8. SKELETAL GROWTH

8.1 Introduction

One of the earliest studies on postcranial growth of immature individuals was done by Johnston (1962). Johnston's study was based on a skeletal sample of young children aged between zero and five years old at Indian Knoll. The main interest in Johnston's and other researchers' studies (e.g., Johnston 1962; 1968; Armelagos et al. 1972; Sundick 1978; Fazekas and Kosa 1978; Buikstra and Cook 1981; Ubelaker 1987; 1989b; Kosa 1989; Lovejoy et al. 1990; Saunders 1992; Saunders et al. 1993; Sciulli 1994; Steyn and Henneberg 1996) was to evaluate the relationship between chronological age and long bone lengths with the aim of assessing skeletal growth rates of subadults. In a more recent study, lengths of long bones have been used to evaluate the extent to which climatic conditions affect growth rates of the upper and lower limbs (Holliday and Ruff 2001).

Comparisons of bone growths between populations are often carried out to assess population variations in skeletal growths (Buikstra and Cook 1981). Descriptive comparisons between populations and measures of effects of environmental insults on populations are essential. For example, Sundick (1978) compared the growth rates of the Alternerding subadults to those of the Indian Knoll. The comparisons can also be made between archaeological and modern skeletal samples such as that between the Sudanese Nubians and white American boys (Armelagos et al. 1972), while Lovejoy et al. (1990) compared the Denver and Libben subadult growths. Holliday and Ruff (2001) evaluated variations in lengths of long bones of the limbs on various modern populations.

Comparisons of skeletal growth rates are useful indicators of possible stress exposure on populations. Most archaeological skeletons have been found to be shorter for their chronological age than modern populations (Johnston 1962; Armelagos et al. 1972; Lovejoy et al. 1990; Saunders 1992). A possible explanation for this observation has been that archaeological populations had less access to a variety of nutritious foods than modern populations, which would have resulted in slow growth in prehistoric times. On the other hand, abundance of food resources in modern times could have resulted in accelerated growth rates. Diseases in the past may have also contributed towards slowed or even retarded growth (Johnston 1962) of prehistoric children. Lesions such as Harris lines are a clear indication of arrested growth during developmental years and are commonly found on archaeological human skeletons. However, the extent to which growth was retarded is often unclear.

Effects of genetic change on growth are slow and can only be seen over successive generations while environmental effects such as nutritional deficiency and pathogen invasion on growth are recognisable within short periods (Saunders 1992). Abrupt changes in skeletal growth can therefore be attributed to sudden environmental changes or influx of a new population with different physical characteristics (Saunders 1992). Such intra population changes in skeletal growth rates need large samples of subadults derived from successive time periods or socioeconomic classes in order to be elicited (Johnston 1968).

For environmental stressors to have an effect on bone lengths, they have to be severe and chronic (Saunders 1992). More rapidly growing bones of the lower limb i.e. femur, tibia and fibula are the most susceptible to unfavourable environmental conditions (Sciulli 1994). Lovejoy et al. (1990) argue that, although the skeletal sample of children represents those individuals who did not survive diseases or other causes of death, they are nonetheless a true reflection of the growth status of the populations from which they were obtained. This is because most infant and children deaths are associated with acute rather than chronic diseases, which means that such individuals would have died before a bony response to stress or diseases was evoked.

8.2 Problems and limitations

Skeletal remains of immature individuals do not always preserve well by comparison to adult skeletons in the archaeological record. For instance, tooth germs of fetuses and newborn babies are easily lost thereby making dental aging difficult. Furthermore, archaeological samples are often not recovered in sufficient in sizes, which makes it difficult to assess any changes in growth rates at different ages (Johnston 1968; Sundick 1978; Ubelaker 1989a; 1989b; Lovejoy et al. 1990; Saunders et al. 1993; Steyn and Henneberg 1996).

