Variations in Torsion of the Lower Limb in Japanese and Caucasians with and without Knee Osteoarthritis

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ABSTRACT. ***Objective.*** Associations between torsion of the lower limb and knee osteoarthritis (OA) appear to be inconsistent across populations. We examined whether femoral and tibiofibular torsion differed between people with and without knee OA (main effect), and whether the differences were consistent across Japanese and Australian Caucasian persons, and between women and men (interaction effect).

Methods. Data collection was conducted in Japan and Australia. Subjects with knee OA included 100 Japanese and 102 Australian Caucasians, and healthy subjects included 52 Japanese and 34 Australian Caucasians. Femoral and tibiofibular torsion were measured using reliable clinical techniques. Three-way analysis of variance was conducted to examine the main and interaction effects.

Results. While there were no significant differences in femoral and tibiofibular torsion between the subjects with and without knee OA as a whole (main effect), there were significant interactions ($p < 0.05$). Femoral antetorsion was lower only in the female subjects with knee OA compared with their healthy counterparts ($p < 0.05$). Tibiofibular torsion was lower only in the Japanese subjects with knee OA compared with their healthy counterparts ($p < 0.01$).

Conclusion. There may be ethnic and sex variations in the relationship between torsion of the lower limb and knee OA; and lower tibiofibular torsion can be a characteristic in a Japanese population with the disease. Longitudinal study is warranted to examine relationships between these variables and knee OA in a population-specific manner to determine whether the observed relationships express cause or effect. (J Rheumatol 2007;34:145–50)

Key Indexing Terms:
OSTEOARTHRITIS KNEE TIBIOFIBULAR TORSION
FEMORAL ANTETORSION VARIATION

The prevalence and incidence of osteoarthritis (OA) of the knee differs between different ethnic groups and the sexes[1]. For example, the incidence of knee OA is higher in women than men after age 50 years, and it increases with age, reaching 1% per year among women between age 70 and 79 years[2]. Further, Japanese females aged over 63 years have a higher prevalence of knee OA than corresponding American women[3]. Such differences do not appear to be entirely due to differences in the prevalence of established risk factors[4-7]. For example, obesity is strongly associated with knee OA, yet Japanese are, in general, considerably lighter than Caucasian people[8]. It appears that different factors may contribute to the prevalence of knee OA in different populations[9].

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Biomechanical studies reported that in people with and without knee OA there were significant relationships between smaller foot progression angle and greater adduction moment at the knee joint during walking, a moment that could result in increased dynamic load at the medial compartment of the joint[10-12]. Foot progression angle is an index of out-toeing angle, which is defined as the angle between the longitudinal axis of the foot and walking direction. A number of factors including torsion of the femur and tibia may be considered to influence foot progression angle during walking[13], and thus it is of interest whether there are relationships between these torsion angles and knee OA. However, the associations observed are inconsistent between different populations[14-16].

Japanese people with knee OA had smaller torsion angles of the tibia than their healthy counterparts, but femoral antetorsion was comparable between the healthy and knee OA groups[14]. On the other hand, femoral antetorsion was significantly lower in a Saudi Arabian population with knee OA than in their healthy counterparts, although tibial torsion was comparable between the healthy and knee OA groups[15]. The results in these studies suggest variations in the relationships between torsion of the lower limb and knee OA across different populations; however, no study has been conducted to confirm this. Therefore we examined whether there were consistent associations between knee OA and torsion of the femur and tibia, and whether any differences were specific to various populations.

The objectives of this multicenter study were to clarify whether femoral and tibial torsion differed between people with and without knee OA, and whether the differences were consistent across Japanese and Australian Caucasian people, and between women and men.

MATERIALS AND METHODS

Study design and variables. This cross-sectional study was multifactorial and comparative. The independent variables of interest were knee condition (healthy, knee OA), ethnic group (Japanese, Australian Caucasian), and sex (female, male) and the dependent variables were femoral antetorsion and tibiofibular torsion.

Subjects. Convenience samples of male and female volunteers over the age of 50 years with (n = 202) and without (n = 86) knee OA were recruited from Japan (n = 152) and Australia (n = 136). Subjects were recruited through advertisements in local newspapers and radio as well as through networks on university campuses, at community health centers, and hospitals. The Japanese group included Mongoloid subjects whose first spoken language was Japanese. The Australian group included Caucasian subjects who resided in Australia at the time of data collection. All Australian subjects resided in Western Australia, and Japanese subjects resided in Tokyo, Kanagawa, Fukushima, Nagano, Nagasaki, and Fukuoka. This study was approved by the Human Research Ethics Committee, Curtin University of Technology, Western Australia, and all subjects provided written informed consent prior to testing.

