Obesity is associated with poorer range of motion and Tegner scores following hamstring autograft anterior cruciate ligament reconstruction in Asians

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Background: Current literature reporting on the impact of BMI on outcomes of orthopaedic surgical procedures is varied and inconsistent. The purpose of our study was to evaluate if body mass index (BMI) affects outcomes of primary anterior cruciate ligament reconstruction (ACLR) in an Asian population.

Methods: We retrospectively reviewed prospectively collected data of 141 consecutive patients who underwent primary ACLR by a single surgeon, the senior author of this study. Flexion range, International Knee Documentation Committee (IKDC) score, KT-1000 translation, Tegner activity level scale, Lysholm score and satisfaction were assessed preoperatively and at 2 years postoperatively. The patients were then stratified into two groups: normal-BMI and high-BMI in accordance with WHO classification. Outcomes were then compared between the two groups. All statistical analysis were performed on IBM SPSS Statistics 20.

Results: There were 81 patients in the normal-BMI group (BMI, 18.5 to 24.9) and 60 patients in the high-BMI group (BMI ≥25). Preoperatively, the only differences were in the gender proportions as well as the pre-injury Tegner score. 2-years postoperatively, patients in the normal-BMI group had better flexion (139° *vs.* 130°; P=0.0001), Tegner scores (5.7 *vs.* 4.8; P=0.005) and satisfaction rate (99% *vs.* 90%; P=0.041). There were no differences in graft failure or complication rates.

Conclusions: Obese patients had poorer range of motion and Tegner scores as compared to their nonobese counterparts following primary ACLR.

Keywords: Anterior cruciate ligament; outcomes; obesity; Asian; arthroscopy

Submitted May 16, 2017. Accepted for publication May 23, 2017.
doi: 10.21037/atm.2017.06.04
View this article at: http://dx.doi.org/10.21037/atm.2017.06.04

Introduction

Although Asian countries have some of the lowest prevalence of obesity worldwide, they are experiencing alarming rates of increase in recent years (1). According to the World Health Organization (WHO), individuals with body mass indices (BMIs) of 25.0 to 29.9 kg/m^2 are considered overweight and BMIs of 30.0 kg/m^2 and above are labelled as obese (2). However, since Asians tend to have higher amounts of abdominal fat at lower BMIs, these cut-offs may be insufficient in identifying Asians with a high risk of obesity-related morbidity. In 2000, the Western Pacific Regional Office of WHO (WPRO) proposed an alternative definition of obesity (BMI ≥25.0 kg/m^2) for Asians (2).

The current literature reporting on the impact of BMI on outcomes of orthopaedic surgical procedures is varied and inconsistent. Some studies report an increased complication rate and length of hospital stay after surgery in obese patients (3,4) while others have not found any increased risk of surgery or postoperative complications (5,6). Most studies comparing the outcomes of orthopaedic surgery in obese patients were conducted in patients following hip or knee arthroplasty (4,6). Very few studies have been conducted on patients following anterior cruciate ligament reconstruction (ACLR) (7,8).

The aim of our study was to evaluate if early outcomes of hamstring autograft ACLR in Asians are affected by obesity. We hypothesized that obese patients had poorer range of motion and functional scores as compared to their nonobese counterparts following hamstring autograft ACLR.

Methods

This study is a retrospective review of prospectively collected registry data of all patients who underwent primary arthroscopic hamstring autograft ACLR by the senior author from 2012 to 2013. This time period was chosen as our hospital registry for ACLR was only set up in 2012 and we wanted at least 2 years of follow-up for all patients. The ethics board of our institution granted us a waiver for approval as we utilized de-identified registry data.

We included all patients who underwent unilateral primary arthroscopic ACLR with hamstring autograft who completed 2-years of follow-up. Patients who had previous bony or ligamentous knee injuries and/or surgical procedures in the operated knee were excluded. A total of 141 patients satisfied the inclusion criteria. A further 18 patients were excluded due to previous knee surgery.

Patients were diagnosed as having a ruptured ACL by means of clinical examination (positive anterior drawer, Lachman's test with a soft end point or pivot shift) and supplemented by confirmatory imaging diagnosis by magnetic resonance imaging. Patients were then counselled and listed for surgery if they had continuing instability symptoms and were keen to pursue an active lifestyle.