Notwithstanding the fact that growth rates differ between boys and girls, most studies based on archaeological skeletal samples tend to pool the data between males and females (Armelagos et al. 1972; Sundick 1978; Lovejoy et al. 1990; Saunders 1992; Saunders et al. 1993; Steyn and Henneberg 1996). The main reason is that methods used to determine sex on immature skeletal remains are not justified and are problematic and usually not attempted. Therefore variations between male and female growth rates are not always possible to evaluate on archaeological samples.

The relationship between long bone lengths and age is dependent on the accuracy of aging techniques. The more accurate the aging technique the more accurate is the growth rate observed in a population. Dental eruption and development are the most accurate methods of estimating age from immature individuals (Massler et al. 1941; Ubelaker 1987; 1989b; El-Nofely and İşcan 1989; Johnston and Zimmer 1989) and in growth studies, only those individuals whose ages were estimated from teeth were included (Armelagos et al. 1972; Sundick 1978; Lovejoy et al 1990; Saunders 1992; Saunders et al. 1993; Steyn and Henneberg 1996). Therefore a substantial number of individuals are usually excluded from growth related studies if teeth of such individuals are not preserved.

Population variations in skeletal growth are of great importance in growth studies. Unfortunately different authors use different age categories, thus making comparisons difficult. Some use age categories of one-year intervals (e.g., Sundick 1978; Lovejoy et al. 1990; Saunders et al. 1993; Steyn and Henneberg 1996) while in some publications age intervals vary in length (e.g., Armelagos et al. 1972). Moreover, the samples themselves vary in size and thus caution needs to be practiced when making inferences on skeletal growth rates of various populations. Moreover, some studies focus on very specific age groups and exclude other subadult individuals. For example, Johnston's (1962) study of the Indian Knoll children focused on children aged between zero and five years only while Armelagos et al. (1972) studied Nubian individuals of zero to 31 years old. Therefore comparison of growth dynamics between these two reports can only be restricted to the first five years of life.

Mortality rates during late childhood and adolescence are usually low which means that the samples available for these age categories are often small. Inter-individual variations in skeletal growth are large and when samples are small the variation effect becomes a compounding problem. Thus for each age category, the sample has to be large so that the mean length of any bone is derived from a wider representation encompassing many individuals of different lengths but from the same age category.

8.3 Materials and methods

Infants and children whose age could be determined from dental development were used to evaluate growth of the Toutswe children. A great emphasis is placed on the use of dental age to establish skeletal growth (Armelagos et al. 1972; Ubelaker 1987; Lovejoy et al. 1990; Saunders 1992; Steyn and Henneberg 1996) but because of the small number of individuals whose age was determined from dental development, other age indicators were considered for inclusion. For example, some infants had only a few germs available to establish dental age (e.g., Dikalate Burial 1). In such cases age indicators like fusion of the temporal bone (Scheuer and Black 2000) were used to improve the accuracy of results from dental development. In order to avoid circular reasoning (Johnston and Zimmer 1989; Saunders 1992), those individuals whose age could only be determined from long bone lengths were excluded.

Maximum diaphyseal lengths of long bones of fetuses and newborn babies were measured to the nearest millimeter using a digital caliper. Bones whose maximum diaphyseal lengths exceeded caliper capacity were measured with a standard osteometric board. Landmarks used in measuring bones have been defined by various authors (e.g. Krogman and İşcan 1986; Ubelaker 1989a; Fazekas and Kosa 1989; Buikstra and Ubelaker 1994; Moore-Jansen et al. 1994). Bones of the left side were used but substituted with their right counterparts if missing or fragmented. Individuals whose long bone lengths were not measurable were excluded. Bones whose epiphyses were attached were also excluded, i.e. only maximum diaphyseal lengths were used for this investigation

Having considered the above parameters for inclusion and exclusion, 25 immature individuals were selected for the study. They ranged from approximately eight months in utero to 16 years old. This sample is made up of 20 humeri, 20 radii, 19 ulnae, 15 femora, 15 tibiae and eight fibulae. No attempts were made to determine sexes of immature individuals and therefore the data used for this analysis is pooled.

Long bones lengths of the Toutswe children were compared to other skeletal samples from southern Africa (Steyn and Henneberg 1996) and other parts of the world.