The presence or absence of knee OA was determined using the clinical classification algorithm developed by the American College of Rheumatology[17]. No radiographic or laboratory data were required for the algorithm. Severity of knee OA was assessed using the Index of Severity of Knee OA (ISK) developed by Lequesne and Samson[18]. Volunteers were excluded if they had rheumatoid arthritis, history of neuromuscular disease, or history of major knee surgery such as total knee arthroplasty or osteotomy. Volunteers classified as having no OA who reported pain during the testing period or who had history of joint injuries or musculoskeletal dysfunction of the lower limbs were also excluded. Due to testing procedures, those who could not lie prone or were so obese that bony landmarks could not be palpated were also excluded.

Testing procedures. Instrumentation for this study was as simple and portable as possible to facilitate collection of data at multiple sites and in 2 countries. All variables including femoral antetorsion and tibiofibular torsion were measured using an electronic digital inclinometer (FAS-A®; MicroStrain, Burlington, VT, USA) as described below.

Femoral antetorsion was defined as the angle between the knee joint line and the femoral neck axis (Figure 1A). It was measured with the subject lying prone, rotating the hip so that the femoral neck was horizontal. The angle of the knee joint line at the dorsal surface of the femoral condyles with respect to the horizontal was measured using an inclinometer (Figure 1A). A positive value was given for antetorsion of the femur and negative value for retrotorsion. This technique has been described in detail and validated against magnetic resonance images (MRI)[19]. It has good intrarater reliability [intraclass correlation coefficient (ICC) = 0.89, minimum detectable change (MDC) = 8.0°][19].

Tibiofibular torsion was measured as the angle between the proximal and distal part of the leg (Figure 1B). The proximal reference was defined as the tangential line on the medial surface of the tibia at the level of the tibial tuberosity and the distal reference was the transmalleolar axis. The medial surface of the tibia was chosen as the proximal reference as it is a flat surface that is clinically accessible, while the dorsal surface of the tibial condyle, which is used in imaging techniques, is difficult to verify clinically. This technique has also been validated against MRI and has good intrarater reliability (ICC = 0.97, MDC = 4.2°)[19].

Data analysis. Power calculations for this study were based on tibiofibular torsion data from clinical studies[14,15,20] and a dry bone study[21] and assumed a common standard deviation of 7.5°. To determine a between-group difference of 5° for a significance of 0.05 and a power of 80%, a sample of 36 subjects in each group was required.

Independent samples t test was carried out to compare age between the healthy and knee OA groups as a whole, by ethnicity, and by sex. Within the knee OA group, differences in body mass index (BMI) and ISK between the 2 ethnic and sex groups, respectively, were also examined using the independent samples t test.

Three-way, 2 (ethnicity) by 2 (sex) by 2 (condition), analysis of variance (3-way ANOVA) was conducted. Normality of distribution was tested using Kolmogorov-Smirnov statistics calculated using a standardized residual for each variable[22]. Homogeneity of variance between each cell was tested using Levene's test. All dependent variables were normally distributed across all subgroups ($p > 0.033$). All variables had homogeneous variance between the subgroups ($p > 0.032$).

The 3-way ANOVA was conducted to examine differences in the variables between the subjects with and those without knee OA as a whole (main effect for condition), and interaction effects between condition and ethnicity, between condition and sex, and between ethnicity and sex on the variables. Where significant interactions were observed, post hoc independent t tests were carried out for each set of subgroups. Main effects for ethnicity and sex on the variables were not considered in this study, as they have been reported[23].

Statistical alpha of 0.05 ($p < 0.05$) was considered to be the level of significance. SPSS 10 (SPSS Inc., Chicago, IL, USA) was used to calculate these statistics.

RESULTS

Age was comparable between the healthy subjects and those with knee OA regardless of ethnicity or sex. The severity of knee OA was moderate (Table 1) and comparable between the Japanese (6.8 ± 4.2) and Australian Caucasians (7.1 ± 3.9; p = 0.605) and women (7.1 ± 3.9) and men (6.6 ± 4.2; p = 0.318). In the group with knee OA, BMI ranged from underweight to obese (BMI range 17.7 to 44.8) and was lower in the Japanese than the Australian Caucasians (25.3 ± 3.7 vs 27.3 ± 4.2, respectively; $p < 0.001$), and also in the women compared with men (25.8 ± 3.9 vs 27.3 ± 4.2, respectively; p = 0.013).

