Anthropometry of Anterior Cruciate Ligament in Singaporean Chinese

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Abstract

Accurate reproduction of the anatomy of the anterior cruciate ligament during reconstructive surgery is paramount for obtaining good functional results. Graft size and length are important components of the reconstruction and the references we have used are Western figures. We feel that these Western figures do not apply to our local population. We performed an anthropometric study to test the hypothesis that the anterior cruciate ligament in the Singaporean Chinese is smaller than that quoted in Western literature. The study revealed that the anterior cruciate ligament in Singaporean Chinese is shorter and narrower. More importantly, the anterior cruciate ligament orientation in our study population is more vertical. This suggests that placement of the femoral tunnel in anterior cruciate ligament reconstruction has to be in a more vertical position to reproduce the physiometry of the anterior cruciate ligament.

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Introduction

Anterior cruciate ligament (ACL) reconstruction is a technically precise and demanding operation. Attention to factors such as the tunnel position, graft selection, fixation and rehabilitation play an important role in determining the final outcome. The reference figures that we have always used in our reconstruction of the ACL are from the Western literature.[1-7] We feel that these are not applicable to the Asian population. During knee arthroscopy, we noticed that the anterior cruciate ligaments in our Asian patients were smaller than those described in the Western literature. We undertook an anthropometric study of the ACL in Singaporean Chinese population to test the hypothesis that the ACL in Singaporean Chinese is smaller than the Western population.

Materials and Methods

Thirty cadaveric knees were harvested at the Department of Forensic Medicine, Singapore General Hospital for the purpose of this study. The knees were harvested 15 cm above and below the knee joint, keeping the overlying soft tissues intact. The knees were defrosted 24 hours before the commencement of the dissection and were exercised through the entire range of motion to absorb the crimp. Care was taken throughout the defrosting process to prevent dehydration. The knees were mounted onto a custom-made jig (Fig. 1) using intramedullary rod fixation, which maintained the knee in 90° flexion. We used a pair of vernier calipers to measure the various parameters.

A medial parapatellar approach was used. The extensor apparatus was reflected laterally and the intercondylar notch exposed. Particular care was taken throughout the dissection to preserve both collateral ligaments and as much of the capsular envelope as possible to maintain the soft tissue tension. The anterior fibres of the ACL were identified and measured. The circumference of the ACL, taken in the middle between the femoral and tibial insertions, was measured. A section of the medial condyle was osteotomised to expose the femoral insertion of the ACL (Fig. 2) with particular care being taken to preserve the integrity of the lateral collateral ligament. Measurements were taken of the posterior fibres of the ACL. The angle described between the femur and the ACL, angle α (Fig. 3), and the angle described between the ACL and the sagittal plane, angle β (Fig. 4), were measured with a goniometer. The ACL was sectioned flush with the bone and the femoral and tibial footprints were measured in the sagittal and coronal plane. The

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Fig. 1. Photograph shows the jig maintaining the knee in 90° flexion.

Fig. 2. Close up of the anterior cruciate ligament. The medial femoral condyle was osteotomised to expose the femoral insertion. Notice that there is no specific bundle and there is a spiral to the fibres.

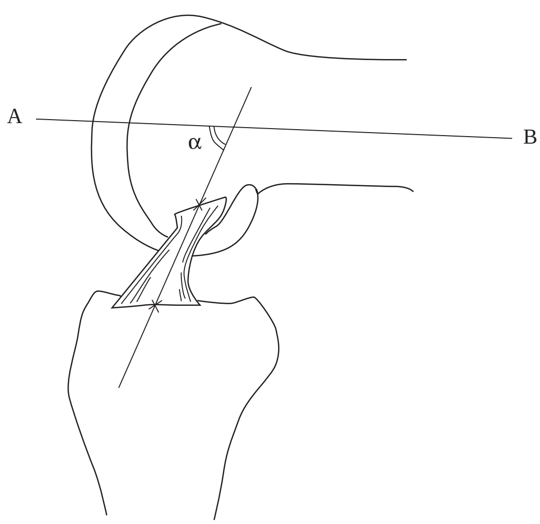

Fig. 3. Schematic diagram of the knee flexed to 90° flexion to illustrate angle α. The "X" marked in the diagram indicates the mid-point of the footprint of the ACL insertion. Line AB indicates the longitudinal axis of the femur.

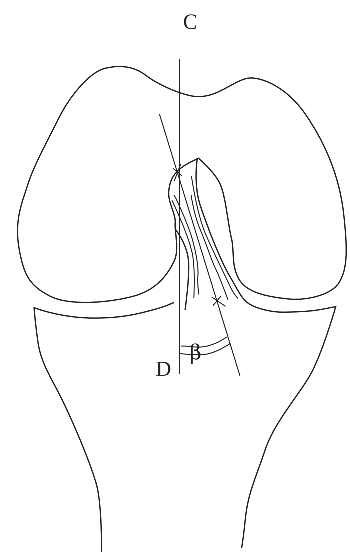

Fig. 4. Schematic diagram of the knee flexed to 90° flexion to illustrate angle β. The "X" marked in the diagram indicates the mid-point of the footprint of the ACL insertion. Line CD indicates the sagittal plane.

centre of each footprint was identified and the mid-substance ACL length was measured between these 2 points.

