# Goniometric alignment of the normal knee joint and the factors which affect it

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## Abstract

*Objectives* Establishing a normative database for anterior plane knee joint alignment in a population is helpful in assessing patients with disorders of the knee joint specially osteoarthritis. Therefore we aimed at establishing the normal alignment in the Sri Lankan adult population using the goniometer which is an inexpensive and simple method of measurement.

*Methods* A total of 420 healthy adult volunteers (210 men and 210 women) above 25 years of age were recruited and the anterior plane knee alignment was measured using a hand held metal goniometer.

*Results* The mean knee joint alignment was 180.56° (SD 2.39) and 183.04° (SD 2.34) in males. The knee joints of the females were varus-oriented by, 2.48° than those of males ($p< 0.0001$). In the females the knee joint alignment showed a gradually varus inclination with increasing age ($p< 0.05$). Lifting heavy weights in males caused a significant varus inclination of the knee joint while BMI and squatting for long periods did not have an effect on the normal alignment.

*Conclusions* Female knees are more varus inclined than that of males in the Sri Lankan participants and this inclination increases with age. Reasons for this could be genetic and lifestyle differences and may partly explain the reason for the predominance of varus osteoarthritis in Sri Lankan females.

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## Introduction

The knee is a complex synovial joint of the hinge variety, formed between the distal end of the femur and the proximal end of the tibia and is one of the largest weightbearing joints in the body. It has two compartments, and weight distribution to each is dependent on the alignment between the femur and the tibia. The alignment of the knee joint is the angle formed between the axis of these two bones in the anterior plane. While several methods are employed to measure this angle, the gold standard is the mechanical angle. The mechanical angle is measured on a full length anteroposterior weight bearing limb radiograph extending from the hip to the ankle [1]. The mechanical angle in caucasian males is reported as 178.3° (SD 2) [1]. When the alignment is within this range the knee is considered as neutrally aligned. Knees with an alignment angle less than the lower limit of normal range are classed as varus and knees which have an alignment more than the upper limit are classed as valgus.

Disease processes involving the knee can affect its alignment. Osteoarthritis (OA) is one such disease. Several studies have proven that a change in the knee joint alignment (KJA) is a major contributor to the progression of OA [2, 3]. Further studies have shown that varus or valgus alignment increase the risk of development of OA [4, 5].

Measurement of the KJA in patients with chronic knee disorders is not carried out as a routine procedure at orthopedic units in Sri Lanka. The reasons for this may be the lack of facilities to obtain a full length limb radiograph and the procedure exposes the patient to a high level of radiation. Researchers trying to establish normal knee alignment values also have problems recruiting volunteers for their studies due to this reason [6].

Another simpler but equally accurate method of measuring this angle is by the goniometer which is a physical measurement method and causes no discomfort or health risk to the participants [7, 8]. If the KJA measured by the goniometer can be established in a healthy normal population, it will encourage medical professionals to use this simple method to perform routine measurements of the alignment in examination of the diseased knees and interpret the findings based on population norms. However, such comparison would require a representative normative database specific for the population studied. As the normal alignment of the knee joint may differ between races due to differences in the build of the body, Western values cannot be used as representative norms for South Asian populations. Therefore, the main aim of the present study was to create a normative database for knee alignment angles for Sri Lankan adult males and

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females, which have not been established hitherto. The present study also aims to examine the association between the KJA and a number of potential risk factors for OA namely age, BMI, lifting heavy weights in the occupation and prolonged habitual squatting [9-11].

## Methods

The study was conducted at the Faculty of Medicine, University of Peradeniya, Sri Lanka from 2010 to 2012. Approval was granted by the Committee on Research and Ethical Review of the Faculty of Medicine, University of Peradeniya. The study population consisted of persons accompanying the patients attending the Out Patient Department of Teaching Hospital Peradeniya and the Nuclear Medicine Unit, Faculty of Medicine, University of Peradeniya. Study sample was recruited on randomly selected days during the study period. Clinic number of patients were chosen randomly and the accompanying persons of these patients were selected until the desired number of participants was recruited. An online random number selection program (Research Randomizer©) was used to select the days of the month and the clinic numbers. Written informed consent was obtained from each participant.

