Different squatting positions after total knee arthroplasty: a video-based observational study

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Abstract

Aims There are no methods to assess patient's squatting ability after TKA (total knee arthroplasty), this study aimed to evaluate the different squatting position of a series of patients who underwent primary TKA.

Methods From May 2018 to October 2019, we retrospectively reviewed 154 videos recording the squattin-related motions of patients after TKA. Among the included patients, 119 were women and 35 were men. Their mean age at the index surgery was 61.4 years (range, 30 to 77). The median follow-up was 12 months (range, 6 to 156). We classified those squatting-related motions into three major variations according to squatting depth: half squat, parallel squat, and deep squat. The angle of hip flexion, knee flexion and ankle dorsiflexion were measured in the screenshots captured from the videos at the moment of squatting nadir.

Results A total of 26 patients were classified as half squat, 75 as parallel squat, and 53 as deep squat. The angle of hip flexion, knee flexion and ankle dorsiflexion all differed significantly among the three squatting positions ($p<0.001$). In the parallel squat group, the mean knee flexion angle(°) was 116.5 (SD, 8.1; range, 97 to 137). In the deep squat group, the mean knee flexion angle(°) was 132.5 (SD, 9.3; range, 116 to 158). Among the three squatting positions, deep squat showed the highest hip, knee and ankle flexion angle. And the next was parallel squat.

Conclusion Our squatting position classification offers a pragmatic approach to evaluating patient's squatting ability after TKA. However, the relation between squatting position and daily activity requires further investigation.

Introduction

Total knee arthroplasty has been shown to improve quality of life and reduce pain. However, functional deficits can still be observed to persist after surgery.[1] The unfulfillment of preoperative expectations has been reported as one of the main determinants of postoperative dissatisfaction.[2, 3] High-flexion activities such as squatting, kneeling and floor transfers are mainly listed as demanding tasks. Among them, squatting is an important position especially for Asian, Africa and Middle East population, which can be used for a number of activities, including toileting, household chores, socializing, working, and religious acts.[4]

During the postoperative follow-up, clinicians often rely on patient-reported outcome measures (PROMs) to quantify the trajectory of functional recovery of TKA patients.[5] Although squatting-related items has been involved in some of PROMs, they merely appears as a binary options of "can" or "cannot", or descriptions of ease or complexity of accomplishing the task.[6-8] Even the specially developed questionnaire, "High-flexion Knee Scoring System", or the isolated subdomain "floor life" in the "Korean Knee Score", are inadequate to evaluate their squatting ability and completeness in detail.[9, 10]

Current researches about squatting depth are mainly performed amongst powerlifters. Depending on the squatting depth, the Olympic barbell squat can be classified into four fundamental variations: the quarter squat, the half squat, the parallel squat, and the deep squat. And the knee flexion angle increases according to the sequence mentioned above.[11, 12] Therefore, considering the paucity of methods to assess the squatting ability after TKA, this study aimed to evaluate the different squatting position of a series of patients who underwent primary TKA.

Patients And Methods

This study is a descriptive and retrospective analysis of clinical data. Our Institution Review Board approved the study. From May 2018 to October 2019, we had acquired 236 videos recording the functional recovery of patients after TKA, which were taken in the clinic. The inclusion criteria included patients who underwent primary TKA and were followed up for at least 6 months postoperatively. We excluded (1) patients with multiple co-morbidities that would limit their activity level. (2) patients whose videos did not record squatting-related motions. (3) patients who performed squatting with the aid of holding. (4) patients who cannot help lifting their heels from the ground.

A total of 154 patients (228 knees) were included, of whom 119 were women and 35 were men. Their mean age at the index surgery was 61.4 years (range, 30 to 77). The median follow-up was 12 months (range, 6 to 156). Demographic and clinical data, including diagnosis, age, gender, weight, height and operative recordings were collected from the electronic medical records, and the body mass index (BMI) were calculated as well. Within this cohort, the diagnosis was osteoarthritis in 147, and rheumatoid arthritis in 7. Among them, six patients had a stiff knee, and three patients had an ankylosed knee. The indications for TKA were severe pain associated with stiffness and limitation of daily activities. Primary TKAs were completed by two senior surgeons. A midline straight longitudinal skin incision and a standard medial parapatellar approach were employed in all knees. Follow-up evaluation was performed at regular intervals (6 weeks, 3 months, 1 year and yearly thereafter). The details of the patients were summarized in **Table I**.

Range of motion (ROM) measurements

Squatting is defined as a position where the legs are extremely flexed, bringing the body down over the feet. This position demands maximal flexion at the hip, knee and ankle joints. In each video, the patient was asked to stand sideways and try to squat with legs moving symmetrically according to his capability. From a standing position, the patient was verbally cued to squat down to the nadir. The patient held the position for 2 seconds and then returned to the relaxed standing position. This procedure was repeated for 3 times. During the squat executions, the patient was “guarded” by one of his relatives.

