Clinico-radiological assessment of normal variation of alignment of femur and tibia in different age groups in Indian ethnic population

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Citation

S Mukhopadhyay, K Mukhopadhyay, B Acharyya. *Clinico-radiological assessment of normal variation of alignment of femur and tibia in different age groups in Indian ethnic population*. The Internet Journal of Orthopedic Surgery. 2008 Volume 15 Number 1.

Abstract

The mechanical axis deviation and the normal relationship of the joints of lower extremity has been the focus of several recent studies. We tried to carry out standardization of the same values in different age-groups. Sixty normal joints from 30 subjects are chosen and divided into 7 age-groups (5-10years, 11-15 years, 16-20 years, 21-30 years, 41-50 years, and 51-60 years). Congenital deformities of spine, pelvis and lower limbs were excluded. The calculated mechanical axis deviation shows a value of 7.54mm±4.8 (5-10yr); 11.34mm±6.9 (51-60yr); (4.1±4mm Bhave et al). In few sporadic subjects the mechanical axis deviated laterally in contrary to the majority of observations (4.32 ±3.38 mm, and was 10-13mm in some subjects). However, this needs a larger and more radiologically accurate measurement system. Rest of the standardized values(in degrees) are following:mLPFA:70.6±8.5(5-10yr) and 94.4±5.7(51-60yr);LPFA:76.9±8.6(5-10yr) and 98.4±5.07(51-60yr); Femoral valgus:7.06±0.623(5-10yr) and 5.9±1.4(51-60yr);mLDFA 88.25±2.2(5-10yr) and 86.5±0.8(51-60yr);aLDFA:82.06±2.04(5-10yr) and 81.7±1.8(51-60yr);MPTA:87.7±3.6(5-10yr) and 86±1.9(51-60yr);mLDTA:91.25±2.13(5-10yr) and 89.7±2.4(51-60yr);MNSA:138.9±6.5(5-10yr) and 125±3.3(51-60yr). The MAD found to be different in different age-groups and its range is more in the elderly as compared to standard values. The few subjects showing lateral shifts of MA in relation to knee joint center are frequent in younger age groups but also found in different subjects sporadically. Measurement of mechanical axis deviation and joint orientation and alignment parameters are thus useful determining the normal range of anatomical and mechanical variation of lower extremity. The values obtained in the present study show tendency to increasing varus of proximal femur and knee as age advances. The normal ranges of the values may thus help determining surgical options in deformity correction.

INTRODUCTION

The mechanical axis deviation of lower limb and the normal relationship of the joints of lower extremity has been the focus of several recent studies[1,2].Most of the studies mainly included adult subjects and relevant data are also available in various publications. In the present study we tried to carry out standardization of the same values in different age-groups of Indian ethnic population.

In standing position, forces on the hip joints are divided equally. Considering each lower extremity as one-sixth body weight, then two-thirds of the body–weight will be above the hips or one-third in each hip. Stabilization of the trunk in the antero-posterior plane by ligament and muscle forces probably increases the load.

To have a better understanding of the alignment and joint orientation, the complex three-dimensional shapes of bones and joints can be simplified to basic line drawings. For purpose of reference, these line drawings should refer to either the frontal, sagittal or transverse anatomic planes.

In different age groups these parameters change due to different anatomical variation in different parts of hip joint, femur, knee joint, tibiae and ankle joint. The dynamic variation has also been found to show variation in different racial groups.

The objective of present study is to show the differences in these parameters in different age groups. A comparative trial was not possible as no values are available in the literature for other age groups except adults using similar nomeclature.