A total of 420 healthy adult volunteers (210 females and 210 males), over the age of 25 years were recruited for the study. Detailed accounts of the type of occupation, with special reference to lifting of heavy weights were recorded. The average number of hours spent in the squatting position per day was also documented. A detailed medical history was taken from all potential participants. Individuals with a history of pain, disease or injury to the knee, hip or ankle joint and those with a history of open surgery to the lower limb joints were excluded from the study (n=39).

Frontal plane knee joint alignment was measured with a hand-held goniometer by a single investigator according to the method described before [7]. Measurements were taken with the participant in an erect standing position, bare foot with toes placed forward and feet placed a shoulder-width apart. The centre of the patella and the centre of the ankle were located and marked with a pen. The centre of the goniometer was placed on the centre of the patella and the fixed arm of the goniometer was placed vertically along the thigh visually bisecting it. The movable arm was placed on the long axis of the lower leg proximally along the first 4-5 cm of the subcutaneous border of the tibia and distally in line with the middle of the ankle. The measurement of the angle on the medial aspect of the knee joint was read up to 1 degree on the protractor.

The mean KJA was calculated for males and females separately. The effects of potential factors affecting the KJA (viz. age, BMI, lifting heavy weights, prolonged squatting) on knee alignment were examined in both sexes in multiple linear regression models. Statistical analyses were done using the statistical software SPSS® version 16.0.

## Results

The descriptive statistics of the sample is given in Table 1. The mean knee joint alignment was 180.56° (SD 2.39) in females and 183.04° (SD 2.34) in males. The knee joint of females had a 2.48° varus angulation than that of males ($p< 0.0001$). Females had a higher BMI than males ($p= 0.02$). KJA in females in the normal, overweight and obese BMI groups are given in Table 2.

**Table 1. Descriptive statistics of males and females**

| | *Males (n = 210)* | *Females (n = 210)* |
|---|---|---|
| Mean age (SD) years | 55.2 (19.0) | 54.8 (18.3) |
| Mean BMI (SD) | 22.7 (2.9) | 23.5 (4.4) |
| Number of participants lifting heavy weights | 14 (6.7%) | 10 (4.7%) |
| Number of participants spending >3h/day in squatting position(n) | 7.6% (16) | 21% (44) |
| Mean knee joint angle (SD) | 183.04 (2.34) | 180.56 (2.39) |

**Table 2. KJA for each BMI group in females**

| *BMI group (range)* | *Mean knee alignment (SD)* |
|---|---|
| Normal (18.9-22.9) | 180.9 (2.4) |
| Overweight (23-27.5) | 180.7 (1.9) |
| Obese (>27.6) | 178.7 (2.1) |

BMI – Body mass index

Multiple regression models that examined potential factor affecting the knee joint angle in males and females are given in Tables 3 and 4, respectively. After adjusting for other factors, only lifting heavy weights remained significantly associated with KJA of males (Table 3). Men who lifted heavy weights had a mean varus angulation of 2.114° compared to those who did not lift heavy weights ($p= 0.001$). For females, multiple linear regression revealed age as a significant factor that determines KJA (Table 4). A 0.35° of varus angulation with each decade of advancing age was observed in females ($p= 0.0002$). The age-knee alignment correlation of both males and females is shown in Figure 1. Similar to their male counterparts, more females who lifted heavy weights had a varus angulation than those who did not, but the difference was not statically significant ($p= 0.116$).

