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Factors contributing to inherent varus alignment of lower limb in normal Asian adults: Role of tibial plateau inclination

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ABSTRACT

Purpose: This prospective study aimed to evaluate radiographically, mechanical or hip–knee–ankle (HKA) axis in healthy, asymptomatic, Asian (Indian and Korean) adults between 20 and 40 years of age to determine the incidence of inherent varus (mechanical limb alignment of >3° varus) and the factors influencing it.
Methods: Three hundred and eighty-eight lower limbs were evaluated using full length, standing hip-to-ankle radiographs in 198 healthy, asymptomatic, Asian (Indian and Korean) adults between 20 and 40 years of age to assess the hip–knee–ankle (HKA) angle, medial proximal tibial angle (MPTA), femoral bowing and femoral neck–shaft angle to determine the incidence of inherent varus (mechanical limb alignment of >3° varus) and the factors influencing it.
Results: Overall, the mean HKA angle was 177.6° ± 2.6° with 34.5% of limbs in inherent varus (mean HKA angle 174.9° ± 1.8°). The incidence of inherent varus was significantly higher ($p = 0.01$) in males (40%) compared to females (28%) but similar among Indian (34%) and Korean subjects (35%). The hip–knee–ankle (HKA) angle showed significant positive correlation ($r = 0.82$, $p < 0.001$) with only the medial proximal tibial angle (MPTA).
Conclusions: Inherent varus alignment of the lower limb is fairly common among asymptomatic, Asian adults. These results raise several pertinent questions regarding the role of inherent varus in the aetiopathogenesis of knee osteoarthritis and in lower limb realignment procedures.

1. Introduction

One of the primary goals of total knee arthroplasty (TKA) is to restore a neutral mechanical alignment of the lower limb. The rationale behind this is to improve long-term survival of the implant by restoring the mechanical axis of the limb within 3° of neutral alignment so that load distribution is even on medial and lateral compartments of the knee [1–6]. Previous reports have shown that the mean mechanical alignment of lower limb in normal healthy adult subjects is in mild varus of approximately 1.5°–2.5° [6–8]. However most of the data from these studies are derived from the Caucasian population; there are only two reports with a small number of adults investigated in Asian subjects. Tang et al. [9] in an analysis of 50 normal Chinese adults have reported a mean mechanical alignment of 177.8° or 2.2° varus. In a similar study involving 59 normal Pakistani adults, Khattak et al. [10] have reported a mean mechanical alignment of 178.9° or 1.1° varus. However, both these studies have not analysed variations in normal mechanical alignment and the factors which may contribute to this variation.

Bellemans et al. [11] based on a recent study conducted in 250 normal, skeletally mature Caucasian subjects between the ages of 20 and 29 years has reported that 25% of these subjects had a "constitutional varus" where the natural mechanical alignment was 3° varus or more. The authors concluded that in these subjects, who are in excessive varus alignment since skeletal maturity, restoring neutral alignment after TKA would be unnatural for them and would involve excessive medial soft-tissue release [11]. Although placing components in varus malalignment have been reported to result in poor outcome [2,4], a recent study by Magnussen et al. [12] reported that in patients with preoperative varus deformities, residual postoperative varus limb alignment does not lead to increased revision rates.

To the best of our knowledge, the incidence of inherent varus among normal Asian adults has not been reported and the factors influencing this have not been studied. We hypothesised that inherent varus is more common among normal Asian adults than what has been reported for Caucasian subjects, and that it is related to an extra-articular deformity such as excessive femoral bowing or proximal tibia vara. Hence the purpose of this large international, two-centre study was to determine the incidence of inherent varus in a large population of healthy, asymptomatic, Asian adults between 20 and 40 years of age and to determine factors influencing it.

2. Materials and methods

This international, two-centre study was conducted prospectively in two Asian countries (India and South Korea) with the purpose

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of determining the incidence of inherent varus among a large cohort of healthy, young adults and factors influencing it. The aim was to simultaneously recruit 100 healthy, asymptomatic adult volunteers between the age group of 20 and 40 years from each centre for this radiographic study over a 3-month period from January 2010 to March 2010. Ethics committee approval was obtained at both the centres before the start of the study. An informed consent was obtained from every volunteer who participated in the study.

The study participants were recruited from among hospital staff, relatives accompanying patients attending hospital OPDs and a nearby university campus using printed flyers/posters highlighting aims of the study and the inclusion criteria for participation. The inclusion criteria for participation in this study were healthy, asymptomatic, adult volunteers between the age group of 20 to 40 years who provided informed consent for participation in the study. All volunteers were interviewed by an investigator before participation regarding any symptoms related to the lower limb such as pain, instability or deformity especially in relation to the knee joint in the present or past. Exclusion criteria were a history of having symptoms previously listed, any fracture or major trauma to the lower limbs at any time in the past, and a history of having undergone any musculoskeletal-related surgical procedure on the lower limbs. During evaluation of radiographs, all full-length radiographs which were considered unsuitable for measurement owing to poor visibility of centre of the femoral head or excessive rotation of the limb as judged by the profile of the lesser trochanter and the fibula were excluded from analysis.

