# Normal knee angles in the adult Saudi population

*Ahmed F. El Fouhil, MSc, PhD, Khalid I. Khoshhal, FRCS, ABOS, Nizar A. Al-Nakshabandi, MD, FRCPC, Ahmed A. Al-Boukai, MD, FRKSU, Muhammad Atteya, MSc, PhD.*

## ABSTRACT

**الأهداف:** دراسة زوايا الركبة عند السعوديين البالغين، ومقارنة قيمها بالمعلومات المنشورة الخاصة بالشعوب الأخرى.

**الطريقة:** أُجريت هذه الدراسة في مستشفى الملك خالد الجامعي، الرياض، المملكة العربية السعودية خلال الفترة من يناير إلى ديسمبر 2009م. تمت دراسة الأشعة الأمامية الخلفية لناحيتي الجسم لعدد 333 ركبة سليمة منها 120 ذكر و213 أنثى وبمدى عمري يتراوح من 18–65 عاماً. و قد تم قياس الزاوية القصبية الفخذية، والزاوية الوحشية الفخذية القاصية، والزاوية الوحشية القصبية الدانية، وحساب متوسط كل منهم. كما تم اختبار علاقة كل زاوية بالعمر والجنس وناحية الجسم ومقارنتها بمثيلاتها من الشعوب الأخرى.

**النتائج:** بلغ متوسط الزوايا القصبية الفخذية والوحشية الفخذية القاصية والوحشية القصبية الدانية عند الشعب السعودي 174.41°، 90.07°، 89.42° على الترتيب. و قد ظهر عدم ارتباط أي من الزوايا بالجنس. ولكن ظهر ارتباط الزاوية القصبية الفخذية بناحية الجسم، والزاوية الوحشية الفخذية القاصية بالعمر. كما ظهرت اختلافات بين متوسط ومدى الزوايا عند الشعب السعودي ومثيلاتها من الشعوب الأخرى، فقد وُجد اختلافاً ملحوظاً بين متوسط كل الزوايا عند السعوديين ومتوسطها عند الأوروبيين والأمريكيين، وبين متوسط الزاوية القصبية الفخذية عند السعوديين ومتوسطها عند الصينيين، وبين متوسط الزاوية الوحشية القصبية الدانية عند السعوديين الذكور ومتوسطها عند الصينيين الذكور. كما ظهر اختلافاً ملحوظاً بين متوسط الزاوية القصبية الفخذية لفئات عمرية منتقاة من الشعب السعودي ومتوسطها لنفس الفئات العمرية من الشعب الياباني والأسترالي.

**خاتمة:** تعزز الدراسة الحاجة إلى تحديد القيم المرجعية لزوايا الركبة لكل شعب على حدا.

**Objectives:** To study knee angles in the adult Saudi population and compare their values to the published data from other populations.

**Methods:** Antero-posterior bilateral radiographs of 333 normal knees of 120 males and 213 females, with age range of 18-65 years, were studied retrospectively at King Khalid University Hospital, King Saud University, Riyadh, Saudi Arabia, from January 2009 to December 2009. Tibiofemoral (TFA), lateral distal femoral (LDFA), and lateral proximal tibial (LPTA) angles were measured and the mean of each angle was calculated. The relationship between each angle and age, gender, and side of the body was tested, and compared with the international figures.

**Results:** The mean for TFA in Saudis was 174.41°, LDFA was 90.07° and LPTA was 89.42°. All angles were not significantly related to gender. Significant relations existed between TFA and side of the body, and between LDFA and age. Variations in means and ranges of knee angles between the Saudi and other populations were determined. A significant difference existed between means of TFA, LDFA, and LPTA of Saudis and those of Caucasians, between mean of TFA of Saudis and that of Chinese, and between mean of LPTA of Saudi males and that of Chinese males. The means of TFA of selected age groups in Saudis differed significantly when compared to those in the corresponding age groups in Japanese and Australian Caucasians.

**Conclusion:** Knee angles are like many other skeletal angles that may have ethnic variation between different populations. The study reinforces the need for reference values of knee angles in a given population.