**Table 3. Multiple linear regression of knee alignment in males**

| *Factor* | *Unstandardized coefficient (degrees)* | *SEM (degrees)* | *Significance (p)* |
|---|---|---|---|
| Age | 0.001 | 0.008 | 0.885 |
| BMI | 0.038 | 0.056 | 0.493 |
| Lifting heavy weights | -2.114 | 0.636 | **0.001** |
| Prolonged squatting | -0.308 | 0.614 | 0.614 |
| Overall model: Adjusted $R^2$ = 0.037, $p$ = 0.020 | | | |

SEM – Standard error of means

**Table 4. Multiple linear regression of knee alignment in females**

| *Factor* | *Unstandardized coefficient (degrees)* | *SEM (degrees)* | *Significance (p)* |
|---|---|---|---|
| Age | -0.035 | 0.009 | **0.0002** |
| BMI | -0.029 | 0.037 | 0.427 |
| Lifting heavy weights | -1.185 | 0.751 | 0.116 |
| Prolonged squatting | -0.442 | -.400 | 0.270 |
| Overall model: Adjusted $R^2$ = 0.081, $p$ = 0.0003 | | | |

SEM – Standard error of means

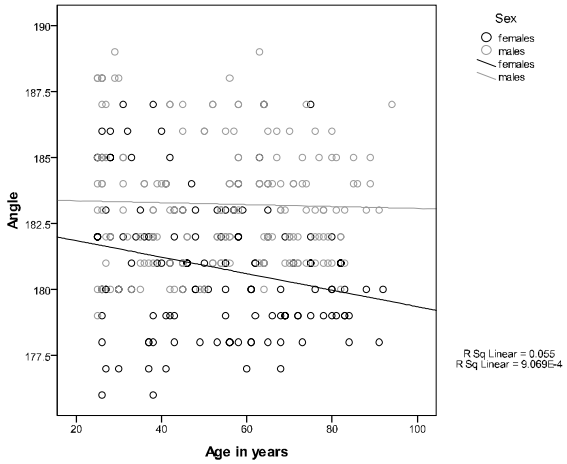


Figure 1. **Age-KJA correlation in males and females.**

## Discussion

Although methods such as radiological and goniometric techniques have been used in the measurement of the knee joint alignment (KJA), the goniometric method being non-invasive, demonstrated the possibility of recruiting a large number of participants (420 adults) for the study, with almost 100% compliance [1,3,7,12].

The KJA observed in this study were 180.56º in female and 183.04º in males, respectively. The readings are more varus oriented than that observed by Kraus *et al* who reported 183.97º in female and 185.89º in males. The observed KJA difference between sexes in this study is similar to that reported before [7].

The current study shows an increasing varus orientation of the knee joint with increasing age in females, but not in males. This gender difference in age-related changes in KJA could be related to endocrine factors. Females loose the protective effect of oestrogen on articular cartilage with aging, especially following menopause [7, 14]. Because in neutrally aligned limbs, the medial compartment bears 60%-70% of the force across the knee during weight-bearing, wear and tear on the medial compartment of the knee causes more is more causing varus angulation with advancing age. In contrast males retain the anabolic effects of androgens for a longer period of their life span thus protecting the articular cartilages against wear and tear and the joint ligament from weakening [14]. The age-related deformation of KJ could

predispose individuals to osteoarthritis in which a main feature is pathological levels of varus angulation of the knee joint. Thus it can be speculated that age-related varus angulation is a biomechanical predisposing factor for osteoarthritis which is more common among women.

The BMI did not seem to affect the KJA in either of the sexes. However in the females there was a significant difference between the KJA values in the normal (< 23) and obese group (>27.6). BMI is known as a significant and independent predictor for the development and progression of knee OA and its effect is stronger in women than in men [15-17]. Recently it has been suggested that the relationship between obesity and knee OA may be mediated through changes in knee joint alignment [18].

Males involved in lifting heavy weights had more varus oriented knees and this was statistically significant, even after adjusting for age and BMI. This group included labourers had carried very heavy loads for more than 5-10 years, placing their knees under a huge strain daily. In 14% the sample were in the squatting position for 3 hours or longer during the day. However this did not seem to affect the KJA in either of the sexes.

In conclusion the participants in the present study have more varus inclined knees than the values recorded for the Western population and the female knee is more varus oriented and the varus orientation increases with advancing age and those with occupations requiring lifting of heavy weights. This normative data base in a healthy adult population can be used as a reference when measuring the KJA in patients with disease of the knee.

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