All ACLR procedures were performed by the senior author. They were done arthroscopically through anteromedial and anterolateral portals, with a pneumatic tourniquet applied over the operated limb and a prophylactic dose of intravenous antibiotics (cefazolin or vancomycin in patients with penicillin allergy) at anaesthesia induction. All autografts were harvested from the ipsilateral leg. The gracilis and semitendinosus tendons were prepared and doubled over to make a quadrupled graft. The graft was then utilized as a single-bundle reconstruction through a transtibial technique. Tibial fixation was by bio-interference screws (Arthrex, Naples, FL, USA). The Transfix® (Arthrex, Naples, FL, USA) ACLR system was used for a transverse femoral graft fixation in all patients. Bio-TransFix® screws were used for the femoral fixation.

All patients followed the standard rehabilitation protocol of our institution postoperatively. They were seen regularly by the outpatient physiotherapy team for at least 6 months postoperatively. Range of motion of the operated knee was measured by two independent physiotherapists using a goniometer at each of the follow-up visits. Functional outcomes were measured using reliable and validated scoring assessments. We used the International Knee Documentation Committee (IKDC) 2000 Subjective Knee Evaluation Form (9), Tegner score (10) and Lysholm score (11). Anteroposterior laxity of the knee was assessed by evaluating the side-to-side difference by using the KT-1000 arthrometer (12). Satisfaction scores were rated out of a maximum of six using a questionnaire adapted from the North American Spine Society Low Back Pain Instrument (13), with higher scores indicating poorer results. We stratified scores into: satisfied (1-3) and dissatisfied (4-6).

Patients were classified into 2 BMI groups according to the WHO classification: normal-BMI group (18.5–24.9 kg/m^2) and high-BMI group (BMI ≥25 kg/m^2). Demographics and perioperative details were then compared between the two groups. Range of motion, functional outcome scores and satisfaction rates were then compared between the two groups pre-operatively and at 2-years postoperatively.

To obtain a power of at least 80% and a 2-sided 0.05 significance level, 36 individuals were needed in each group. The mean preoperative scores were compared with the mean postoperative scores within each BMI class. We usd the paired *t* test if data were normally distributed or the Wilcoxon rank-sum test if data were nonparametric. Comparison between the 2 groups' scores preoperatively and at 2-years postoperatively was made using the unpaired *t* test if data were normally distributed or the Mann-Whitney *U* test if data were nonparametric. Comparisons of proportions were made using the Z-score analysis. IBM

SPSS Statistics, version 20 (SPSS, Chicago, IL, USA) was used for statistical analysis.

Results

There were 81 patients in the normal-BMI group and 60 patients in the high-BMI group. There were no patients in the study group with a BMI of less than 18.5. Demographics are shown in *Table 1*. There were statistically significant differences in the gender distribution, preoperative flexion range as well as the pre-injury Tegner score between the two groups. 93 percent of the high-BMI group were male compared to 77 percent in the normal-BMI group (P=0.010). The normal-BMI group had a better preoperative flexion range of 141 degrees compared to 134 degrees in the high-BMI group (P=0.0001). The pre-injury Tegner score for the normal-BMI group was 7.5 compared to 6.7 in the high-BMI group (P=0.009). At 2 years postoperatively, there were statistically significant differences in the flexion range, Tegner score and satisfaction rates. The high-BMI group had a worse flexion range of 130 degrees compared to 139 degrees in the normal-BMI group (P=0.0001). The high-BMI group had a postop Tegner score of 4.8 compared to 5.7 in the normal-BMI group (P=0.005). 90% of the patients in the high-BMI group were satisfied with their surgery compared to 99% in the normal-BMI group (P=0.041). The loss in flexion range and improvement in KT-1000 side-to-side difference, Tegner and Lysholm scores within each BMI-group from preoperative to 2-years postoperatively is statistically significant (*Table 2*). The mean graft size was 7.5 mm for both groups. The mean follow-up duration was 3.5 years for both groups. There was 1 graft rupture in each group. No other complications were reported.

Discussion

Kowalchuk *et al.* (14) found a strong association of obesity, smoking and severe chondrosis at time of surgery and a lower dichotomized IKDC 2000 patient-reported outcome after ACLR. However, a systematic review conducted by Kluczynski *et al.* (15) in 2014 concluded that there is a lack of consensus in the literature regarding the association between BMI and ambulatory knee and shoulder surgery. They mentioned that several factors may have contributed to contradictory findings, including variation in measuring and classifying anthropometry, postoperative outcomes and follow-up time. Bowers *et al.* (16) hypothesized that athletes could reduce certain intra-articular pathologic processes with maintenance of lower body weight and BMI and therefore improve long-term functional outcomes after ACLR. Our study focused on the short-term outcomes at 2 years following ACLR using various scoring systems—the IKDC 2000 Subjective Knee Evaluation Form, Tegner Score as well as the Lysholm Score. A search on PubMed amongst the English language literature with the terms "anterior cruciate ligament", "body mass index", "obesity", "outcomes" and "Asian" did not show any other studies to date on outcomes of ACLR in Asians stratified by body mass index.