***Saudi Med J 2011; Vol. 32 (11): 1143-1148***

*From the Department of Anatomy (El Fouhil, Atteya), Department of Radiology (Al-Nakshabandi, Al-Boukai), College of Medicine, King Saud University, Riyadh, and the Department of Orthopedics (Khoshhal), College of Medicine, Taibah University, Al-Madinah Al-Munawarah, Kingdom of Saudi Arabia.*

*Received 28th June 2011. Accepted 13th September 2011.*

*Address correspondence and reprint request to: Dr. Ahmed F. El Fouhil, Department of Anatomy, College of Medicine, King Saud University, PO Box 2925 (28), Riyadh 11461, Kingdom of Saudi Arabia. Tel. +966 (1) 4671314. Fax. +966 (1) 4671300. E-mail: ahmedfathala@hotmail.com*

The knee joint is the largest and one of the most complex joints of the body. It is a weight-bearing joint, which allows free movement mostly in one plane and plays an important role in locomotion by shortening and lengthening of the lower limb. The weight of the body is supported on the vertically apposed ends of the 2 largest bones of the body, the femur and tibia. These together with ligaments, and the reinforcing effects of tendons, provide considerable stability for the joint especially during extension.[1] To understand deformities of the lower extremities, it is important to first understand and establish the parameters and limits of normal alignment. Axial alignment at the knee joint is investigated by studying knee orientation angles, between orientation lines of the joint and the axes of the bones. Knee joint orientation angles are referred as distal femoral and proximal tibial angles.[2] The configuration of the femoral neck is such that it overhangs the shaft and the anatomical axes of the femur and tibia do not coincide; these together result in the formation of the tibiofemoral angle. Such angle determines the functional adequacy of the knee joint.[1] Several methods for assessing knee angles have been utilized.[3,4] Establishing a range of normal values is of clinical importance in that it enables the physician to determine whether the knee angles are within normal limits. Knowledge of the normal range of values of the knee angles in the population is essential to orthopedic surgeons in the reconstruction and management of angular deformities.[3] Although many studies have been conducted to establish mean values for the knee angles, data describing normal limits for these measurements are lacking for different ethnic groups, particularly in Middle East countries. Reports from the African countries[1,3] suggested that the Caucasian ranges may not be appropriate for Africans and the same could be applied for Saudis. Previous report from the research group of the present study[5] showed the difference between the Saudi and various other populations in regard to Böhler's and Gissane's angles of the calcaneus. Therefore, the aim of this study is to provide anthropometric baseline data concerning the range of normal values of the knee angles in the adult Saudi population for practicing orthopedic surgeons in Saudi Arabia and compare their values to the published data from other populations.

## Methods.

In this retrospective study, we reviewed 333 antero-posterior bilateral radiographs of the knee, with an age range of 18-65 years (mean 40.38 years), collected from King Khalid University Hospital, King Saud University, Riyadh, Saudi Arabia, from January 2009 to December 2009. The study has been approved by the Institutional Review Board, College of Medicine, King Saud University. The radiographs comprised knee joints of both sides of 120 males and 213 females. They were obtained in the standing position. All radiographs were of normal limbs without congenital or acquired deformities and with no arthritic changes. Only radiographs in which extremity was positioned with the patella straight ahead were used.

***Measurement of tibiofemoral angle.***[3] On each radiograph, 2 longitudinal axes, one through the center of the femoral shaft (anatomic axis of femur), and one through the center of the tibial shaft (anatomic axis of tibia), were drawn. The tibiofemoral angle (TFA) lying between the 2 axes was measured (**Figure 1**).

***Measurement of femoral and tibial angles.***[2] The frontal plane knee joint orientation line of the distal femur was drawn as a line tangential to the most distal points on the convexity of the 2 femoral condyles. The plane knee joint line of the proximal tibia was drawn across the flat or concave aspect of the subchondral line of the 2 tibial plateaus. The lateral angle formed between the anatomic axis of the femur and the knee joint line of the femur lateral distal femoral angle (LDFA) was measured. Similarly, the lateral angle formed between the anatomic axis of the tibia and the knee joint line of the tibia lateral proximal tibial angle (LPTA) was also measured (**Figure 2**).