These included the Libben sample and Denver from Colorado (Lovejoy et al. 1990), Alternerding, in Germany and Indian Knoll in USA (Sundick 1978). The St Thomas Church sample is from Canada (Saunders et al. 1993). Reference was also made to the sample from Nubian cemeteries in Sudan (Armelagos et al. 1972). The samples used represent different geographic areas as well as time periods.

8.4 Results

The samples of bones per age category are very small and in some age groups there were no individuals. This makes it difficult to make statistically sound conclusions about the growth of the Toutswe children. Table 8.1 shows the mean lengths of different long bones with increase in age. There is a general increase in lengths of all bones from one age category to the next at relatively constant rate. Any decrease in length from one age to the other can only be explained as a result of small samples used. There is a small number of individuals with evidence of cribra orbitalia and porotic hyperostosis. The lesions are small in all cases and therefore it is suggested that there may have been no significant stunted growth on individuals involved.

By comparison to other samples, the Toutswe children appear to have had relatively longer humeri, but were shorter than the St Thomas's Church individuals in this regard (Figure 8.1). The St Thomas's Church children had longer humeri than the rest of the populations throughout all age categories. However, the Toutswe measurements of the humeri exceed the St Thomas's Church measurements by a minimal margin at approximately nine years. Between one and three years, the Toutswe show relatively shorter humeri by comparison to other samples. Between six and 11 years, the Toutswe lie generally between the St Thomas' Church sample and other samples. By comparison to K2 children, the Toutswe had a slightly shorter humeri in early years (between one and five years old). After five years, the Toutswe show a tendency of longer humeri than the K2 children.

While the Toutswe and other samples show a tendency to increase humeri lengths at varying rates for each age category, the Libben sample shows a constant increase throughout the years (Lovejoy et al. 1990). For instance the Toutswe sample shows the lowest value at approximately three years but remains in between the others from four years onwards approaching the Libben values with increase in age. In the earlier years, they appeared to have been shorter (Toutswe), but later they were at par and even larger than some of the children.

The radii lengths are clustered around each other for the first few years of life (Figure 8.2). At approximately three years, the Toutswe children had the shortest radii lengths but they grew relatively faster that some of the children because at approximately 12 years, the Toutswe children had the longest radii lengths.

Table 8.1 Long bones lengths of subadults

	Humerus		Radius		Ulna		Femur		Tibia		Fibula	
Age	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean
Newborn/fetal	1	64.5	1	54.0	1	60.0	1	79.0				
0-0.5	3	69.4	2	62.6	2	55.2	3	79.0	2	69.2		
0.5-1.5												
1.5-2.5	1	104.0	1	82.0	1	92.0	1	132.0	1	111	1	107.0
2.5-3.5												
3.5-4.5	4	133.6	3	110.1	3	124.2	2	209.5	2	170	2	167.5
4.5-5.5												
5.5-6.5	2	160.6	2	133.5	2	146.5	2	230.1	2	194.3	2	193.0
6.5-7.5	3	190.3	3	148.9	3	162.7	2	263.0	2	221.0	1	241.0
7.5-8.5	2	200.0	2	160.0	2	177.0	1	278.0	1	234.0	1	224.0
8.5-9.5												
9.5-10.5	1	220.9	1	190.8	1	210.0	1	320.0	1	270.0		
10.5-11.5	2	233.0	2	177.8	2	191.5			1	287.0		
11.5-12.5												
12.5-13.5	1	220.7	1	180.2								
13.5-14.5	1	234.0	1	186.0	1	205.0	1	331.0	1	264.0	1	242.0