A series of screenshots at the moment of the squatting nadir were captured from the videos. Independent review of the screenshots was performed by two observers to measure the angle of hip flexion, knee flexion and ankle dorsiflexion. Actually, the angle of hip flexion represents the forward bending motion

contributed by both hip and spine. Hip flexion=180°- [angle between trunk and thigh]. Knee flexion=180°-[angle between thigh and calf]. Ankle dorsiflexion= 90°-[angle between calf and dorsum pedis]. All measurement was conducted by using Digimizer v5.4 (Acacialaan, Belgium).

Squatting position classification

We classified those squatting-related motions into three major variations on the basis of squatting depth: half squat, parallel squat, and deep squat. In the half squat, the patient descends until reaching 90° of knee flexion. In the parallel squat, the eccentric phase ends when the inguinal fold is in a straight horizontal line with the top of the knee, while in the deep squat the eccentric phase is carried out until the top of the thighs fall below the horizontal plane(**Figure 1**).

All identifying marks were removed from the videos, which were then sorted and labeled. Two other observers who were not involved in the ROM measurement participated in the classification process. Before embarking on the review, each observer was provided with the same descriptions and diagrams of the different squatting positions. Video reviews were performed independently in random order by each observer on two separate occasions, at least one month apart. Observers repeated their readings without knowledge of the previous results. The order of the videos was randomized using a sequential random number generator to prevent possible recall. Inter-observer variability was measured by comparing the sorting of two observers on each occasion, while intra-observer reliability was determined by comparing the two reviews of each observer.

Statistical analysis

Assessment of inter- and intra-observer consistency was accomplished by the use of the kappa coefficient (κ). According to Landis and Koch,[13] agreement was graded as slight (κ = 0 to 0.2), fair (κ = 0.21 to 0.40), moderate (κ = 0.41 to 0.60), substantial (κ = 0.61 to 0.80) or almost perfect (κ = 0.81 to 1.0). For ROM measurement, we used one-way analysis of variance (ANOVA) among three squatting positions. All tests were two-sided and statistical significance was set at $p<0.05$. All analyses were carried out using the statistical package SPSS version 26.0 (IBM Inc., Armonk, New York).

Results

A total of 26 patients were classified as half squat, 75 as parallel squat, and 53 as deep squat (**Table I**). The results of ROM measurement were summarized in **Table II**. The angle of hip flexion, knee flexion and ankle dorsiflexion all differed significantly among the three squatting positions ($p<0.001$). In the parallel squat group, the mean knee flexion angle(°) was 116.5 (SD, 8.1; range, 97 to 137). In the deep squat group, the mean knee flexion angle(°) was 132.5 (SD, 9.3; range, 116 to 158). Among the three squatting positions, deep squat showed the highest hip, knee and ankle flexion angle. And the next was the parallel squat.

Inter-observer reliability analysis revealed kappa coefficient of 0.82 (almost perfect) for the squatting postition classification. Intra-observer reliability analysis revealed kappa coefficient of 0.83 (almost perfect) for observer A, and 0.86 (almost perfect) for observer B.

Discussion

The main finding of this study was the squatting position classification based on squatting depth. And the results confirmed that this classification showed excellent reliability, as judged by the inter- and intra-observer variability. From half squat to deep squat, the flexion angle of hip, knee and ankle joint all increased with a statistical significance, which indicates that deeper squat requires more contribution from all those joints. It is the author's belief that the use of this classification, based on the squatting depth will act as a guide for the assessment of patient's squatting ability after TKA.

Notably, few studies focus on the squatting ability after TKA. Most squatting-related items in PROMs present as a binary options of "can" or "cannot", or subjective sense of difficulty along with this motion.[6-8] No further divisions and descriptions of squatting depth have been highlighted in those literatures and scales. Our classification of squatting position was raised by reference to the exercise program in athletic training, which was categorized based on the squatting depth.[11, 12] Actually, the squatting depth patients can achieve after TKA is associated with their ability to participate in the functional activities especially floor-based lifestyle. Our classification did build a hierarchy for assessing patients' squatting ability. However, the mode a patient performs squatting is not exactly the same as that of an athlete. With normal and intact knee joints, an athlete can perform any of the squatting positions effortlessly. By contrast, not all patients can perform deep squat and some of them reach their limits before deep squat.[14] Therefore, apart from the three finite positions, the angle of knee flexion at the squatting nadir should also be considered.

As one of the high-flexion knee functions, squatting is based on an excellent ROM.[4, 15] But sometimes patients who bend their knees well may not achieve deep squat. Because squatting is defined as a position where the legs are extremely flexed during load-bearing conditions. It is in sore need of increased activity of muscles especially quadriceps to enhance knee stability.[16, 17] Therefore, squatting is a tough mission for patients with weaker extension strength.[18] Nowadays, the ROM of the operated knee is used as a key indicator assessing the outcome after TKA in many literatures.[19-21] As mentioned above, the ROM is still miles off reflecting patient's high-level functions. That highlights the importance of our classification for squatting position.