All computed radiographs were obtained on Digital x-ray system (Advantex, General Electric Medical Systems, Milwaukee, WI, 40 KV, 4 mA). Images were reviewed on a Picture Archiving and Communicating

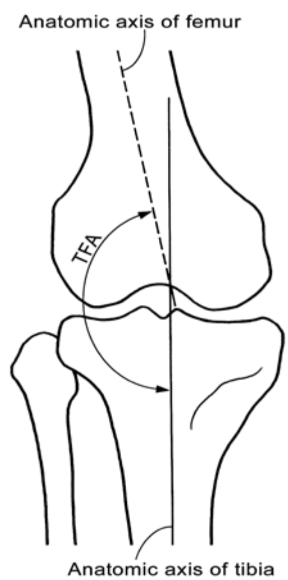


**Figure 1** - Antero-posterior view of knee joint showing tibiofemoral (TFA) angle.

**Disclosure**. Authors have no conflict of interests, and the work was not supported or funded by any drug company.

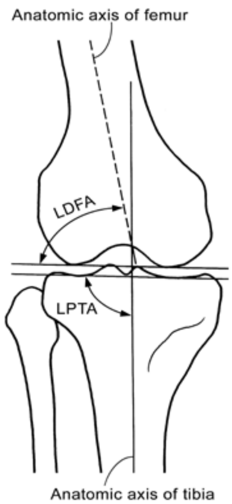


**Figure 2 -** Antero-posterior view of knee joint showing lateral distal femoral (LDFA) and lateral proximal tibial (LPTA) angles.

**Table 1 -** Age and angle measurement in all Saudi cases (N=333).

| Variable | Mean±SD | Range | 95% CI |
|---|---|---|---|
| Age (years) | 40.39±11.57 | 18.00-65.00 | 39.14-41.64 |
| Rt TFA | 174.17±2.36 | 165.20-177.20 | 173.92-174.42 |
| Rt LDFA | 90.05±3.85 | 78.40-99.10 | 89.64-90.47 |
| Rt LPTA | 89.23±2.72 | 81.40-99.40 | 88.94-89.52 |
| Lt TFA | 174.64±1.65 | 168.00-177.00 | 174.46-174.82 |
| Lt LDFA | 90.09±2.21 | 81.90-94.90 | 89.85-90.33 |
| Lt LPTA | 89.61±2.32 | 83.70-97.60 | 89.36-89.86 |
| Mean TFA | 174.41±1.75 | 169.05-177.10 | 174.22-174.60 |
| Mean LDFA | 90.07±2.65 | 81.80-95.94 | 89.78-90.36 |
| Mean LPTA | 89.42±1.93 | 83.10-93.60 | 89.21-89.63 |

Rt - right, Lt - left, TFA - tibiofemoral angle, LDFA - lateral distal femoral angle, LPTA - lateral proximal tibial angle, SD - standard deviation, CI - confidence interval

System (PACS) Monitor (Centricity, version 1-Ø CSR4 Service Pack 1, General Electric Medical Systems, Wisconsin, USA). All angles were obtained by utilizing a virtual Electronic Goniometer by 2 consultants independently, then the average of their readings were taken.[5]

***Statistical analysis.*** Results were expressed as mean ± standard deviation. A 95% confidence level was used to calculate a confidence interval, which is a range of values around the mean where the "true" (population) mean can be expected to be located, with 95% certainty. T-test for dependent samples was used to compare right and left angles. T-test for independent samples was used for comparing mean angles in males versus females. Analysis of variance (ANOVA) was used to compare mean angles between age groups followed by the post-Hoc Duncan test for multiple comparisons. Comparison with other studies was carried out using t test for independent samples. Results were considered significant when $p \leq 0.05$. The statistical software for data analysis used was the Statistical Package for Social Sciences version 16.0 (SPSS Inc, Chicago, Illinois, USA).