Figure 8.1 Growth curves of humeri of Toutswe children and other populations

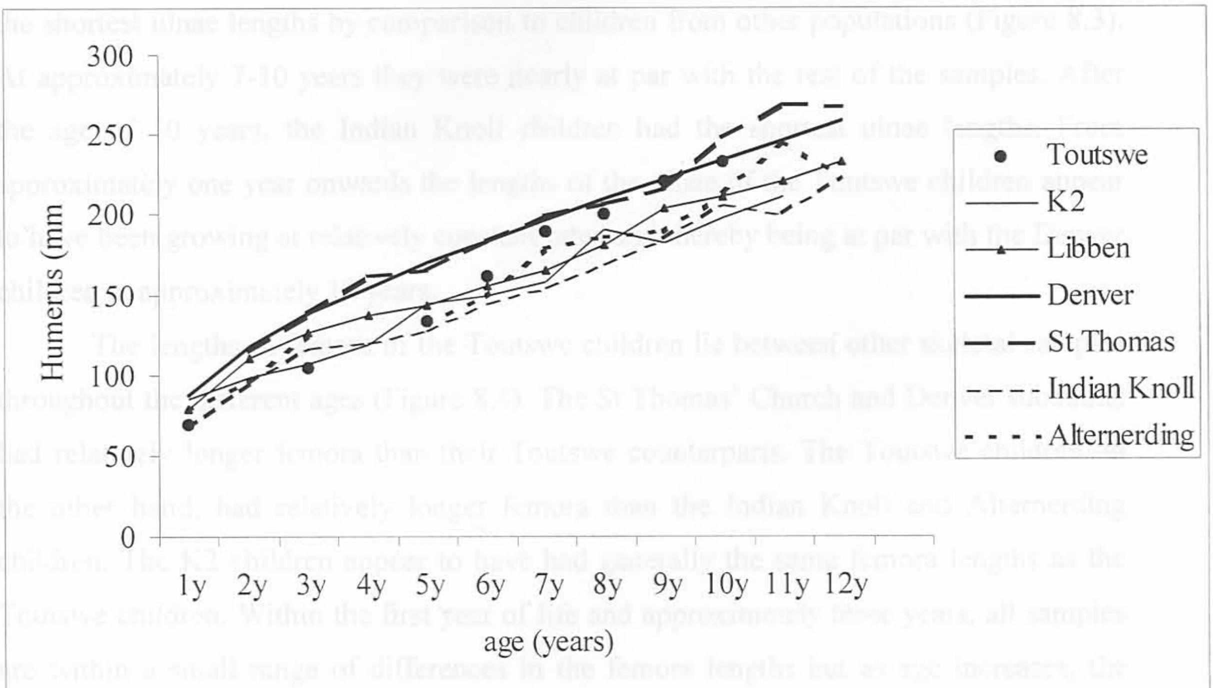
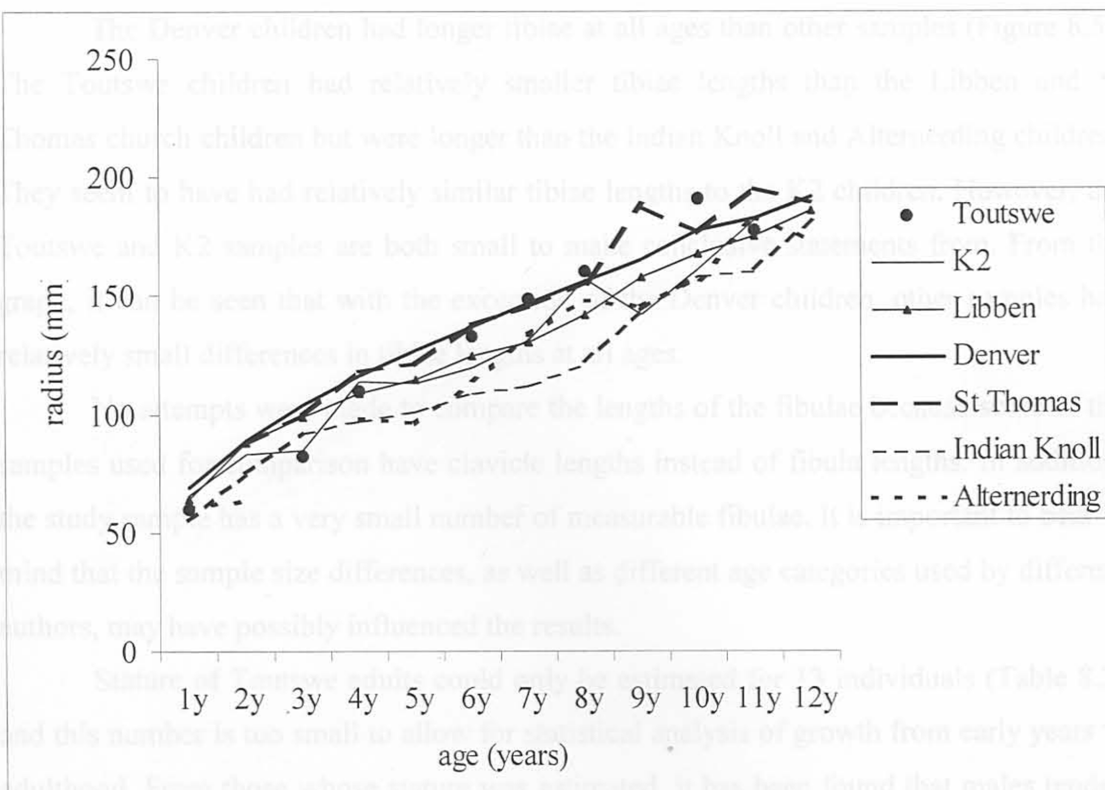


