# A Review on Anthropometric Parameters of the Normal Radiological Knee and Leg Bones in the Evaluation of Sexual Dimorphism and Racial Variations

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## ABSTRACT

A review is presented on the anthropometric parameters of the normal radiological knee and leg bones that can be used to ascertain sex and identify race. Sexual dimorphism has been shown to exist between species but the degree of dimorphism may vary and remain uncertain except through certain anthropometric parameters. The Tibio femoral angle, femoral condyle angle, Tibia condyle angle, Quadriceps angle, distal femur anthropometry as well as knee height ratios have been researched and shown not only to be sexually dimorphic but also identify race. These parameters have shown significant differences between males and females in Africans (Nigerians and Malawians) as well as Caucasians and comparison between African values and Caucasians have shown significant differences defining race. Knee height ratios although not sexually dimorphic in Nigerians as with Caucasians; show racial differences between Nigerians and Caucasians. This knowledge could help in implants design and prosthesis for particular sex and race and also help in forensics to determine gender and race in skeletal remains and specimen.

***Keywords:*** *Anthropometric parameters of the knee, sexual dimorphism, Tibio femoral angle, Femoral condyle angle, Tibia condyle angle, Quadriceps angle, Distal femur anthropometry, knee height ratios*

## INTRODUCTION

It has been argued that some species or race are more sexually dimorphic then others. One indication of the degree of dimorphism is life expectancy. According to the NCHS (National Centre for Health Statistics), current life expectancy for white females (non Hispanic) is 80.6years and 75.8 years for white

males; showing that white women live 4.8 years or 6.3% longer than the males. For blacks (non-Hispanic), 76.5 years for women and 69.6 for men showing that black women live 6.9 years or 9.9% longer than their male counterpart. This is taken as a strong signal that blacks are more sexually dimorphic than white. Other arguments has been that Europeans are more sexually dimorphic then their African counterparts taken into consideration, their superior beard growth, the pattern of Baldness which occurs more in them, abundance of sexually dimorphic body hairs(chest and back.) and shape of their nose which tends to differ more than it does among other races. However some anthropometric parameters and indices of the knee joint and leg bones have been shown to help in this argument, identifying sex and showing variations among race.

## ANTHROPOMETRIC PARAMETERS OF THE KNEE JOINT

**The Tibio femoral angle**------ angle between the axis of the femoral shaft (AFS) and axis of tibia shaft (ATS). Showed from a study of the Radiographic measurement of the axial relationship of the normal knee joint of Adult Nigerians that Nigerian males had a mean tibio- femoral angle of 176.0°$\pm$1.52.° While Nigeria females had a mean tibio femoral angle of 175.16° $\pm$1.22.° This showed significant higher values than the females; clearly indicating sexual difference which could be as a result of genetic makeup and inheritance which manifest as sexual dimorphism as reported by previous authors on most anthropometric parameters (Oladipo et al., 2006, Oladipo et al., 2007, and Daniel 2002). It has been suggested that genetic factors exert a substantial influence on the individual differences in body shape and configuration and therefore should be considered in developing standards for various populations (Livhitis et al., 1994). The results, when compared with Caucasian values as reported by Keats et al., 1996 , showed significant ethnic differences which were 174.0° ±2.6° for Caucasian males and173.0° ±2.5° for Caucasian females.

Previous studies have shown that white have more anterior bowing and shorter femur than blacks (Troiter et al., 1952, Steward 1962) a fact that could explain for the racial differences that has been reported here. As with the Nigerian values, comparing the Caucasian values as given by Keats et al 1966 also shows

sexual dimorphism among its subjects. In a study from 323 radiograph of the knee joint in adult Malawians comprising 219 males and 104 females of age 18 – 55 years by Igbigbi et al., 2002 the tibio- femoral angle of Malawians showed 174.4 ± 3.47 for males and 174.46 ± 4.30 for females. The result was reported to show ethnic difference between Caucasian values 174.4° ± 3.47° for males as 174.46° ± 4.3° for females as against 174.0°± 2.6° and 173.0° ±2.5°recorded for Caucasians by Keat el al., 1966. This further gives evidence to the fact that the tibio-femoral angle differs among race and can be used in identifying race.