## Results.

**Table 1** shows the means (± standard deviation) and ranges of TFA, LDFA and LPTA of all cases. Comparison of the means of TFA, LDFA and LPTA of the right side to those of the left side in all cases studied showed a statistically significant difference in case of TFA. Comparison of the means of TFA, LDFA and LPTA of the right side to those of the left side in males showed a significant difference in case of TFA, while, in females, no significant difference was detected in any of the angles tested (**Table 2**). Comparison of the overall means (of both sides) of TFA, LDFA and LPTA of males to those of females showed no statistically significant difference in all angles (**Table 2**). Measured angles were divided according to age into 3 age groups. The age group ≥60 years had the lowest means for all angles studied. The age group 30-59 years had the highest means for all angles. Using analysis of

**Table 2 -** Comparison of tibiofemoral, lateral distal femoral angle, and lateral proximal tibial angle in Saudi males and females (N=333).

| Variables | Tibiofemoral angle | | | | Lateral distal femoral angle | | | | Lateral proximal tibial angle | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | Male | | Female | |
| Side | Right | Left | Right | Left | Right | Left | Right | Left | Right | Left | Right | Left |
| Mean ±SD | 174.09 ±2.25 | 174.81 ±1.63 | 174.22 ±2.43 | 174.54 ±1.67 | 89.50 ±3.91 | 90.35 ±1.39 | 90.35 ±3.81 | 89.94 ±2.56 | 89.85 ±1.21 | 89.82 ±1.36 | 88.88 ±3.24 | 89.50 ±2.72 |
| *P*-value | 0.018* | | 0.234 | | 0.140 | | 0.277 | | 0.838 | | 0.202 | |
| Overall mean±SD | 174.45±1.74 | | 174.38±1.76 | | 89.93±2.33 | | 90.15±2.83 | | 89.83±1.18 | | 89.19±2.22 | |
| *P*-value | 0.844 | | | | 0.680 | | | | 0.093 | | | |

*significant $p \leq 0.05$

variance (ANOVA), there was no statistically significant difference in both TFA and LPTA between the different age groups. A significant difference was present in case of LDFA between age group ≥60 years and those of 18-29 years and 30-59 years (**Figure 3**).

Comparison of the means of TFA of different age groups in Saudi population to those of corresponding age groups in Japanese and Australian Caucasians showed a statistically significant difference in all age groups (**Table 3**). Comparison of the means of TFA of Saudi males and females to those of Malawians, Europeans, Chinese and American Caucasians showed a significant difference from all of them, with the exception of Malawians (**Table 4**). Comparison of the mean of LPTA of Saudi males to those of Malawian, European, Chinese and American Caucasian males showed a significant difference from all of them, with the exception of Malawian males. There was a significant difference between the mean of LPTA of Saudi females and those of European and American Caucasian females, while no significant difference was found between the mean of LPTA of Saudi females and those of Malawian and Chinese females (**Table 5**). Comparison of the means of LDFA of Saudi males and females to those of Malawian males and females showed no significant difference. There was a significant difference between the means of LDFA of Saudi males and females compared to those of European males and females (**Table 6**).

**Discussion.** The purpose of the present study was to provide normative data on the knee angles in adult Saudis, and to compare their trends with those reported by previous studies. All radiographs, of the present study and of the compared population, were obtained in the standing position. Regarding TFA in the Saudi population, the present results showed that

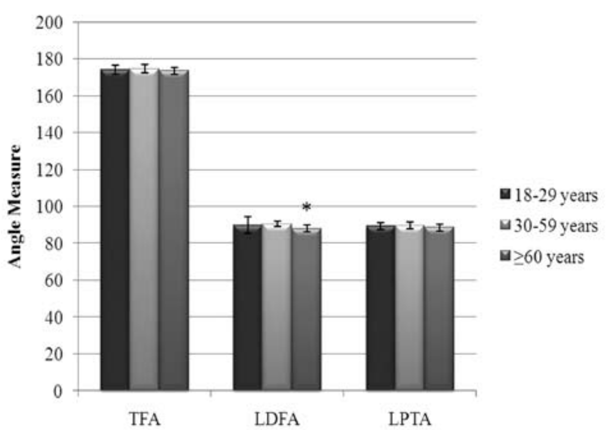


**Figure 3** - Comparison of means of tibiofemoral (TFA), lateral distal femoral (LDFA), and lateral proximal tibial (LPTA) angles between age groups in Saudis. *Significantly different from the other 2 groups ($p$≤0.05).