The relationship to osteoarthritis of knee joint and consequences of mono/bi/tricompartmental osteoarthritis

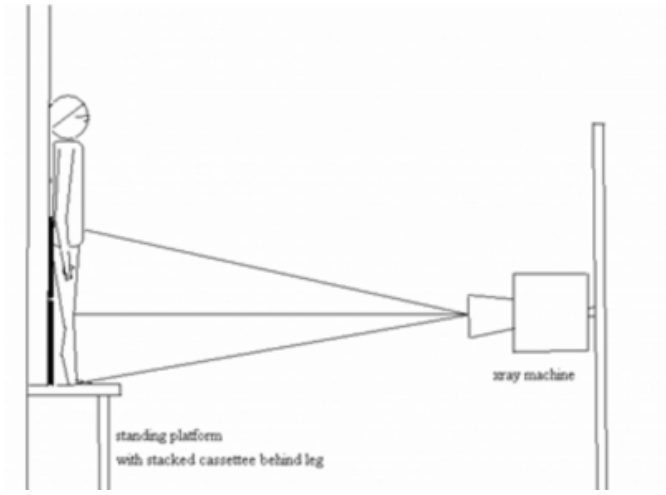
such as varus deformities of knee to the mechanical axis deviation is not included in the present study as they need long-term follow-up of individuals throughout their life.

MATERIALS AND METHODS

After obtaining local ethical committee approval 30 healthy subjects were chosen who volunteered to take part in the study. Written consents were obtained from patient or their parents who kindly agreed to allow us taking single lower limb x-ray. When explained about minor risk involved with a single X-ray obviously only 5 female subjects consented and took part in the study. Sixty normal joints from randomly selected 30 subjects (Male 25,female 5) are chosen and divided into 7 age-groups (5-10 y, 11-15 y, 16-20 y, 21-30 y, 41-50 y, 51-60 y). Congenital deformities of spine, pelvis and lower limbs were excluded. No sex, occupation, body-weight bias considered. Full length standing AP x-rays taken with 300mA X ray machine(fig-1) keeping legs slightly internally rotated and with intermalleolar distance of 30cm (or less in children) to keep limbs parallel.

Figure 1

Figure-1 position of patient with hip,knee extended, standing against the stacked cassett at a fixed distance from the X-ray tube with standard exposure.



We did not have the facility for telescopic x-ray machines and used 300mA standard X-ray machines with tables. The chest stand is use for subject placement. The problem of the obstacle created by the table top in guarding beams of x-rays to reach the floor was overcome by making the subject to stand on a long stool .

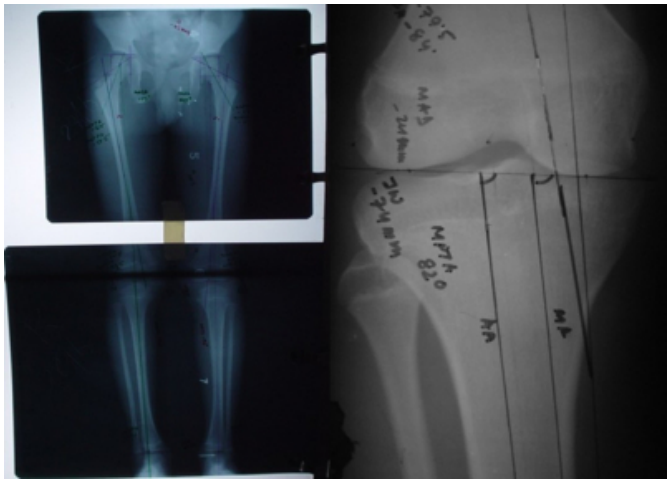
The subject was made to stand bare-footed, with hip, knee in full extension, the ankle plantigrade, patellae facing forward with tibiae vertical and with slight internal rotation .There was equal weight bearing on both limbs.

The tube is focused at the knee; the film-focus distance adjusted according to the height of the patient .No grid was used due to non-availability of long grid. Exposure was set to 75-95kv depending on distance and size of patient.30-50mA per second setting used with individualized adjustments.

The need to adjust the collimated beam according to the height of the patient dictated different film-focus distances for different subjects. The resulting magnification is calculated form the marker scale used was 10-13 %(Fig-2, 3) .Necessary correction for magnification was done for each value obtained by the first author (S.M).All the results are being reviewed by senior authors.