Figure 8.2 Growth curves of radii of Toutswe children and other populations



During the early years, i.e., between one and six years, the Toutswe children had the shortest ulnae lengths by comparison to children from other populations (Figure 8.3). At approximately 7-10 years they were nearly at par with the rest of the samples. After the age of 10 years, the Indian Knoll children had the shortest ulnae lengths. From approximately one year onwards the lengths of the ulnae of the Toutswe children appear to have been growing at relatively constant rates and thereby being at par with the Denver children at approximately 12 years.

The lengths of femora of the Toutswe children lie between other skeletal samples throughout the different ages (Figure 8.4). The St Thomas' Church and Denver subadults had relatively longer femora than their Toutswe counterparts. The Toutswe children on the other hand, had relatively longer femora than the Indian Knoll and Alternerding children. The K2 children appear to have had generally the same femora lengths as the Toutswe children. Within the first year of life and approximately three years, all samples are within a small range of differences in the femora lengths but as age increases, the differences in lengths between samples also increase. Thus the rate of femur growth varies with increase in age.

The Denver children had longer tibiae at all ages than other samples (Figure 8.5). The Toutswe children had relatively smaller tibiae lengths than the Libben and St Thomas church children but were longer than the Indian Knoll and Alternerding children. They seem to have had relatively similar tibiae lengths to the K2 children. However, the Toutswe and K2 samples are both small to make conclusive statements from. From the graph, it can be seen that with the exception of the Denver children, other samples had relatively small differences in tibiae lengths at all ages.

No attempts were made to compare the lengths of the fibulae because some of the samples used for comparison have clavicle lengths instead of fibula lengths. In addition, the study sample has a very small number of measurable fibulae. It is important to bear in mind that the sample size differences, as well as different age categories used by different authors, may have possibly influenced the results.

Stature of Toutswe adults could only be estimated for 13 individuals (Table 8.2) and this number is too small to allow for statistical analysis of growth from early years to adulthood. From those whose stature was estimated, it has been found that males tended to have been relatively taller than females.