Nigerians however had higher values from that of Malawians having 176.0° ± 1.52° and 175.16° ± 1.22° for males and females respectively as against 174.4° ± 3.47° and 174.46° ± 4.3° for males and females respectively, showing differences even among Africans.

**FEMORAL ANGLE AND TIBIA ANGLE**

Studies on the femoral angle (angle between the axis of the femur shaft and axis of femoral condyle and tibia angle (angle between the axis of tibia shaft and axis of tibia condyle) (Keats et al., 1966) carried out on adult Malawians in a research to determine the normal axial angles of the knee joints in adult indigenous Malawians by Igbigbi et al., (2003) showed results, which when compared with results of Caucasians as given by Keats et al., 1966 showed some differences.

**Table showing Comparism of the axial angles of the knee joint in adult Negroid Malawians with data on Caucasian found in listed literature.**

| ANGLE | MALAWIANS | | CAUCASIANS | |
|---|---|---|---|---|
| | AUTHORS Igbigbi et al., 2003 | | AUTHORS Keats et al., 1966 | |
| | MALES N = 149 FEMALES N = 122 | | MALES N=25 FEMALES | |
| FEMORAL ANGLE(FA) | | | | |
| RANGE | 72°- 102° | 80°- 102° | 75°-85° | 75°-85° |
| MEAN &SD | 89° ± 5.6° | 90 ° ± 5.2° | 80.2 ± 2.0° | 81.2 ± 2.8° |
| TIBIA ANGLE (TA) | | | | |
| RANGE | 80°- 94° | 83°- 96° | 85°- 100° | 87°- 98° |
| MEAN &SD | 89.6° ± 2.9° | 89.1 ± °3.2° | 93.5 ± 3.5 | 92.4 ± 2.5 |

In both sexes the average (mean) femoral angle was greater in the Malawians than in Caucasians, but the mean tibia angle was greater in Caucasians than in the Malawians showing racial variations and thus making the femoral angle and tibia angle knee parameters for classifying Race. The result also exhibits sexual dimorphism in both Malawians and Caucasians. However certain limitations can occur in this method, variability of measurement of the X-ray film due to magnification aberrations. Inter observer variation errors can arise. All these could affect the result if these limitations were not addressed.

**Q-ANGLE**

The Q- angle which is defined as the acute angle formed by the vector for the combined pull of the quadriceps femoris muscle and patellar tendon

was studied in adult Nigerians by Omolulu et al and it showed 10.7°$\pm$2.2° for men in the supine position and 12.3°$\pm$2.2° in the standing position for the right knee. The left knee Q angle showed 10.5°$\pm$2.6° in the supine position and 11.7°$\pm$2.8° in the standing position this, when compared with the values for women showed significant difference in the Q angle, which was 21°$\pm$4.8° for the right knee in the supine position and 22.8°$\pm$4.7° in the standing position. For the left knee Q angle showed 20.9°$\pm$4.6° in the supine position and 22.7°$\pm$4.6° in the standing position, making the Q-angle of the knee a sexual dimorphic parameter. It has been argued that the greater Q-angle in women was due to their widely spread hips and shorter femur length, or a combination of both. The female values also show significant differences with that of Caucasians (Bylt et al., 2000, Hahn et al., 1997).

**Distal femur anthropometry** has been argued to play a role in sexual identification. There is a debate about whether distinct designs of femoral component for men as women are needed based on morphology and sized difference between genders. Questions have been asked whether anthropomorphic difference exist between men and women (Booth 2006, Conley 2007, Macdonald et al., 2008, Hitt et al., 2003, Singh et al., 2008). In a study on the differences between the distal femora of men and women by (Jess et al., 2008); the distal femur of 100 women and men were measured inter operatively after preparation for prosthetic implantation.

