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Antropometric study on the parameters of double-bundle anterior cruciate ligament reconstruction using magnetic resonance imaging

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Abstract

Background: The reconstruction techniques of double-bundle anterior cruciate ligament (ACL) can restore normal kinematics on the knees and its stability. Data regarding the reconstruction parameters of double-bundle ACL and ACL footprint' size on femur and tibia have never existed in Indonesia. **Purpose:** This study aims to obtain the reconstruction parameters' value of double-bundle ACL to determine the parameter value suitability with a minimum size, and the correlation of these parameters with age, sex, ethnicity, and body mass index (BMI). **Methods:** This study employed an analytic observational study with a cross-sectional design. In this study, eight parameters were measured, then analyzed based on age, gender, ethnicity, and BMI. The measurements were carried out using OsiriX program. **Result:** The average width of lateral condylar ridge amounted to 15.734 mm; the average diameter of ACL femoral footprint reached 15.85 mm; the average surface of ACL femoral footprint reached 72.72mm^2; the average diameter of ACL tibial footprint 16.04 mm; the average surface of ACL tibial footprint amounted to 72.69mm^2, and the average width of intercondylar notch reached 21.29 mm. In addition, no significant correlation was identified between age, sex, ethnicity, and BMI to the double-bundle ACL reconstruction parameters**. Conclusion:** Double-bundle ACL reconstruction can be performed because the reconstruction parameters' values have exceeded the minimum size. Subjects' characteristics based on age, sex, ethnicity, and BMI do not affect these parameters' values. The surface measurements of ACL femoral footprint and ACL tibial footprint significantly correlate with age.

Keywords: anthropometry, ACL footprint, double-bundle ACL, MRI

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INTRODUCTION

The significant occurrence of anterior cruciate ligament (ACL) injuries needs to be a concern at this time. The quite large morbidity of ACL injuries in the community, especially athletes, becomes a concern at present. Data in the United States shows out of 200,000 cases on ACL injuries, half of which require reconstructive surgery (Singh, 2018). A meta-analysis study indicated that ACL injury incidence reached 68.6 cases per 100,000 people which resulted in ACL rupture as the most common injury in the orthopedics field (Sanders, et al. 2016).). ACL injuries can also cause other tissue injuries and degenerative joint disease, with the result a major surgery is required (Mardina, et al. 2014).

ACL's anatomical position requires to identify and understand well to obtain maximum ACL reconstruction results for the patients. ACL ligament anatomy consists of two bundles, i.e., anterolateral and posteromedial bundles, attached to the inferoposterior area of the lateral condylar ridge, and the cartilage surface of posterior side on the femur to between the tibial eminences. These matters are substantial to carry out ACL reconstruction as anatomical as possible.

There are two types of ACL reconstruction techniques; single-bundle and double-bundle techniques. The double-bundle reconstruction technique has the advantages to support anteroposterior and rotational stability compared to single-bundle reconstruction, which only supports anteroposterior stability. In this case, the double-bundle

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technique can be an option in ACL rupture reconstruction because it can provide greater results than a single-bundle technique (Siebold, 2014). Besides, a reconstruction that is identical to anatomical conditions is expected to restore normal ACL kinematics and maintain knee condition as excellent as possible for the long term (Harner, et al. 1999; Shiberu, & Tamiru, 2016)..

Double-bundle reconstruction has a certain indication, i.e., the width of the lateral condylar ridge is more than 14 mm to obtain the bone distance between two tunnels at least two mm (Siebold, 2014). In addition, it is also required to identify intercondylar notch width more than 12 mm, thus the visualization of ACL insertion location can be observed clearly, and no impingement occurs during ACL graft insertion (Siebold, 2014). Graft impingement on intercondylar notch is one of the troubling complications in double-bundle reconstruction (Yasuda, et al. 2011). as a result, intercondylar notch width is one of the determinants of whether double-bundle ACL reconstruction can be performed or not.