Figure 8.3 Growth curves of ulnae of Toutswe children and other populations

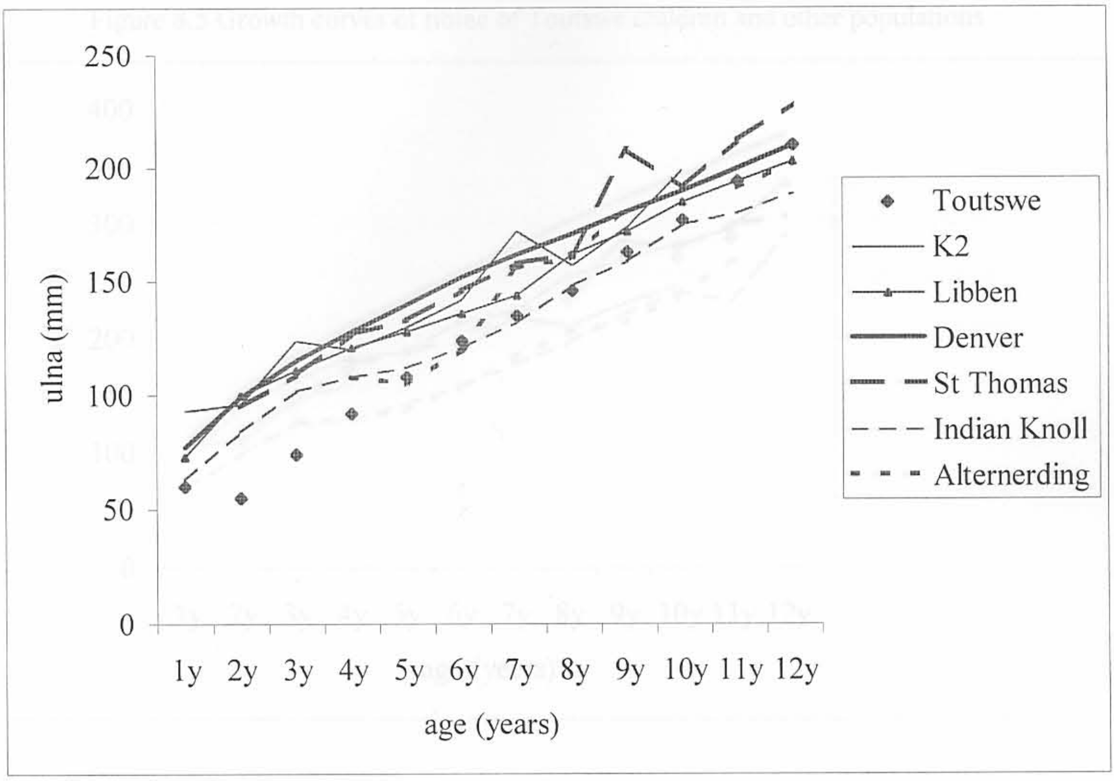


Figure 8.4 Growth curves of femora of Toutswe children and other populations

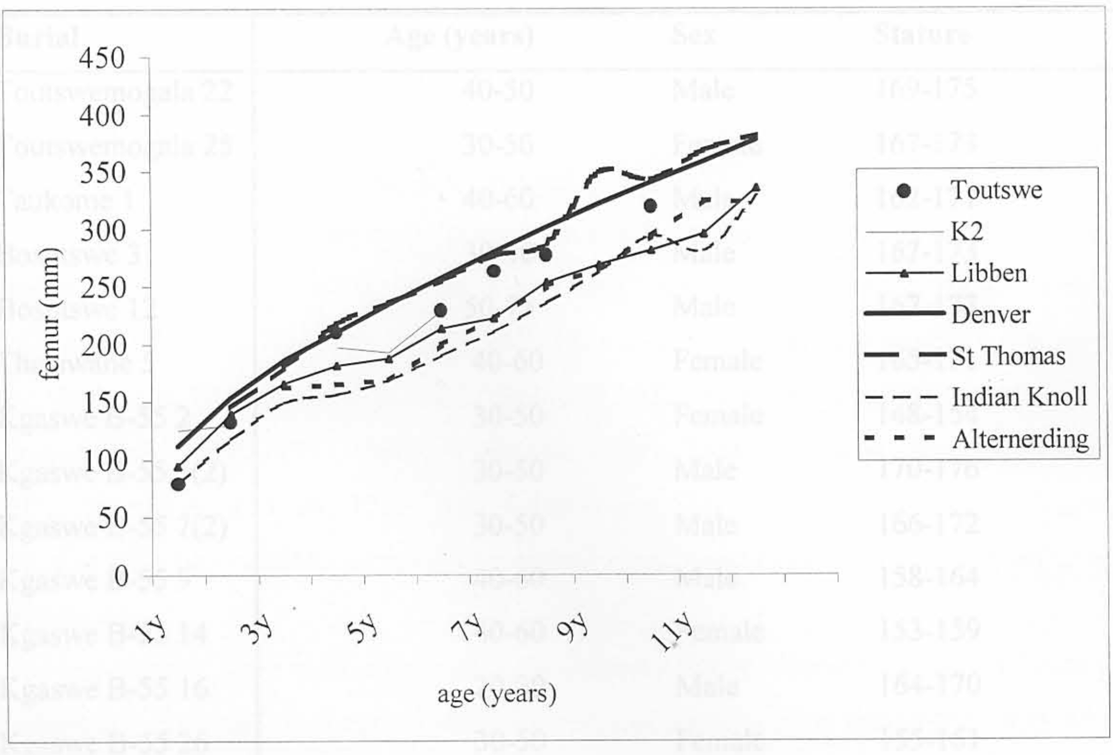


Figure 8.5 Growth curves of tibiae of Toutswe children and other populations

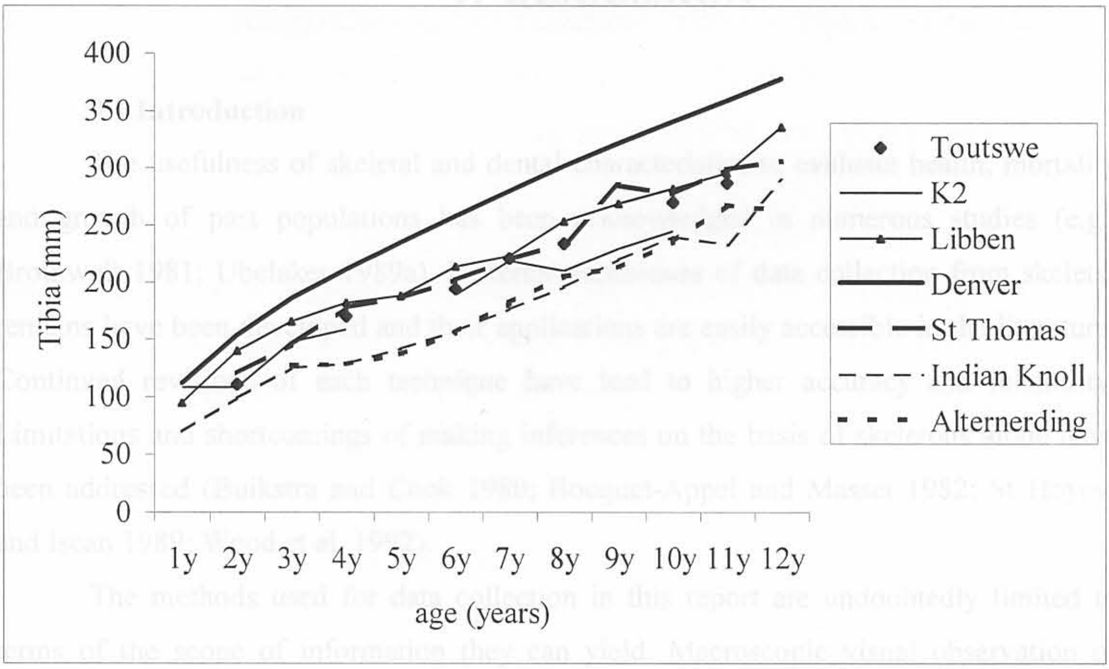


Table 8.2 Estimated statures of adults

Burial	Age (years)	Sex	Stature
Toutswemogala 22	40-50	Male	169-175
Toutswemogala 25	30-50	Female	167-173
Taukome 1	40-60	Male	162-171
Bosutswe 3	30-40	Male	167-173
Bosutswe 12	50-75	Male	167-173
Thatswane 5	40-60	Female	165-171
Kgaswe B-55 2	30-50	Female	148-154
Kgaswe B-55 5(2)	30-50	Male	170-176
Kgaswe B-55 7(2)	30-50	Male	166-172
Kgaswe B-55 9	40-60	Male	158-164
Kgaswe B-55 14	40-60	Female	153-159
Kgaswe B-55 16	20-30	Male	164-170
Kgaswe B-55 26	30-50	Female	155-161