In our study, we noticed some significant preoperative differences between the normal-BMI and high-BMI groups. The high-BMI group had a higher percentage of males compared to the normal-BMI group. This does not come as a surprise as studies have proven that males in general tend to have a higher body mass index as compared to the female gender due to a higher muscle mass (16-18). We also found that the patients in the high-BMI group had a lower flexion range as compared to the normal-BMI group. An early study by Spyropoulos *et al.* (19) which involved biomechanical gait analysis of obese men revealed that mean hip and knee flexion were not significantly different for obese and nonobese subjects. However, more recent studies have eluded that knee flexion is weaker and limited in obese individuals compared to their nonobese counterparts (20,21). The third finding was that the pre-injury Tegner score was lower in the high-BMI group. The Tegner activity level scale is a graduated list of activities of daily living, recreation and competitive sports. The patient is asked to select the level of participation that best describes their level of activity. The lower pre-injury activity levels seen in the high-BMI group of out study has been proven in previous publications (22-24). Obese individuals have been found to be substantially less active than nonobese individuals particularly when there was a free choice of activity or no activity (22).

Comparing flexion range between the normal- and high-BMI group, there was a 9-degree difference with the high-BMI group doing worse. It is known from studies done on patients undergoing total knee arthroplasty that pre-operative flexion range determines post-operative flexion range (25). This may in part explain the poorer flexion range in the high-BMI group as they started with a poorer preoperative flexion range as compared to the normal-BMI group. Furthermore, there is evidence of reduced

Table 1 Comparative data between normal- and high-BMI groups

Demographic, perioperative and outcomes data	BMI <25 kg/m^2 (n=81)	BMI ≥25 kg/m^2 (n=60)	P value
Demographic data			
Age, ± SD (years)	28.2±5.7	29.7±6.2	0.139
Male, number [%]	62 [77]	56 [93]	0.010
Body mass index, ± SD (kg/m^2)	22.3±2.1	28.7±3.2	0.0001
Perioperative data			
Right side, number [%]	40 [46]	29 [48]	1.00
General anaesthesia, number [%]	81 [100]	60 [100]	1.00
Length of stay, ± SD (days)	1±0	1±0	1.00
Meniscectomy performed, number [%]	38 [47]	26 [43]	0.674
Preoperative (preop) outcomes			
Flexion range, ± SD (degrees)	141±7	134±10	0.0001
IKDC, number [%]			
A	0 [0]	0 [0]	0.240
B	5 [6]	1 [2]	
C	16 [20]	9 [15]	
D	60 [74]	50 [83]	
KT-1000 side-to-side difference, ± SD (millimeters)	7.2±3.7	7.0±3.9	0.324
Pre-injury Tegner score ± SD	7.5±1.8	6.7±1.7	0.009
Preop Tegner score ± SD	3.2±1.8	2.7±1.8	0.105
Lysholm score ± SD	61.7±2.4	60.1±21.1	0.668
2-year outcomes			
Flexion range, ± SD (degrees)	139±5	130±8	0.0001
IKDC, number [%]			
A	21 [26]	13 [21]	0.125
B	29 [36]	16 [27]	
C	10 [12]	19 [32]	
D	21 [26]	12 [20]	
KT-1000 side-to-side difference, ± SD (millimeters)	2.2±1.2	2.4±1.5	0.737
Tegner score ± SD	5.7±1.9	4.8±1.8	0.005
Return to pre-injury Tegner score, number [%]	35 [43]	18 [30]	0.110
Lysholm score ± SD	92.5±8.2	89.8±13.2	0.138
Satisfaction			
"Satisfied", number	80	54	0.041
"Dissatisfied", number	1	6	
Satisfaction rate (%)	99	90	

Table 2 P values for comparative outcomes (preoperative *vs.* 2-years) within each BMI group