Femoral antetorsion. Overall, femoral antetorsion was comparable between the groups with and without knee OA (Table 1). However, there was significant interaction between condition and sex, where femoral antetorsion was significantly lower in the women with knee OA than in the healthy women, whereas it was comparable between the men with and those without knee OA (Table 2). There were no differences in femoral antetorsion between the sexes in the healthy group (p = 0.068) and in the knee OA group (p = 0.146). In addition, there were no other significant 2-way (ethnicity × sex, condition × ethnicity) or 3-way (condition × ethnicity × sex) interactions in femoral antetorsion.

Tibiofibular torsion. Overall, tibiofibular torsion was comparable between the groups with and those without knee OA (Table 1). However, there was significant interaction between condition and ethnicity (Table 3). The Japanese subjects with knee OA had significantly lower tibiofibular torsion compared with their healthy counterparts, while in the Australian group there was no significant difference in the variable between the 2 groups (Table 3). Moreover, tibiofibular torsion in the Japanese with knee OA was significantly lower than in the

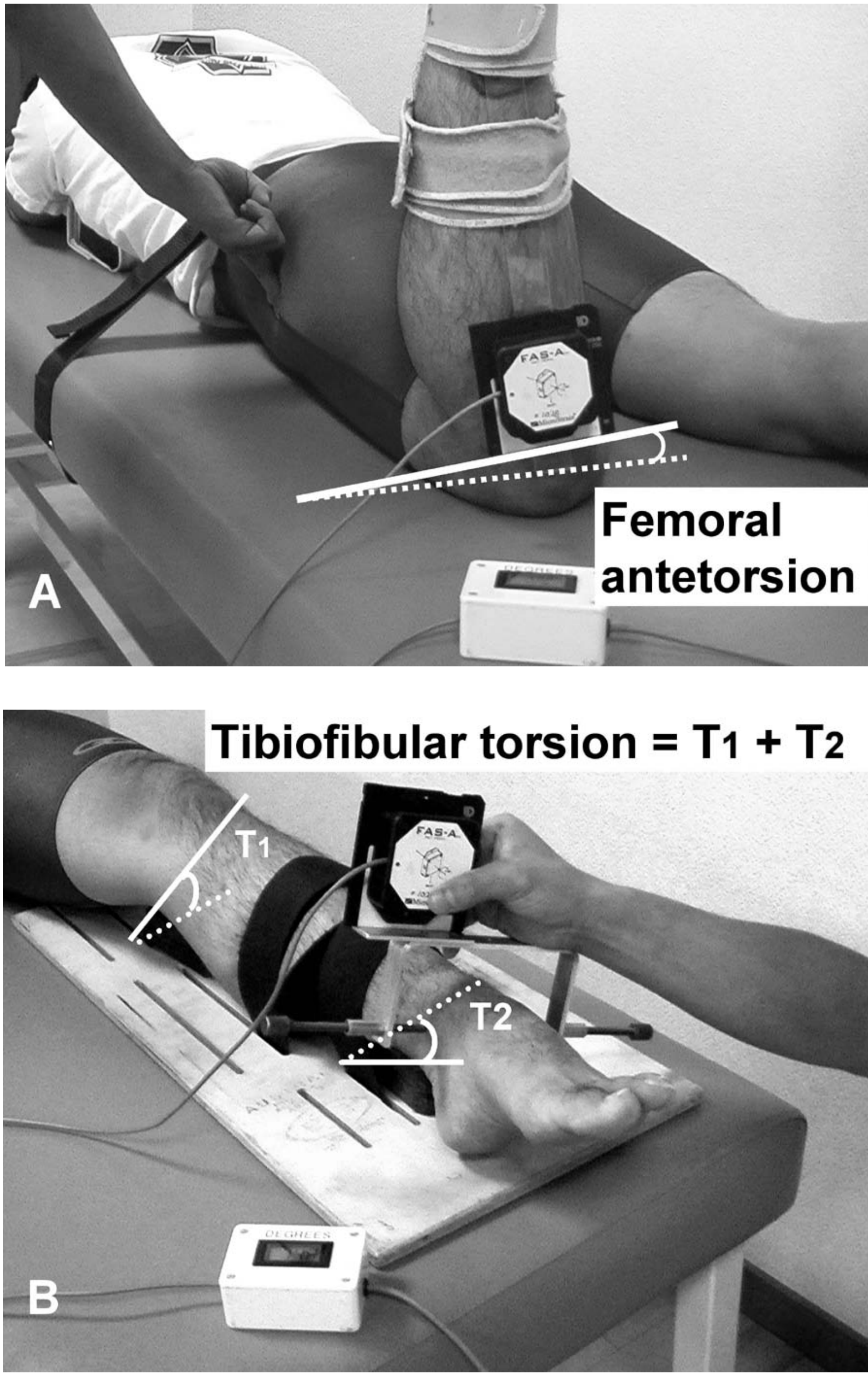

Figure 1. Clinical technique of measuring femoral antetorsion and tibiofibular torsion using a digital inclinometer. A. Femoral antetorsion: when the horizontal position of the femoral neck axis is clinically detected, the angle between the knee joint line (solid line) and the horizontal line (broken line) is defined as femoral antetorsion. Higher values indicate more antetorsion of the femur. B. Tibiofibular torsion: 2 components at the proximal and distal part of the leg are measured and summed to represent tibiofibular torsion. T_1 represents the angle of the tangential line of the medial surface of the tibia (solid line) with respect to the horizontal (broken line). T_2 represents the angle between the transmalleolar axis (solid line) and the horizontal (broken line). Higher values indicate more external torsion of the leg.

Australians with the disease ($p < 0.001$), while it was comparable between the healthy Japanese and Australian subjects ($p = 0.505$). Additionally, there were no other significant 2-way (ethnicity × sex, condition × sex) or 3-way (condition × ethnicity × sex) interactions in tibiofibular torsion.

DISCUSSION

Femoral antetorsion was comparable between the subjects with and those without knee OA overall, but it was lower in the women with knee OA than in the healthy women. Previous studies have not compared femoral antetorsion between those with and without knee OA in women alone.

Table 1. Characteristics of subjects with and without knee OA (mean ± standard deviation).

Variable	All Subjects Healthy, n = 86*	Knee OA, n = 202	p
Age, yrs	67.5 ± 9.4	69.5 ± 8.1	0.065†
Body mass index	—	26.3 ± 4.1	—
Index of severity of knee OA	—	6.9 + 4.0	—
Dependent variable			
Femoral antetorsion (°)**	14.7 ± 10.7	13.3 ± 10.6	0.537††