Squatting, one of the high-flexion motions, has been blended into daily lifestyles of people from different corners of the globe. Weiss et al. conducted a questionnaire survey including 176 patients to quantify the patient's function and mobility after knee arthroplasty, and found squatting to be the most difficult activity for them.[22] Ghomrawi et al. compared patients' and surgeon's recovery expectation prior to

primary TKA, and found that more than 50% of the patients had higher expectations than their surgeon, which was driven by expectations of high-level activities such as squatting.[23] To fill the gap between surgeons and patients in evaluating the outcome of TKA, numerous PROMs emerged over the years. And more of them incorporated a section devoted to high-flexion or high-level activities.[6, 9, 10] Even so, with no further division of squatting positions, respondents might make the wrong tick, which usually causes a ceiling effect along with the questionnaire. Perhaps this could also explain why some comparative studies regarding to the outcome after TKA ends up with no difference unexpectedly.[19, 24] Besides, the squatting variations we put forward could be helpful for surgeons in evaluating and quantifying their patients' outcome after TKA. Namely, more detailed terminology about squatting positions could be conductive to the homogeneity of results awaiting for the systematic reviews in this regard.

Before initiation of the study, we set a limit to the observation time and only included patients who underwent primary TKA. But it is believed that our classification applies equally to the evaluation for squatting ability of patients who underwent unicompartmental knee arthroplasty or total knee revision. And the same goes for that of patients before surgery or followed less than 6 months. Although modern knee prostheses have closely approximated the feel and function of a healthy knee, deep squat cannot be guaranteed for each patients after TKA.[15, 25] As our results showed, the knee flexion angle in the deep squat group ranged from 116° to 158°, which is similar to the result summarized by Mulholland et al.[4] Many patients would reach their limits at certain points when trying to squat due to some of reasons.[17, 26, 27] However, patients are likely to compensate for any functional insufficiency of their knees by adjusting the kinematics and kinetics of other joints. Except for the compensation of hip-spine complex, some patients can achieve deep squatting by lifting their heels up,[28] which is more common among patients with limited ROM of hip joint.

There were three limitations in this study. First, patients we included could not constitute a consecutive series due to follow-up bias, so the incidence of different squatting positions could not be determined. Second, our classification mainly focused on the squatting depth, without considering the elapsed time from squatting down to rising up, which was also associated with patient's activity level. Eventually, we had not yet worked out the connection between the squatting positions and the daily activities that patients can perform, which could be conducted in the future.

Conclusions

Our squatting position classification offers a pragmatic approach to evaluating patient's squatting ability after TKA, which is one of the most important motions in daily lifestyles. However, the relation between squatting position and daily activity requires further investigation.

Abbreviations

TKA: Total knee arthroplasty; PROMs: Patient-reported outcome measures; BMI: Body mass index; ROM: Range of motion

Authors' contributions

JS: Analyzed the data, Wrote the manuscript.

GZ: Performed the surgery, Wrote the manuscript.

TL: Study co-ordinator, ROM measurements.

JS: ROM measurements, Analyzed the data.

YD: Squat position classification, Analyzed the data.

QZ: Squat position classification.

YZ: Participated in the design of the study, Performed the surgery.

YW: Created the concept, Wrote the manuscript.

Declarations

All authors read and approved the final manuscript.

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Availability of data and materials

The dataset supporting the conclusions of this article is included within the article.

Ethics approval and consent to participate

This study was approved by the Ethics Committee and in accordance with the standards of the National Research Council. Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table I. The details of the patients.

Variation	Half squat	Parallel squat	Deep squat
Patients(n)	26	75	53
Gender			
Male	3	20	12
Female	23	55	41
Age(years)	62.5(11.4)	61.6(8.5)	60.6(6.9)
Height(cm)	160.7(6.8)	160.7(7.2)	161.9(7.5)
Weight(kg)	67.3(9.4)	68.7(10.4)	67.9(11.3)
BMI(kg/m2)	25.9(2.6)	26.6(3.6)	25.8(3.4)
Side			
Unilateral	14	40	26
Bilateral	12	35	27
High-flexion TKA	23/26	63/75	51/53
Patellar resurfacing	22/26	56/75	40/53
Median Follow-up(months)	6(6-60)	8(6-120)	12(6-156)

BMI, body mass index

Values are presented as mean (standard deviation).

Table II. Results of ROM measurement in the three squatting positions.

Variation	Half squat	Parallel squat	Deep squat	P value
Hip flexion(°)	138.9(12.2) *§	145.2(10.5) *£	149.9 (10.3)§£	<0.001
Knee flexion(°)	99.0(6.4) *§	116.5(8.1) *£	132.5(9.3) §£	<0.001
Ankle dorsiflexion(°)	13.3(7.9) *§	20.5 (8.7) *£	25.1 (9.6) §£	<0.001

Values are presented as mean (standard deviation).

*:p<0.05 Half squat vs Parallel squat;§:p<0.05 Half squat vs Deep squat;£:p<0.05 Parallel squat vs Deep squat

Figures

Figure 1

Different squatting positions after total knee arthroplasty. (a) Half squat. (b) Parallel squat. (c) Deep squat