**Table 3** - Comparison of tibiofemoral angle among age groups in Saudi population (present study) versus Japanese and Australian Caucasian populations.[4]

| Population | Age groups | | | | | |
|---|---|---|---|---|---|---|
| | 18-29 years | | 30-59 years | | ≥60 years | |
| | n | Mean±SD | n | Mean±SD | n | Mean±SD |
| Saudi | 84 | 174.2±2.4 | 222 | 174.6±1.41 | 27 | 173.6±1.8 |
| Japanese | 30 | 180.9±2.8 | 51 | 179.7±2.6 | 39 | 180.5±2.9 |
| Australian | 26 | 178.5±3.1 | 31 | 178.1±2.2 | 25 | 179.2±2.0 |
| P1 | <0.0001* | | <0.0001* | | <0.0001* | |
| P2 | <0.0001* | | <0.0001* | | <0.0001* | |

P1 - $p$-value of Saudi versus Japanese population, P2 - $p$-value of Saudi versus Australian population, *significant ($p$≤0.05).

**Table 4** - Comparison of mean tibiofemoral angle among males and females in Saudi population (present study) versus Malawian,[3] European[8], Chinese,[7] and American Caucasian[6] populations.

| Population | Gender | | | |
|---|---|---|---|---|
| | Male | | Female | |
| | n | Mean ± SD | n | Mean ± SD |
| Saudi | 120 | 174.4±1.7 | 213 | 174.4±1.8 |
| Malawian | 219 | 174.1±3.5 | 104 | 174.5±4.3 |
| European | 25 | 173.1±1.4 | 25 | 172.5±1.9 |
| Chinese | 25 | 177.8±2.7 | 25 | 178.7±1.8 |
| American | 25 | 177.7±2.3 | 25 | 178.7±1.8 |
| P1 | 0.3778 | | 0.8613 | |
| P2 | 0.0005* | | <0.0001* | |
| P3 | <0.0001* | | <0.0001* | |
| P4 | <0.0001* | | <0.0001* | |

P1 - Saudi versus Malawian population, P2 - Saudi versus European population, P3 - Saudi versus Chinese population, P4 - Saudi versus American Caucasian population, SD – standard deviation, *significant ($p$≤0.05).

**Table 5** - Comparison of mean of lateral proximal tibial angle among males and females in Saudi population (present study) versus Malawian[1], European[8], Chinese,[7] and American Caucasian[6] populations.

| Population | Gender | | | |
|---|---|---|---|---|
| | Male | | Female | |
| | n | Mean±SD | n | Mean±SD |
| Saudi | 120 | 89.8±1.2 | 213 | 89.2±2.2 |
| Malawian | 219 | 89.6±2.9 | 104 | 89.1±3.2 |
| European | 25 | 93.5±3.5 | 25 | 92.4±2.5 |
| Chinese | 25 | 94.9±2.3 | 25 | 90.1±1.9 |
| American | 25 | 91.0±1.4 | 25 | 90.1±1.9 |
| P1 | 0.4708 | | 0.7452 | |
| P2 | <0.0001* | | <0.0001* | |
| P3 | <0.0001* | | 0.0511 | |
| P4 | <0.0001* | | <0.0001* | |

P1 - Saudi versus Malawian population, P2 - Saudi versus European population, P3 - Saudi versus Chinese population, P4 - Saudi versus American Caucasian population, *significant ($p$≤0.05)

**Table 6 -** Comparison of mean of lateral distal femoral angle among males and females in Saudi population (present study) versus Malawian[1] and European[8] populations.