Tibiofibular torsion (°)	40.6 ± 9.9	39.7 ± 12.7	0.832††

* Number of subjects for these subgroups unless otherwise indicated. ** n = 79 for healthy and n = 196 for knee OA group, since fat around the pelvis and the greater trochanter prevented measurement of femoral antetorsion in some subjects. † Independent samples t test. †† 3-way analysis of variance (main effect).

Findings from the few studies that have compared femoral antetorsion without specifying sex are inconsistent, showing significant differences between subjects with and those without knee OA in Saudi Arabia[15] and Sudan[16], in contrast to comparable results in Japan[14]. These inconsistent results may be attributable to the ethnic difference in the subjects studied. The inconsistency may also be due to differences in the ratio of women to men in these studies. To clarify whether the difference was consistent across populations, our study was controlled for the ethnic group and sex. Consequently, the findings indicate that the difference in femoral antetorsion between people with and without knee OA is inconsistent across populations, and that there is a relationship between femoral antetorsion and knee OA only in a female population. More population-specific studies controlling for sex and ethnic groups would help to confirm an explanation for these inconsistencies.

Tibiofibular torsion was also comparable between the subjects with and without knee OA; however, in the Japanese it was significantly lower in those with knee OA compared with their healthy counterparts. The results are consistent with 2 previous studies in Japanese and Saudi Arabian people[14,15], respectively.

The reason for ethnic variation in tibiofibular torsion associated with knee OA is of interest. Nagamine, *et al*[24] speculated that smaller tibiofibular torsion among Japanese with knee OA may be associated in part with traditional Japanese sitting on the floor, called "Seiza" (sitting upright), with their knees fully bent and their buttocks on their heels. The repeti-

Table 2. Results of 3-way analysis of variance (interaction effect: condition × sex) in subjects with and without knee OA by sex (results of post hoc t tests are shown for femoral antetorsion where significant interaction was observed). Data are mean ± SD.

Variable	Interaction Effect (p)	Female Healthy, n = 53*	Female Knee OA, n = 133*	Female t Test (p)	Male Healthy, n = 33*	Male Knee OA, n = 69*	Male t Test (p)
Age, yrs	—	68.0 ± 9.8	69.4 ± 7.7	0.362†	66.6 ± 8.7	69.7 ± 8.8	0.101†
Femoral antetorsion, degrees**	0.044	16.5 ± 10.8	12.5 ± 10.8	0.029	12.0 ± 10.1	14.8 ± 10.2	0.212
Tibiofibular torsion, degrees	0.949	35.8 ± 7.9	34.7 ± 11.1	—	48.2 ± 7.8	49.3 ± 9.8	—

* Number of subjects for these subgroups unless otherwise indicated. ** n = 48 healthy and n = 128 knee OA in women, and n = 31 healthy and n = 68 knee OA in men, since fat around the pelvis and the greater trochanter prevents measurement of femoral antetorsion in some subjects. † Independent samples t test.