The parameter data of ACL reconstruction regarding ACL insertion size in the lateral condylar ridge width on the distal femur, intercondylar notch width, and ACL footprint size on femur and tibia have never existed in Indonesia, especially in Dr. Soetomo General Hospital Surabaya. Based on the background, this study aims to obtain patients' ACL insertion measurement in the Dr. Soetomo General Hospital as a basis for double-bundle ACL reconstruction. In this study, the evaluation is carried out using MRI. The procedure for using the MRI does not require an invasion of the patient's body, so it is greater than the ligament biopsy procedure (Setiawati, et al. 2017. Sukmaningtyas, H., Pandelaki, J., Astuti, M. D. K., Fauziah, Riwanto, & Muttaqin, 2018).Based on the explanation above, this study was conducted to obtain the parameters' value of double-bundle ACL reconstruction to determine parameter value suitability with a minimum size, and identify the correlation of these parameters with age, sex, ethnicity, and BMI.

METHODS

This study was an observational analytic study with a cross-sectional design. This study involved eight variables which were studied, and then analyzed based on age, sex, ethnicity, and BMI. The subjects were knee MRI examinations evaluated on sagittal, axial, and coronal sections with inclusion criteria: patients with 17-50 years old, patients with no ACL structure rupture, patients with no degeneration of distal femur and proximal tibia, and patients that had never experienced fracture on the distal femur and proximal tibia. The samples were the entire knee MRI results of patients at Dr. Soetomo General Hospital which fulfilled the inclusion criteria and excepted from exclusion criteria. The minimum sample size was calculated with the sample size formula for anthropometric study. The grouping was carried out with consecutive sampling by picking research samples that fit the inclusion criteria and excepted from exclusion criteria.

MRI electronic data obtained were then accessed using the OsiriX program to carry out measurements with the program's digital ruler on the width of lateral intercondylar ridge, ACL insertion on proximal tibia, and femoral intercondylar notch, as well as the surface area of ACL footprint on femur and tibia. In carrying out the measurement, the researchers were assisted by a radiology consultant in the musculoskeletal field to reduce bias.

Table 1. The Average of Double-Bundle ACL Reconstruction Parameters

Measurement	Size (Mean ± SD)
The width of the lateral condylar ridge	15.734 mm ± 0.4836
The width of ACL femoral footprint	7.0158 mm±0.47632
The length of ACL femoral footprint	15.8540 mm±1.76179
The surface of ACL femoral footprint	72.7202 mm^2±0.69432
The width of ACL tibial footprint	8.1563 mm±0.02559
The length of ACL tibial footprint	16.0429 mm±1.62422
The surface of ACL tibial footprint	72.6968 mm±0.66420
Intercondylar notch width	21.290 mm±2.8080

RESULTS

Table 1 contains the measurement results in the average of lateral condylar ridge width, the width, length, and surface of ACL femoral and tibial footprints, as well as the intercondylar notch width of 65 samples used.

In this study, the average width of the lateral condylar ridge reached 15.734 mm. On ACL femoral footprint, the average width reached 7.0158 mm; the average length reached 15.8540 mm; and average surface reached 72.7202 mm^2. Meanwhile, On ACL tibial footprint, the average width amounted to 8.1563 mm; the average length amounted to 16.0429 mm; and average surface amounted to 72.6968 mm^2. In addition, the average of intercondylar notch width reached 21.290 mm.

Age variable correlation was obtained using the statistical test of the Pearson Correlation Test. It was obtained that age did not affect the diameter of the lateral condylar ridge with p-value = 0.085. There was a significant correlation between age and the surface of the ACL femoral footprint with p-value = 0.016. There was a significant correlation between age and the surface of the ACL tibial footprint with p-value = 0.014. There was no significant correlation between age and intercondylar notch diameter with p-value = 0.138.

The gender variable correlation was obtained using the Mann-Whitney analysis test. It was found that there was no correlation between sex and the width of the lateral condylar ridge (p = 0.379). There was no correlation between gender and the width of ACL femoral footprint (p = 0.806). There was no correlation between sex and the length of ACL femoral footprint (p = 0.517). There was no correlation between gender and the surface of ACL femoral footprint (p = 0.879). There was no correlation between gender and the width of ACL tibial footprint (p = 0.194). There was no correlation between sex and the length of ACL tibial footprint (p = 0.412). There was no correlation between gender and the surface of ACL tibial footprint (p = 0.879). There was no correlation between sex and intercondylar notch width (p = 0.682).