We used the independent two-sample *t*-test to analyse the data.

Results

There were 18 males and 12 females in the study. The mean weight of the cadavers was 61.7 kg (range 40 to 75 kg). The average age of the cadavers in this study was 70 years (range 60 to 78 years).

We could not detect any specific anatomic bundles of the ACL in our dissection. The fibres of the ACL described a spiral, namely, the most anterior fibres on the tibial footprint insert into the superior part of the femoral footprint while the most posterior ACL fibres on the tibial footprint insert into the inferior part of the femoral footprint. The femoral footprint was oval in shape, orientated obliquely in an antero-inferior direction, attaching to the medial surface of the lateral femoral condyle posteriorly. The tibial footprint was oriented in an anterior-posterior direction. At the tibial footprint, the most anterior ACL fibres passed beneath the transverse meniscal ligament anteriorly while the posterior fascicles blend with the posterior attachments of the lateral meniscus. Overall, the anterior length of the ACL in Singaporean Chinese was 34.0 ± 3.8 mm while the mid-substance length measured 23.4 ± 2.9 mm and the posterior length measured 26.1 ± 4.8 mm. The circumference of the ACL was 26.0 ± 5.0 mm (Table I). We observed that the cross-section of the ACL at the mid-point between the tibial and femoral insertion was circular.

In males, the anterior length of the ACL was 35.6 ± 3.1 mm while the posterior length was 25.6 ± 1.5 mm. The midsubstance length was 24.5 ± 2.8 mm and the mid-ligament circumference was 26.3 ± 4.5 mm. Angle α was 59 ± 8° and angle β was 14 ± 7°. The femoral footprint measured 13.5 ± 3.4 mm in the longitudinal axis and 8.8 ± 2.5 mm in the shorter axis. The tibial footprint measured 15.1 ± 2.1 mm in the longer axis and 10.8 ± 3.0 mm in the shorter axis (Table I).

In females, the ACL was smaller measuring 20.9 ± 0.1 mm in the mid-ligament length. The anterior length of the ACL was 27.4 ± 2.7 mm while the posterior length measured 31.4 ± 4.1 mm. The midsubstance circumference was 18.7 ±1.0 mm. Angle α was 69 ± 1° while angle β was 9 ± 1°. The femoral footprint measures 14.4 ± 0.1 mm in the longer axis while measuring 12.0 ± 2.8 mm in the shorter axis. The tibial footprint measures 9.9 ± 2.4 mm in the longer axis while in the shorter axis, it was 8.5 ± 3.1mm (Table I).

Using the *t*-test for 2 independent samples, we demonstrated statistically significant differences between the sexes in the study population for all parameters except the middle and posterior ACL length as well as the angle described by the femur and the ACL.

There were significant differences in the values of the various parameters between the Western population and the study population (Table II). Although not all measured parameters in this study were examined by previous authors, the parameters which could be compared showed clinically significant difference.

Discussion

Like Odensten,[1,2] we did not find any distinct anatomical bundles in the ACL in the Singaporean Chinese knees. We believe that these subdivisions are more functional rather than anatomical. This is in contrast to other studies which show the presence of anteromedial and posterolateral bands[3,8,9] as well as the presence of an

TABLE I: MEASUREMENTS OF EACH PARAMETERS IN SINGAPOREAN CHINESE, CHINESE MALES AND CHINESE FEMALES

	ACL				Femoral footprint		Tibial footprint		Angles	
	Anterior length (mm)	Middle length (mm)	Posterior length (mm)	Circumference (mm)	Long axis (mm)	Short axis (mm)	Long axis (mm)	Short axis (mm)	Angle α (°)	Angle β (°)
Chinese population (n = 30)	31.5 (9.6)	21.2 (7.4)	25.0 (7.2)	23.1 (7.7)	13.9 (4.0)	10.4 (3.1)	13.1 (4.4)	9.7 (3.4)	64 (17)	12 (6)
Chinese males (n = 18)	35.6 (3.1)	24.5 (3.0)	25.9 (1.6)	26.5 (4.9)	13.4 (3.4)	8.8 (2.4)	15.1 (2.0)	10.7 (3.0)	59 (8)	14 (7)
Chinese females (n = 12)	27.4 (2.2)	20.9 (0.1)	31.4 (4.1)	18.7 (1.1)	14.4 (0.1)	12.0 (2.8)	9.9 (2.4)	8.5 (3.1)	69 (1)	9 (1)
Difference of means (95% CI)*	13.8 to 16.1	-1.6 to 8.9	-1.3 to 26.0	12.5 to 16.4	1.9 to 4.9	1.3 to 11.2	9.1 to 17.4	7.7 to 16.8	- 2.6 to 4.6	11.9 to 18.3