| Population | Gender | | | |
|---|---|---|---|---|
| | Male | | Female | |
| | n | Mean ± SD | n | Mean ± SD |
| Saudi | 120 | 89.9±2.3 | 213 | 90.1±2.8 |
| Malawian | 219 | 89.4±5.6 | 104 | 90.0±5.2 |
| European | 25 | 80.2±2.0 | 25 | 81.2±2.0 |
| P1 | 0.3503 | | 0.8241 | |
| P2 | <0.0001* | | <0.0001* | |

P1 - Saudi versus Malawian population, P2 - Saudi versus European population, *significant ($p$≤0.05)

there was no significant difference in the angle with respect to age and gender. Similar reports on Africans (Malawians),[3] on American Causacians[6] and on Asians (Chinese)[7] further confirmed that TFA did not show sexual dimorphism as it does in Europeans.[3,8] Also, other reports on Asians (Japanese) and Australian Caucasians[4] found no significant difference in TFA with respect to age. An interesting finding was that the angle of the left side was significantly greater compared to that of the right side in overall Saudi cases and in Saudi males, while no significant difference in the angle with respect to the side of the body was found in case of females. The difference observed in overall cases and in males may not be clinically detectable, and whether it is clinically meaningful remains uncertain. However, it may raise the question of how accurate is the use of TFA of the normal side as a good control in orthopedic practice in Saudi Arabia. In Saudis, the age group ≥60 years had the lowest mean, while the age group 30-59 years had the highest mean for TFA. In contrast to Saudis, the age group 30-59 years had the lowest mean for TFA in Japanese and Australian Caucasians.[4] The age groups 18-29 years in Japanese and ≥60 years in Australian Caucasians had the highest means for TFA.[4] Comparison of the means of TFA of different age groups in Saudi population to those of corresponding age groups in Japanese and Australian Caucasians showed a statistically significant difference in all age groups. With regard to the mean values of TFA, the fact that differences do appear between Saudis (results of the present study), Africans,[3] Asians,[7] Europeans,[2,8] and American Caucasians[5] raises the question about the factors (genetic, dietary, environmental) that might explain these variations. In clinical practice, the diagnosis of knee angular deformities is dependent on the range of TFA. The present study suggested that the European ranges (170°-175°)[2,8] may not necessarily be appropriate for Saudis (165.2°-177.2°; results of the present study) whose angles are of wider range. Indeed, if the Europeans ranges were used, some normal Saudis would be wrongly diagnosed as having valgus or varus deformities. African ranges (164°-185°),[3] however, are wider than Saudi ones. In fact, looking at the different ranges reported strongly suggests establishment of country ranges that are appropriate for practicing orthopedic surgeons in their countries of domicile.Regarding LDFA and LPTA in the Saudi population, the present results showed that there was no significant difference in the means of these angles with respect to gender and side of the body. Furthermore, there was no statistically significant difference in the LPTA between different age groups. A significant difference was present in case of LDFA between age group ≥60 years and 18-29 years and 30-59 years. Lateral distal femoral angle and LPTA did not show significant gender differences in Africans[1] as it was reported in Europeans.[9,10] The means of LDFA and LPTA were significantly different compared to those of Europeans and American Caucasians, but not significantly different compared to Africans. From the present results, it appears that knee angles values of Saudis are close to those of Africans. However, a significant difference exists between knee angles values of Saudis and those of Caucasians, in general. Harvey et al[11] attributed the higher prevalence of knee osteoarthritis in Chinese compared with Caucasian population to the difference in knee alignment between the 2 populations. Accordingly, knee alignment differences might also be a potential explanation for the higher prevalence of knee osteoarthritis in Saudis (53.3%) compared to Caucasians (3.8-7.7%).[12]

This study had certain limitations. We only measured the anatomic, but not the mechanical angles of the knee joint. Measuring the mechanical angles needs radiographs comprising both hip and knee joints to determine the mechanical axis of the femur. The number of radiographs available was not sufficient to obtain relevant results.