**THE ANTERIOR POSTERIOR HEIGHT** from the posterior edge of the medial femoral condyle to the flush, anterior cut and **THE MEDIOLATERAL WIDTH** at the transepicondylar axis were measured. The measurements were compared between genders using independent sample t-test. The ratio between anterior posterior and mediolateral dimensions where also calculated for men and women to determine if there is a shape difference between genders. The result showed that the mean aspect ratio was larger for women than men. 0.84 (range, 0.57 - 1.03) versus 0.81 (range, 0.066 – 1.34) respectively which shows that differences in the shape and size of distal femur exists; making the distal femur a reliable parameter for sex determination (sexual dimorphism). The standard derivation and range of each measurement of size and

morphology also suggest variability not only between genders but also within whether these variations and aspect ratios will reflect clinically important differences in outcome after total knee angioplasty (TKA) with available prostheses will require additional study.

Chin et al., (2002) studied the anteroposterior (AP) and mediolateral (ML) dimension of 200 consecutive osteoarthritic knee undergoing unilateral primary total knee Anthroplasty (TKA), and found on average, the distal femur height was 10.5% taller in men than women, and the mean mediolateral (Ml) dimension was 13.7 wider in men than in women with an aspect ratio of 0.82 for women and 0.76 for men.These differences indicate not only that men on average have larger distal femur than females but the shapes are different. Similar anthropometric gender differences were reported in a study by Hilt et al., (2003), which suggested disparities account for femoral component overhang in women and under hang in men with several contemporary implants.

These findings provide evidence of sexual dimorphism when comparing men and women not only in the dimension of the distal femur but also in the morphology and shape as represented by the aspect ratio. In the research/ experimental work however neither a former power analysis nor a sub analysis based on ethnically or race was performed it is however believed that the consecutive nature of sample is representative of the typical patient that are seen in the metropolitan mid-Atlantic tertiary practice. The appropriate number of knee to study in each gender was however not identified this would have required a targeted difference in mean measurement between genders.

Again the difference in aspect ratios that are clinically important is not stated of known in the experimental set up. The study did not address whether there are morphologic differences in the distal femur based on race or ethnicity. It only addressed shape differences based on gender. This will require further study. Anthropometric differences in long bone geometry have been used in the areas of forensic to determine gender in skeletal remains and specimens. Other studies have reported variations in anteroposterior and mediolateral dimensions when comparing the Indian and western populations and discussed the

implications of these differences in implant design.

In the study by Vaidya et al., (2000), available implants were adequate to accommodate the AP and ML dimensions of the femur in 86.8% of Indian men but in only 40% of women. 60% of Indian women studied had femoral AP dimensions smaller than the smallest available implant.

**KNEE HEIGHT RATIOS** which gives an assessment of the patellar height was studied in the radiographic measurement of the axial relationships of the normal knee joint of adult Nigerians and the values reported showed racial variations between Nigerians and Caucasians.

**The Install and salvati ratio (LT/LP)**
Where LT is the length of the patella tendon and LP is the length of the patella measured on a lateral radiograph of the flexed knee was given as 1.02± 0.13 for Caucasians, the Nigerian value was 1.04± 0.07

**The Blackburn and Leister ratio A/B**
Where A is the perpendicular height of the lower end of the articular surface of the patella from the tibia plateau line and "B" is the length of the articular surface of the patella gave a ratio of 0.80± 0.14 for both males and females when this was used in the study on Nigerians, it showed 0.87± 0.02 for both sexes showing a significant difference between Caucasians and Nigerian knee ratio; making it a tool for racial identification.

**BLUMENSAAT's LINE RATIO; LP/WCLP**
Measured as the length of the patella (**LP**) to width of femoral condyle at blumensaat's line **(WCBL)** was given as 0.95 ± 0.07 for Caucasians and 0.95 ± 0.02 for Nigerians in both sexes. Although these values were not sexually dimorphic in Nigerians and Caucasians, they clearly show racial differentiation.

**CONCLUSION**
Knee anthropometry such as the tibio femoral angle, femoral angle, tibia angle, Quadriceps (Q) angle, distal femur dimensions and morphology as well as knee height ratios have been shown to identify gender and race which could help in implant designs and prosthesis for particular sex and race. Also in the areas of forensic to determine gender in skeletal remains and specimen in cases of accidents involving mass deaths where individuals have to be identified based

on skeletal remains and in solving crimes. More research need to be done on other anthropometric parameters to determine if they are sexually dimorphic and can ultimately identify race.

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