Data given as mean (± SD); ACL: anterior cruciate ligament
* Difference of means at 95% confidence intervals

TABLE II: COMPARISONS BETWEEN WESTERN MEASUREMENTS AND STUDY POPULATION

	ACL				Femoral footprint		Tibial footprint		Angles	
	Anterior length (mm)	Middle length (mm)	Posterior length (mm)	Width (mm)	Long axis (mm)	Short axis (mm)	Long axis (mm)	Short axis (mm)	Angle α (°)	Angle β (°)
S'pore Chinese	31.5 (9.6)	21.2 (7.4)	25.0 (7.2)	7.35*	13.9 (4.0)	10.4 (3.1)	13.1 (4.4)	9.7 (3.4)	64 (17)	12 (6)
Dodds[6]	NA	NA	NA	NA	23	NA	17	11	NA	NA
Girgis[3]	38	NA	NA	11	23	NA	29.3	NA	NA	NA
Kennedy[4]	39	NA	NA	NA	NA	NA	NA	NA	NA	NA
Morgan[13]	NA	NA	NA	NA	NA	NA	18	10	NA	NA
Muneta[11]	NA	10.5 (2)	NA	NA	16.0 (2.8)	8.3 (2.8)	17.0 (2.4)	11.0 (1.6)		
Odensten[1]	NA	31 (3)	NA	10 (2)	18 (2)	11 (2)	17 (3)	11 (2)	28 (4)	NA

Data given as a mean (± SD)
ACL: anterior cruciate ligament; NA: data not available
* Width was calculated base on the circular cross-section in the middle of the ACL

intermediate band by Norwood.[10] In our dissection, we noticed that there was a lateral torsion in the ACL fibres from the femoral insertion to the tibial insertion, with fanning of the ligament as it inserts into the tibia. The tibial insertion is longer and wider than the femoral insertion, probably explaining why the ACL usually tears off from the femoral end. We noticed that the femoral insertions were larger in females than males, accounting for the longer posterior length of the ACL in females.

We designed this study to test the hypothesis that the ACL in Singaporean Chinese knees was smaller than the figures often quoted in the Western literature. The mid-substance length of the ACL in our study, averaged at 23.3 ± 3.0 mm, was smaller than those in other studies.[1-7] Odensten et al[1] in their series showed that the ACL measured 31 ± 3 mm in its mid-substance while Muneta's[11] series in Japanese cadavers averaged 10.5 mm ± 2.0 mm. Girgis et al,[3] on the other hand, measured the anterior fibres of the ACL and averaged it to be 38.2 mm while Kennedy et al[4] found the anterior fibres to have mean of 39 mm, with a range of 37 to 41 mm. In our series, the anterior fibres averaged 34.01 ± 3.87 mm. Besides being shorter, the ACL in Singaporean Chinese is also thinner (Table II). The various studies did not measure the same parameters and without the raw data available from previous studies, making meaningful statistical comparisons difficult. However, it would suffice to conclude at this point that clinically significant differences exist between Singaporean Chinese and the Western populations.

We explored the possibility that these differences could be due to differences in physical size alone. A review of the available literature did not indicate the weight of the cadavers in the various studies making any direct comparison in the form of indices difficult. Be that as it may, the magnitude of the differences were too big to be accounted on the basis of physical size variations alone. Furthermore, the different findings between Muneta et al's[11] study and ours excluded that the difference is purely a manifestation of physical size difference as the Singaporean Chinese are comparable in physical size to the Japanese.

Kurosawa et al[12] have demonstrated that the length of the ACL changes with the position of the knee. We excluded the contribution of the knee position to the difference in ACL measurements as the knees in Odensten et al[1] study was similar to ours. Both studies were conducted with the knee flexed to 90°.

Another finding of interest is that the angle described between the ACL and the longitudinal axis of the femur, angle α, measured 64 ± 17° in our dissections whereas in Odensten's series, it was 28 ± 4°. This means that the ACL in Singaporean Chinese is more vertical, partly accounting for the shorter ACL that was observed in this study.

Conclusion

Our study demonstrates that the ACL in Singaporean Chinese is narrower, shorter and more vertical. We feel that this has clinical implications especially during ACL reconstructions. The more vertical ACL in Singaporean Chinese means that the femoral tunnel used in ACL reconstructions could be placed more vertical to reproduce the anatomy in our local population. Furthermore, the narrower ACL suggests that we could possibly use a narrower graft to reproduce anatomy, lowering the incidence of donor site morbidity. However, biomechanical tests on the strength of the native ACL and smaller grafts need to be performed to confirm this.

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