Introduction: The role of lower limb alignment in the development of knee osteoarthritis (OA) has not been clearly defined. Varus or valgus alignment angles have been associated with progression of disease, but the relationship between alignment and the onset of OA remains uncertain. The roles of gender and ethnicity in anatomic variations are also poorly defined. Differences in knee anatomy have been identified in populations that use frequent kneeling activities on a daily basis, such as in the Japanese population [Tamari et al 2006]. Accounting for alignment and other anatomic variations could impact total knee replacement (TKR) design, by improving function or prolonging life of the implant. The objective of this study was to use MR imaging of the hip, knee and ankle to obtain lower limb alignment (HKA) angles, tibial torsion, and tibial widths, and measurements of ACL laxity to identify significant differences between populations and gender. Statistical analysis also investigated correlations of these factors with each other and with general anthropometric measures.

Materials and Methods: MR images of the hip, knee, and ankle were acquired for 97 healthy adult volunteers. Three categories were established, based either on ethnicity or frequency of kneeling activity: Caucasian (24 female, 23 male); Japanese (12 female, 11 male) and a frequent kneeler category (12 female and 11 male) that included people who were Muslim, or participated in sports or other daily activities requiring substantial time in a deep knee flexion position. A GE Signa Excite 1.5 T clinical scanner was used for all MR images, with a phased array surface coil. Coronal images of the knee were acquired with a fast 3D gradient echo sequence (TE: 3 ms, TR: 9 ms, flip angle: 35°, 0.55 mm/pix in-plane resolution, 1.0 mm thick slices, imaging time: ~7 min.). Coronal MR images were also acquired at the hip and ankle joints (TE: 7.7 ms, TR: 3.2 ms, Flip Angle: 35°, NEX: 1.5, 0.94mm/pix in-plane resolution, 2 mm slice thickness, imaging time: ~2 min.). Hip and ankle images were acquired by moving the subject table without re-landmarking the MR system. Therefore, all inferior/superior locations were in the same global coordinate system. The knee coronal imaging planes were adjusted to align with the posterior surfaces of the femoral condyles. The hip joint center was identified as the mid-point of the femoral head, and the ankle joint center as the mid-point between the malleoli. The knee center was identified as the midpoint between the tips of the medial and lateral tibial spines at the slice where peak medial height occurred. Lower limb varus/valgus alignment was then calculated using the mechanical axes of femur and tibia in the coronal plane parallel to the posterior edge of the femoral condyles [Hovinga 2007]. Tibial torsion measurements were measured as previously described by Jend et al. [1986]. Using the coronal knee and ankle images re-sliced into the axial plane, the posterior edge of the proximal tibia and a line defining the shortest distance between the center of the distal tibia and the tangential line drawn to the fibular notch were used to define the tibial torsion angle. Tibial widths were measured parallel to the posterior edge of the tibia in the axial plane. Medial and lateral widths were then defined using the knee center identified from the HKA angle measurement. ACL laxity measurements were recorded using a KT-1000 device. A manual anterior drawer test using the device was conducted until three consistent measurements were recorded.

Results: Significant differences were found in HKA alignment measurements between genders, with men more varus than women (p<0.01) (Fig 1a). While differences in alignment were not significant between cultures and activities, there were trends for the Japanese to have higher varus alignment than the other populations. Tibial torsion measurements showed significant differences based on ethnicity (p<0.01), however no significant differences in gender (Fig 1b). Although tibial widths were greater in males than females (p< 0.0001), the ratio between medial and lateral widths were not significantly different by gender or ethnicity (Fig 1c). The M/L ratio was also not correlated with alignment angles. Significant differences were found for both gender (p=0.002) and ethnicity (p=0.001) in laxity measurements (Fig 1d). No correlations were found between alignment, tibial torsion, tibial width ratios, and laxity measurements. Tibial widths were correlated to height (R2 =0.40), and bodyweight (R2 =0.34).

Discussion: Our study identified significant differences between populations (gender and/or ethnicity) in alignment, tibial torsion, tibial width and laxity measurements. In particular, the Japanese population exhibited greater knee laxity, a lower tibial torsion angle and a trend toward a higher varus HKA alignment. While it is possible that these anatomic differences may be associated with kneeling activities during development, no significant differences were found between the Caucasian and frequent kneeler categories. Unfortunately, variability in the type and frequency of kneeling activities may have contributed to anatomic variability in the frequent kneeler category. Results of an activity questionnaire are currently being analyzed to consider further stratification of this group. Because of the demand for high flexion activities in these populations, further investigation into these anatomic variations may reveal a need and approach for customization of knee implants.


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