Table 3. Results of 3-way analysis of variance (interaction effect: condition × ethnicity) in subjects with and without knee OA by ethnicity (results of post hoc t tests are also shown for tibiofibular torsion where significant interaction was observed). Data are mean ± SD.

Variable	Interaction Effect (p)	Japanese Healthy, n = 52*	Japanese Knee OA, n = 100*	Japanese t Test (p)	Australian Healthy, n = 34*	Australian Knee OA, n = 102*	Australian t Test (p)
Age, yrs	—	68.2 ± 9.9	71.2 ± 7.1	0.056†	66.3 ± 8.5	67.8 ± 8.6	0.390†
Femoral antetorsion, degrees**	0.380	15.6 ± 11.8	12.5 ± 11.4	—	13.6 ± 8.9	14.0 ± 9.8	—
Tibiofibular torsion, degrees	< 0.001	40.0 ± 10.5	33.9 ± 11.8	0.002	41.5 ± 8.9	45.4 ± 10.8	0.057

* Number of subjects for these subgroups unless otherwise indicated. ** n = 46 healthy and n = 97 knee OA in Japanese, and n = 33 healthy and n = 99 knee OA in Australian group, since fat around the pelvis and the greater trochanter prevents measurement of femoral antetorsion in some subjects. † Independent samples t test.

tive and prolonged internal rotation of the toes during Seiza-sitting may result in skeletal modeling, as has been suggested in terms of humeral retroversion in the dominant arm of baseball pitchers and the femoral antetorsion in ballet dancers[25,26]. Alternatively, sitting this way may impair bone growth at the proximal metaphysis in childhood, leading to lower tibiofibular torsion[24].

This traditional Seiza-sitting is favored to sitting on a chair among older Japanese, particularly in rural areas of Japan where traditional housing is still prevalent. This possible mechanism is consistent with a previous multicenter study[27] reporting that a Japanese female population (n = 222) aged 60 to 79 years in a rural town in Japan were at increased risk of having knee pain compared with corresponding Japanese-American females (n = 638) in urban Hawaii, with age-adjusted odds ratio of 3.2 (95% CI 2.1, 4.8). Therefore, there may be cultural or environmental factors that, in part, explain the associations between lower tibiofibular torsion and knee OA among the Japanese population.

Lower tibiofibular torsion may influence foot progression angle during walking[13]. Biomechanical studies have described significant associations between smaller foot progression angle (in-toeing) and greater knee adduction moment[10-12], possibly because the ground reaction force with in-toeing posture passes medial to the center of the knee joint, leading to increased dynamic force on the medial compartment of the knee[12]. Therefore, although it remains unclear whether lower tibiofibular torsion predisposes to or results from knee OA, it is possible that lower tibiofibular torsion cyclically contributes to the progression of the disease. Further longitudinal study is required to examine the relationship between variations in tibiofibular torsion and knee OA in a Japanese population.

There are a number of limitations in our study. The subjects were a convenience sample and had knee OA of moderate severity. These factors limit the generalizability of the findings. Moreover, the numbers of subjects in the healthy Australian and healthy male subgroups were lower than in the other subgroups (n = 34 healthy Australians and n = 33 healthy men). Therefore, lack of differences in comparisons including these subgroups may be type II error, although the sample sizes were very close to those calculated in the power calculations. Given the cross-sectional study design, it remains unclear whether the differences between the subjects with and those without knee OA are causal. The results may only be applied to people with moderate knee OA, and the differences observed should not be extrapolated to other populations. Due to the multiple post-hoc comparisons in the study, there may be increased possibility of committing type I errors. Bonferroni adjustment for the multiple comparisons was not utilized because this adjustment would increase the risk of overlooking some potentially interesting and important findings[28].

To conclude, it is indicated that there are ethnic and sex variations in the relationships between torsion of the lower limb and knee OA, and lower tibiofibular torsion appears to be a characteristic of Japanese people with OA. Further longitudinal study is warranted to examine whether variations in femoral and tibiofibular torsion predispose to knee OA in a population-specific manner and whether preventive or treatment strategies could be developed around the observed differences.

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