Figure 2

Figure-2: Full-length radiograph of lower limb with measurements taken after accurately aligning the films & Figure-3: Knee-joint orientation angles



Radiographic marker scale was used for measurements. Recent nomenclature of joint orientation, alignment and angles adopted from Dror Paley are as follows: aLPFA-Anatomical Lateral Proximal Femoral Angle; mLPFA—mechanical Lateral Proximal Femoral Angle ; MNSA—Medial Neck-Shaft Angle, etc.(m-mechanical, a-anatomical, M –medial, L-Lateral ,P-proximal, D-distal, A-angle, F-Femur, T-tibia); MAD-Mechanical Axis Deviation. The sagittal plane axis measurements were not included in the present study group.

RESULTS

Along with the values for mechanical axis deviations we also carried out measurements to work out values of

different joint orientation angles in frontal plane such as mLPFA, aLPFA, femoral valgus, mLDFA, aLDFA, MPTA, mLDTA, MNSA.

According to available literature frontal plane joint orientation angles measured in adults (mostly females) are depicted in Table-2. In the present study we have measured the same measurements in different age-groups. The individual observations are summarized into mean and standard deviation values in Table-1.

Figure 3

Table-1: Joint orientation angles in degrees in different age groups in present study

Age Group	mLPFA ±SD	aLPFA ±SD	Femoral valgus±SD	mLDFA±SD	aLDFA±SD	MPTA±SD	mLDTA± SD	MNSA±SD
5-10y	70.6±8.5	76.9±8.6	7.06±0.62	88.2±2.2	82.06±2.04	87.7±3.5	91.2±2.14	138.9±6.5
11-15y	85.6±7.7	90.1±10.2	6.4±1.8	86.5±1.5	81.7±1.7	86.3±2.5	88.06±2.9	130.4±8.4
16-20y	88.8±4.14	92.1±5.08	5.8±0.9	85.6±1.4	81.3±1.7	84.2±2.5	90.7±4.6	133.2±8.1
21-30y	86.9±9.08	93.1±11.3	6.05±1.5	84.9±0.7	80.2±2.7	85.5±1.2	92.4±5.7	131.5±9.4
31-40y	87.5±2.6	87.12±2.2	5±1.07	86.9±0.9	80.8±1.2	85.7±0.7	90.6±1.5	130.06±5.4
41-50y	91.6±5.5	94.9±4.5	5.6±0.7	86.4±1.4	81.8±1.8	85.4±2.4	92.2±3.1	129.7±4.02
51-60y	94.4±5.7	98.4±5.07	5.8±1.4	86.5±0.8	81.7±1.8	86±1.9	89.7±2.4	125±3.3

Figure 4

Table -2: Joint orientation angles in adults available in literature

mLPFA	89.4±4.8-Bhave; 94.6±5.5-Chao;89.2±5.2Paley
mLDFA	88.1±1.5-Bhave; 88.1±3.2-Chao ; 87.8±1.6-Paley
aLDFA	81°,range 79°-83°- Paley
MPTA	88.3±2 -Bhave;87.5±2.6-Chao ; 87.2±1.5 Paley
mLDTA	88.7±2.7 -Bhave; 87.1±3.3-Chao ; 88.6±3.8 Paley
MNSA	122±2.6 Bhave; 129 Yoshiroka ;129.7±6.2 Paley

Femoral valgus is variable in normal subjects and in our study the values show a tendency of decreasing valgus angle with increasing age(table-2). Measurements of MAD is again variable and adult values described in literature are 4.1□4mm(Bhave) to 9.7□6.8mm(Paley). Our study shows (Table-3) higher range of values in different age groups suggesting increased tendency to varus in Indian ethnic population.

Figure 5

Table-3: Mechanical axis deviation values in different age-groups.

	MAD after magnification correction (in millimeter) (mean ±SD)						
Age Group	5-10y	11-15y	16-20y	21-30y	31-40y	41-50y	51-60y
	7.54±4.8	1.7 ±1.2	10.7 ±7.1	6.5±4.5	9.3±2.4	10.8±2.4	11.3±6.9
Values (mean ±SD) as % of joint width	15.6± 8.05	3.13± 2.2	16.58± 1.5	10.52 ±8.68	13.64 ± 3.6	15.3 ± 3.1	17.14 ± 11.03