In conclusion, knee angles are like many other skeletal angles that may have ethnic variation between different populations. The present study would stimulate further studies on normal angles related to other joints. Studying the range of each angle in a particular race may help in treatment decisions.[13]

## References

1. Igbigbi PS, Msamati BC, Matanje B. Normal axial angles of the knee joint in adult indigenous Malawians. *East Afr Med J* 2003; 80: 415-418.
2. Paley D. Normal lower limb alignment and joint orientation. In: Paley D, Herzenberg JE, editors. Principles of deformity correction. 3rd ed. New York (NY): Springer-Verlag; 2005. p. 1-18.

3. Igbigbi PS, Msamati BC. Tibiofemoral angle in Malawians. ***Clin Anat*** 2002; 15: 293-296.
4. Tamari K, Tinley P, Briffa K, Aoyagi K. Ethnic-, gender-, and age-related differences in femorotibial angle, femoral antetorsion, and tibiofibular torsion: Cross-sectional study among healthy Japanese and Australian Caucasians. ***Clin Anat*** 2006; 19: 57-69.
5. Khoshhal KI, Ibrahim AF, Al-Nakshabandi NA, Zamzam MM, Al-Bokai AA, Zamzami MM. Böhler's and Gissane's angles of the calcaneus in the Saudi population. ***Saudi Med J*** 2004; 25: 1967-1970.
6. Ilahi OA, Kadakia NR, Huo MH. Inter- and intraobserver variability of radiographic measurements of knee alignment. ***Am J Knee Surg*** 2001; 14: 238-242.
7. Felson DT, Nevitt MC, Zhang Y, Aliabadi P, Baumer B, Gale D, et al. High prevalence of lateral knee osteoarthritis in Beijing Chinese compared with Framingham Caucasian subjects. ***Arthritis Rheum*** 2002; 46: 1217-1222.
8. Bach CM, Steingruber IE, Peer S, Nogler M, Wimmer C, Ogon M. Radiographic assessment in total knee orthroplasty. ***Clin Orthop*** 2001; 385: 144-150.
9. Hovinga KR, Lerner AL. Anatomic variations between Japanese and Caucasian populations in the healthy young adult knee joint. ***J Orthop Res*** 2009; 27: 1191-1196.
10. Nelson AE, Braga L, Braga-Baiak A, Atashili J, Schwartz TA, Renner JB, et al. Static knee alignment measurements among Caucasians and African Americans: the Johnston County Osteoarthritis Project. ***J Rheumatol*** 2009; 36: 1987-1990.
11. Harvey WK, Niu J Zhang Y, McCree PI, Felson DT, Nevitt M, Xu L, Aliabadi P. Knee alignment differences between Chinese and Caucasian subjects without osteoarthritis. ***Ann Rheum Dis*** 2008; 67: 1524-1528
12. Al-Arfaj A, Al-Boukai AA. Prevalence of Radiographic Knee Osteoarthritis in Saudi Arabia. ***Clin Rheumatol*** 2002; 21: 142-145.
13. Escamilla RF, Zheng N, Macleod TD, Brent Edwards W, Imamura R, Hreljac A, et al. Patellofemoral joint force and stress during the wall squat and one-leg squat. ***Med Sci Sports Exerc*** 2009; 41: 879-888.


**Related topics**


Chen YS, Zhao S, Cao L, Zhang XL. Gait analysis of patients with metal-on-metal resurfacing hip arthroplasty compared with big-femoral-head total hip arthroplasty. ***Saudi Med J*** 2011; 32: 394-399.

Ahmed AR, Abd-Elkader SM, Al-Obathani KS. Effect of a 6-week rehabilitation program on gait parameters after total knee arthroplasty. ***Saudi Med J*** 2010; 31: 1032-1035.

Haflah NH, Jaarin K, Abdullah S, Omar M. Palm vitamin E and glucosamine sulphate in the treatment of osteoarthritis of the knee. ***Saudi Med J*** 2009; 30: 1432-1438.

Al-Omran AS, Sadat-Ali M. Arthroscopic joint lavage in osteoarthritis of the knee. Is it effective? ***Saudi Med J*** 2009; 30: 809-812.