All volunteers had a digital, full-length, standing hip-to-ankle radiograph taken using a standard radiographic protocol at each institution. Both lower limbs were positioned with knees in full extension, patellae facing forward and both feet pointing forwards to avoid malrotation of the limb during radiography. A lead shield which covered and protected the pelvis from radiation was used in all volunteers during radiography. The x-ray beam was centered at the knee joints from a distance of 210 cm and a graduated lead loaded collimeter grid was used in front of the x-ray tube so that the entire lower limb from the hips to the ankles received equal amount of radiation minimising distortion and optimising exposure. Digital images of these radiographs were copied and used for measuring various radiographic parameters using the Image J image processing and analysis software (version 1.41, U.S. National Institute of Health).

Angles measured on full-length radiograph are illustrated in Fig. 1. The center of the hip joint was located using a digital "plus" shaped cursor whose centre superimposed on the centre of the femoral head and divided the head into four equal quadrants. A point just above the center of the tibial spines was taken to be the center of the knee joint as it was the most consistent point which was least affected by any minor rotational malpositioning during imaging. The center of the ankle joint was visually selected as the midpoint of the dome of talus. The mechanical axis of femur was drawn from centre of the femoral head to centre of the knee joint. The mechanical axis of tibia was drawn from center of the knee joint to center of the ankle joint. The limb mechanical alignment at the knee or the hip–knee–ankle (HKA) angle was measured as the medial angle between the two axes. The angle between mechanical axis of tibia and tangent to the medial tibial plateau termed as the medial proximal tibial angle (MPTA) was measured for assessment of tibial plateau orientation in coronal plane. If the angle was less than 90º, it was considered to have varus orientation and vice versa. The amount of coronal bowing of the femoral shaft was also measured as the angle between the line drawn from the midpoint of the medullary canal at the level of the lesser trochanter to a distal reference point and the line from the distal reference point to the midpoint of the medullary canal 10 cm proximal to the knee [13]. The neck–shaft angle (NSA) was measured as the angle formed medially between the line joining the centre of the femoral head and the midpoint of the femoral neck base and the anatomic axis of the proximal femur [14]. All the measurements were performed by a single observer at each study centre by

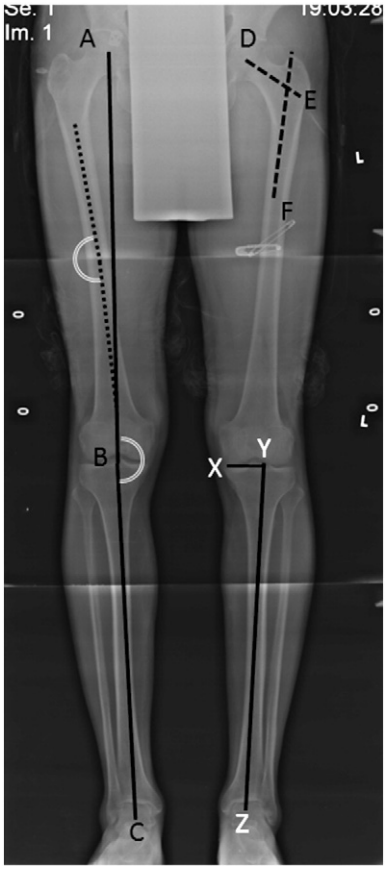

Fig. 1. Various parameters measured on full-length standing hip-to-ankle radiograph. angle ABC — hip–knee–ankle angle, angle DEF — neck shaft angle, angle XYZ — medial proximal tibial angle. Femoral bowing measured as the angle made by the mid-diaphyseal lines of the proximal half and distal half of the femoral shaft (dotted line) which is 177.5° in this subject.

locating the landmarks digitally with the help of tools available in the software. Angles measured on full-length hip-to-ankle radiographs are reportedly reliable. Apart from the radiographs, details of age, gender, height, weight, and body mass index (BMI) was collated by the investigators. Knees were considered in "normal" alignment if the HKA angle was 180° ± 3°, in inherent varus if the HKA angle was <3° from normal alignment (i.e. HKA angle <177°) and in valgus if HKA angle was >3° from normal alignment (i.e. HKA angle >183°). Similarly, subjects having a femoral bowing of >5° were considered to have excessive femoral shaft bowing in the coronal plane [13,15]. The neck–shaft angle was considered normal if it was within the range of 120°–130°, in varus if <120° and in valgus if >130° [14,16].

A total of 105 volunteers from the Indian population and 100 volunteers from the Korean population were recruited within the 3-month study period. Based on their full-length radiographs, five Indian participants and six Korean participants had to be excluded as their radiographs were found to be unsuitable for measurements. Hence, data from 200 limbs (100 volunteers) in the Indian population and 188 limbs (94 volunteers) in the Korean population was available for analysis. Percentages of limbs in each alignment group were calculated overall and for each of the two population groups. A multiple regression analysis was performed to determine the effect of height, weight, BMI, gender, femoral bow, medial proximal tibial angle (MPTA) and neck–shaft angle (NSA) on the HKA angle. Data between groups were compared using Student's *t*-test and Fisher's exact test and a p value of <0.05 was taken to be statistically significant. Statistical analysis of the pooled data was performed by a statistician using the SPSS 16.0 statistical software (SPSS Inc, Chicago, IL, USA).