The ethnicity variable correlation was obtained using the Mann-Whitney analysis test. There was no correlation between ethnicity and the width of the lateral condylar ridge (p = 0.734). There was no correlation between ethnicity and the width of ACL femoral footprint (p = 0.621). There was no correlation between ethnicity and the length of ACL femoral footprint (p = 0.822). There was no correlation between ethnicity and the surface of ACL femoral footprint (p = 0.984). There was no correlation between ethnicity and the width of ACL tibial footprint (p = 0.494). There was no correlation between ethnicity and the surface of ACL tibial footprint (p = 0.392). There was no correlation between ethnicity and intercondylar notch width (p = 0.479).

BMI variable correlation was obtained using ANOVA analysis test, in which it was identified that there was no difference between intercondylar notch width and division based on BMI (p = 0.059). No difference was identified between the width of ACL femoral footprint and the division based on BMI (p = 0.079). There was no difference between the length of ACL femoral footprint and the division based on BMI (p = 0.649). Surface differences were identified between the ACL femoral footprint and the division based on age (p = 0.026). There was no difference between the length of ACL tibial footprint and the division based on BMI (p = 0.713). There were significant differences between the width of ACL tibial footprint and the division based on height (p = 0.036). There was no difference between the width of ACL tibial footprint and the division based on BMI (p = 0.723).

DISCUSSION

In this study, it was identified that there were no differences in the width of the lateral condylar ridge on the distal femur compared based on ethnicity, gender, age, and BMI. This study suggested that the average width of the lateral condylar ridge reached 15.72 mm. The size of the lateral condylar ridge was considered as crucial matter because the surface area of the ACL femoral footprint was affected by lateral condylar ridge and cartilage inferior border on joint surfaces. These matters would affect ACL reconstruction to generate as anatomical as possible (Bhattacharyya, 2018). Studies on the width of the lateral condylar ridge and its effects on ACL were still minimal, thus it was difficult to provide comparative views between the results of this study and previous studies.

Intercondylar notch width did not indicate any difference when compared based on ethnicity, gender, age, and BMI. This study exposed that the width range of intercondylar notch amounted to 16.7-28.4 mm, with an average of 21.15 mm. It indicated that intercondylar notch size had fulfilled the functional size, in which the minimum width of the intercondylar notch is 12 mm (Yasuda, et al. 2011. Marzo, et al. 1992).

In this study, the parameters of ACL footprint on distal femur measured did not suggest any differences in the size of ACL femoral footprint when compared based on ethnicity, gender, age, and BMI. In addition, the average surface of ACL footprint on the distal femur amounted to 72.66 mm, with an average length of 15.80 mm and an average width of 6.98 mm. It was identified that the ACL footprint on the distal femur was influenced by ACL insertion size(Siebold, 2014. *Yasuda, et al. 2011 Mochizuki, et al. 2014 Ferretti, et al. 2012. Mochizuki, et al. 2014)*.Furthermore, identification found that age and sex affected ACL insertion size (Siebold, 2014. A study stated that men's ACL insertion size was longer and wider than women's (Amis, & Jakob, 1998. Colombet, et al. 2006). However, this study showed no differences in size, both in length and width, of ACL footprint on distal femur when compared with age and sex factors.

The parameters of ACL tibial footprint, which were then compared based on ethnicity, gender, age, and BMI, did not suggest any difference in the size of ACL tibial footprint. The mean surface of ACL footprint on proximal tibia reached 72.6 mm. This value was greatly smaller than the size of previous studies, in which the tibial insertion was wider in men than women, with a surface range from 114 mm^2-229 mm^2 (Siebold, et al. 2008). ACL insertion size varied among individuals, and it could depend on the knee size of each individual (Odensten, & Gillquist, 1985).).

This study needs to develop by involving a larger number of samples. Further research is required with a larger and wider range of samples to confirm the existence of covariation and to obtain the references of condylar ridge's geometric size, ACL femoral footprint, ACL tibial footprint, and intercondylar notch which can be generalized.

CONCLUSION

Double-bundle ACL reconstruction can be carried out because the reconstruction parameters' values performed on the subject have exceeded the minimum size. Subjects' characteristics based on age, gender, ethnicity, and BMI do not affect these parameters' values except the surface measurements of ACL femoral footprint and ACL tibial footprint have a significant correlation with age.

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