Figure 6

Table-4 : MAD lateral to knee joint centre in adolescents and adult subjects

Age	Joint Width (mm) (Right-R, Left-L)	MAD (mm)	Percentage of joint width	average of the percentage values (mean ±SD) 6.66±5.35
15years	60 mm(R)	0.89	1.67%	
23years	70(R),66(L)	8.9, 6.23	14.3%,10.6%	
25years	78(R)	8.01	11.54%	
50years	75(L)	0.9	1.33%	
60years	80(R),85(L)	1.78, 3.56	2.5%,4.7%	
MAD lateral to joint centre (mean ±SD)		4.32 ±3.38		

It has also been noted that in few subjects the mechanical axis is actually lateral to the joint centre (Table-4). These subjects did not have any symptoms or clinical malalignment while recruiting them in the study. All the measurements were repeated to minimize observer bias.

DISCUSSION

The joint orientation angles have been given various names by different authors in available literature(Chao et al 1994,Cooke et al 1987,Krackow 1984,Moreland et al 1987) (5,6,7,8).The axial alignment parameters of the lower extremity was described using special reference points by Hsu RWW et al(5).Hsu described tibial mechanical angle, femoral mechanical angle, proximal anatomic angle of femur, distal anatomic angle of femur, overall anatomic angle of femur, knee plateau angle etc. with respect to horizontal. Later Paley et al standardized the nomenclature (1).

To measure knee joint orientation Cooke et al (1987, 1984) obtained radiographs of the knee& hip after positioning the patient in a QUESTOR frame to improve reproducibility. In 79 asymptomatic young adults, the distal femoral orientation line measure valgus of 86□ 2.1□. Paley et al described in mLDFA to be 87.5□2.5□ as normal. In a retrospective study of 25 knees in adult patients of different ages, the normal MAD was 9.7□6.8mm medial (Paley et al, 1994).

Bhabe et al demonstrated MPTA of 88.3□ 2□ in patient older

than 60 years. Cooke et al and Moreland found MPTA as 86.7° 2.3° and 87.2° 1.5° respectively.

Moreland et al (1987) reported that the ankle is slight valgus (89.8° 2.7°).LDTA according to Paley et al and Chao et al was 88.6° 3.8°) and 87.1° 3.3°.Inman measured 107 cadavers and deduced ankle joint orientation equivalent to LDTA of 86.7° 3.2°, with a range of 80-92°.

Our study shows more varus orientation of the proximal femur (MNSA) in young and young adult population as compared to the available adult data (table-1and 2).The data also suggests slightly lesser values of mLDFA as age advances. Clearly proximal tibial varus angle (MPTA) showed lesser values than available data suggesting increasing proximal tibial varus tendency in our Indian ethnic study group.

The MAD found to be different in different age-groups and its range is more in the elderly age groups, as compared to standard values. The few subjects showing lateral shifts of MA in relation to knee joint center are frequent in younger age groups but also found in different subjects sporadically with a mean value of 4.32mm (±3.38.).In a recent study Sabharwal S et al (4) examined 253 children from 1-18 years and found a tendency of valgus orientation in frontal plane radiograph. The study also showed that after 7 years of age the measurements fall in the adult reference range.

In our study on the other hand despite looking at 60 unaffected lower limbs noticed valgus orientation of mechanical axis in five different patients from 15-60 years of age. The difference in values was found despite the fact that our study group contains more males than females, bearing the fact in mind that prevalence of osteoarthritis of knee in females is higher than males. It is debatable whether the findings can be extrapolated in a larger population group. Certainly similar examinations in larger study group may provide a better estimate of the orientation in Indian ethnic population to support or refute the abovementioned finding.

Measurement of mechanical axis deviation and joint orientation and alignment parameters are thus useful determining the normal range of anatomical and mechanical variation of lower extremity. The values obtained in the present study show tendency to increasing varus of proximal femur and knee as age advances which may be related to early osteoarthritic changes in knee of the Indian population. The normal ranges of the values may thus help in further studies of measurement of deformity in Indian ethnic population as a reference standard which is so far unavailable in published English literature. It is also difficult to perform this type of study in an area with limited resources. Moreover, the data provided might help in planning deformity correction, navigation surgeries, and interpretation of CT scannograms in future.

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