BMI groups	Flexion range	KT-1000 side-to-side difference	Tegner score	Lysholm score
BMI <25 kg/m^2 (n=81)	0.038	<0.0001	<0.0001	<0.0001
BMI ≥25 kg/m^2 (n=60)	0.016	0.0006	<0.0001	<0.0001

knee flexion following ACLR especially when hamstring autografts are utilized (26-28). Nakamura *et al.* (26) suggested that the loss of knee flexor strength following the harvest of hamstring tendons might be more significant than has been previously estimated. Ageberg *et al.* (27) also concluded that patients undergoing hamstring autograft ACLR have lower hamstring power as compared to patients undergoing patellar tendon autograft ACLR. Hart *et al.* (28) conducted a systematic review on knee kinematics and joint moments following ACLR. They found that lower peak knee flexion angles were evident more than 3 years post-ACLR. These effects combined with the generalized sarcopaenia associated with obese individuals (21) may account for the reduced flexion seen in the high-BMI group as well. However, whether the difference of 9 degrees between the two groups is clinically significant is debatable.

Our study also found that the Tegner scores at 2 years postoperatively were lower in the high-BMI group compared to the normal-BMI group. The lower pre-injury Tegner scores in the high-BMI group could explain this finding. A similar trend of lower activity levels in high-BMI patients following ACLR was seen in a recent study by Rodríguez-Roiz *et al.* (29). While the 2-year Tegner score was lower in the high-BMI group, there was no statistically significant difference in the percentage of patients who returned to pre-injury Tegner score between the normal- and high-BMI groups. This has been reported previously by Ballal *et al.* (7) in their study on a Western population. In their study of 49 normal-BMI patients compared against 43 high-BMI patients, they found no differences in the Knee Injury and Osteoarthritis Outcome Score (KOOS) as well as rate of return to pre-injury activity levels. They concluded that primary hamstring autograft ACLR is an effective treatment option in patients irrespective of preoperative BMI and that high BMI does not adversely affect functional outcomes.

Looking at the trends within each group, we can see that the changes in flexion range, KT-1000 side-to-side difference, Tegner and Lysholm scores from preoperative to 2-years postoperatively were all significant. We had previously discussed the loss of knee flexion following hamstring autograft ACL (27), which explains the statistically significant loss of flexion in both groups. However, this is unlikely to translate to a clinically significant difference as the absolute reduction in flexion range is within 5 degrees. There is significant improvement in the anteroposterior laxity in both groups as is expected after ACLR. The reduction in Tegner scores and improvement in Lysholm scores in both groups were also found to be statistically significant. This has been the trend in most studies on patients following ACLR. This was recently reported in a systematic summary by Anderson *et al.* (30). Despite the lower Tegner scores, we found a high satisfaction rate of 99% in the normal-BMI group and 90% in the high-BMI group. Schmale *et al.* (31) reported similar findings in this study of 29 patients who underwent transphyseal ACLR where the mean satisfaction score was 9 with less than 50 percent of patients maintaining their pre-injury activity level. However, usage of the satisfaction score from the North American Spine Society Low Back Pain Instrument (13) has not been validated in patients following ACLR.

A limitation of our study is that it is a retrospective review of prospectively collected registry data with a relatively small same size and short-term results. Another limitation of our study relates to our analysis of only two BMI groups. This was because of the small number of patients with a BMI of more than 35, and further subdivision was therefore not possible. Another criticism of our study would be the use of satisfaction scores from the North American Spine Society Low Back Pain Instrument (13), which has not been validated for use in patients following knee surgery. However, this is the satisfaction score that has been used in our registry and we are in the process of changing this. Considering the strengths, our study is adequately powered based on our power analysis and we feel that our results are still valid and valuable given the fact that we used prospectively collected registry data. Use of a single surgeon cohort also ensures homogeneity. A larger, prospective matched pair

study will be useful to further evaluate the impact of BMI on the outcomes of ACLR.

Conclusions

Primary hamstring autograft ACLR restores knee stability in both non-obese and obese individuals. However, obese patients had poorer range of motion and Tegner scores as compared to their nonobese counterparts following hamstring autograft ACLR 2 years postoperatively.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The ethics board of our institution granted us a waiver for approval as we utilized de-identified registry data.

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Cite this article as: Bin Abd Razak HR, Chong HC, Tan HC. Obesity is associated with poorer range of motion and Tegner scores following hamstring autograft anterior cruciate ligament reconstruction in Asians. Ann Transl Med 2017;5(15):304. doi: 10.21037/atm.2017.06.04

