	134.0
12	146.92	154.6	142.7	138.2	
13	153.94	159.0	147.2	147.4	
14	158.70	162.0	150.0		
15	160.44	162.1	151.1		
16	162.72	162.7	152.2		

Table 2. Height-for-age (cm) Males

Age	Magnambougou	50th Perc	5th Perc	Urban	Rural
8	126.52	129.6	120.5	124.9	120.5
9	131.82	134.8	125.3	128.0	125.5
10	135.84	140.3	130.1	135.5	131.2
11	140.66	146.4	135.0	138.2	133.5
12	143.69	153.0	140.2	144.5	138.0
13	150.73	159.9	145.7	150.2	
14	159.83	166.2	152.0		
15	160.66	171.5	158.3		
16	170.25	175.2	163.4		

Table 3. Weight-for-age (kg) Females

Age	Magnambougou	50th Perc	5th Perc	Urban	Rural
8	22.25	26.58	20.68	23.5	21.2
9	24.93	30.45	23.05	26.5	23.0
10	28.13	34.72	25.75	28.0	25.2
11	31.07	39.23	28.82	31.2	27.5
12	34.81	43.84	32.30	35.0	
13	41.64	48.26	35.98		
14	47.70	52.10	39.45		
15	46.90	54.96	42.32		
16	55.67	56.44	44.20		

Table 4. Weight-for-age (kg) Males

Age	Magnambougou	50th Perc	5th Perc	Urban	Rural
8	22.97	26.66	21.31	16.31	16.0
9	25.30	29.73	23.25	17.30	16.5
10	26.32	33.30	25.51	17.40	16.6
11	29.74	37.46	28.24	18.60	17.8
12	31.97	42.27	31.64	19.20	
13	36.91	47.81	35.85		
14	42.04	53.76	40.66		
15	45.97	59.51	45.50		
16	48.13	64.39	49.76		

Table 5. Mean Arm Circumference (cm) Females

Age	Magnambougou	50th Perc	5th Perc	Urban	Rural
8	16.67	18.9	16.0	16.3	16.0
9	17.64	19.7	16.6	17.3	16.5
10	18.28	20.6	16.8	17.4	16.6
11	18.91	21.4	17.5	18.6	17.8
12	19.63	23.1	18.9	19.2	
13	21.32	23.7	19.7		
14	22.79	24.6	20.6		
15	22.45	25.4	21.3		
16	22.45	25.6	21.9		

Table 6. Mean Arm Circumference (cm) Males

Age	Magnambougou	50th Perc	5th Perc	Urban	Rural
8	16.38	18.7	16.2	16.1	16.3
9	17.13	19.4	16.4	16.2	17.3
10	17.09	19.9	17.3	17.3	16.2
11	17.89	21.1	18.1	17.8	16.8
12	18.47	22.5	19.0	18.4	17.3
13	19.45	23.8	20.0	19.3	
14	20.34	25.4	20.8		
15	21.67	26.6	22.5		
16	22.23	27.6	23.3		

Table 7. Mean Head Circumference (cm) Females

Age	Magnambougou	50th Perc	5th Perc	Urban	Rural
8	50.97	52.72	49.58	50.6	49.5
9	51.29	52.09	49.89	51.2	50.0
10	51.50	52.46	50.20	50.9	49.9
11	51.25	52.83	50.51	51.3	50.5
12	52.05	53.20	50.82	51.8	
13	52.13	53.57	51.13		
14	53.38	53.94	51.44		
15	53.18	54.31	51.75		
16	53.92	54.68	52.06		

Table 8. Mean Head Circumference (cm) Males

Age	Magnambougou	50th Perc	5th Perc	Urban	Rural
8	50.97	52.73	50.55	51.2	50.5
9	51.29	53.12	50.86	51.3	51.0
10	51.53	53.50	51.22	51.6	51.1
11	51.84	53.89	51.58	51.7	50.9
12	52.20	54.27	51.94	51.9	51.9
13	52.75	54.66	52.31	52.4	51.9
14	53.54	55.04	52.67		
15	53.37	55.43	53.03		
16	53.32	55.81	53.39		

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