# Gait Analysis of Patients With a Rotating Hinge Knee Prosthesis After Revision Total Knee Arthroplasty

**Takehiro Ohmi** (ohmi.spt@tmd.ac.jp)
Tokyo Medical and Dental University: Tokyo Ika Shika Daigaku https://orcid.org/0000-0002-0772-0698
**Takumi Yamada**
Tokyo Metropolitan University: Shuto Daigaku Tokyo
**Sadaya Misaki**
Sonoda Daiichi Hospital
**Tomohiro Tazawa**
Sonodakai Joint Replacement Center Hospital
**Ryota Shimamura**
Tokyo Metropolitan Rehabilitation Hospital
**Junpei Kato**
NEC Livex, Ltd.
**Kazutaka Sugimoto**
Sonodakai Joint Replacement Center Hospital

**Research Article**

**Keywords:** total knee arthroplasty, gait, gait analysis, rotating hinge knee, revision

**Posted Date:** October 20th, 2021

**DOI:** https://doi.org/10.21203/rs.3.rs-648611/v1

Abstract

***Background/Objective:*** The number of revision total knee arthroplasty (TKA) procedures performed worldwide is increasing. The rotating hinge knee type (RHK) is used for revision TKA. There has been no report on motion analysis of patients with RHK prosthesis. Therefore, this study aimed to clarify the kinetics and kinematics during gait in patients who underwent revision TKA with an RHK prosthesis.

***Methods:*** This study had a cross-sectional design. The patients who underwent revision TKA with an RHK prosthesis (R-RHK; 14 patients, 24 knees), those who underwent unilateral primary TKA with a cruciate-retaining (CR) type prosthesis (uniCR; five patients, 5 knees), and those who underwent bilateral primary TKA with a CR type prosthesis (bilCR; 10 patients, 20 knees) were included. Their comfortable gait was analyzed. Spatiotemporal parameters and knee joint angle and moment were calculated. The knee joint angle and tibia translation were compared among the three groups using analysis of variance and a post-hoc Tukey test. The knee adduction moment was compared between groups by analysis of covariance controlling for gait speed.

***Results:*** Gait speed of the R-RHK group was significantly less than that of the other groups. The knee joint angle, knee adduction moment, and tibia translation were not different between the R-RHK, uniCR, and bilCR groups during gait and at the beginning of the stance phase.

***Conclusions:*** The gait of patients undergoing revision surgery using an RHK prosthesis because of aseptic loosening may have the same biomechanics as that of patients undergoing primary TKA using a different type of prosthesis.

# Introduction

Total knee arthroplasty (TKA) is the treatment of choice for severe knee joint osteoarthritis (KOA). There is a wide variety of protheses available for TKA. Surgeons determine the appropriate prosthesis for TKA based on the grade of deformity of the knee arthritis. A bicruciate-retaining type of implant can preserve the anterior cruciate ligament and posterior cruciate ligament [1, 2]. A cruciate-retaining (CR) type of implant is substituted for posterior cruciate ligament sufficiency [3]. A posterior-stabilized type of implant, with a constrained condylar design to address collateral ligament insufficiency, is substituted for the posterior cruciate ligament [4, 5]. An Australian registry reported that the frequencies of usage of CR and posterior-stabilized implants are 72% and 28%, respectively [6]. The CR type implant is selected more frequently than the posterior-stabilized type implant worldwide [6]. A rotating-hinge knee (RHK) prosthesis is used for the treatment of global instability or severe bone loss around the knee [7, 8]. Bolanos has described gait analysis parameters for patients treated using CR and posterior-stabilized total knee designs [9]. However, there has been no report on the motion analysis of patients with RHK prosthesis. Thus, the kinetics and kinematics of patients who underwent RHK prosthesis have never been analyzed.

The number of revision TKAs performed worldwide is increasing, along with increasing life expectancy [10]. The main reasons for revision TKA are septic loosening, polyethene wear, pain, instability, stiffness, component malposition, patellar maltracking, and aseptic loosening [11–15]. Approximately 25% of revision TKAs were due to aseptic loosening [16]. Hildin et al. reported that aseptic loosening was associated with increased knee adduction moment (KAM) during gait [17].

The NexGen RHK (Zimmer, Warsaw, Ind, USA) is a modern modular rotating hinge design. It has the characteristics of included modular augments to address bone defects and modular fluted canal filling stems; provides more reliable alignment and additional fixation; and allows 25° of internal and 25° of external rotation of the polyethene inlay and can control the tibial translation (anteriorly to posteriorly and laterally to medially) [8]. The RHK type has undergone revision TKA [8]; however, its motion analysis has never been reported.

Therefore, the purpose of this study was to clarify the kinetics and kinematics during gait in patients who underwent revision TKA using an RHK prosthesis. The knee varus angle in the stance phase during gait is not different between patients who have undergone revision TKA using an RHK prosthesis and those who have undergone primary TKA. Thus, we hypothesized that the knee varus angle and KAM of patients who received the revised TKA selected for RHK prosthesis are the same as those of patients who received the primary TKA selected for CR implant.

## Materials And Methods

# Study Design and Setting

This study had a cross-sectional design in vivo. The Institutional Review Board approved the study design (approval number, 18031). All participants provided signed informed consent before participating in the study.

# Participants/Study Subjects

The patients were those who underwent revision TKA after primary TKA. The inclusion criteria were as follows: 1) patients [R-RHK] who underwent revision TKA using an RHK prosthesis for aseptic loosening; 2) a time lapse of 6 months or more since revision TKA, and 3) patients who could walk independently. The component used in all cases was the NexGen RHK (Zimmer, Warsaw, Ind). The control group inclusion criteria were as follows: 1) patients who underwent primary TKA using the CR type prosthesis (with or without anterior-stabilizing bearing) (unilateral primary TKA with the CR type prosthesis [uniCR] and bilateral primary TKA with the CR type prosthesis [bilCR]); 2) a time lapse of 2 months or more since TKA, and 3) patients who could walk independently. The reason why we included patients who underwent primary TKA using the CR type prosthesis in the control group was that the CR type was the most common thigh component in the world [6]. The reason why not only the uniCR group but also the bilCR group was included was that cases of simultaneous bilateral TKA have increased. In both groups, patients with rheumatoid arthritis or other conditions that affect motor function such as neurologic disease were excluded. There were six participants in the R-RHK group. The control group included 14 patients (24 knees): five patients (5 knees) in the uniCR group and 10 (20 knees) in the bilCR group. Participants' demographics are presented in Table 1.

# Procedures

All participants were assessed at a comfortable gait pace using a three-dimensional motion analysis system (Vicon Nexus; Oxford Metrics, London, UK) with 10 cameras operating at a sampling rate of 100 Hz. The ground reaction force was captured using two force plates (Kisler Japan, Tokyo, Japan) at a sampling rate of 1,000 Hz. Fifty-six 9-mm infrared reflective markers were attached to anatomical locations using the point cluster method. Markers were placed on the bilateral anterior superior iliac spine, posterior superior iliac spine, thigh clusters, shank clusters, calcaneus, lateral malleolus, and head of the second metatarsal bone. In addition, the medial condyle of the thigh and medial malleolus were attached to the participant's body. Thigh clusters consisted of the greater trochanter and lateral femoral epicondyle markers plus nine markers evenly distributed across the anterior and lateral thigh. Shank clusters consisted of the lateral condyle marker plus six additional markers evenly distributed across the anterior and lateral shank. Patients were asked to walk at their self-selected speed along an 8-meter walkway. Data on the participant's foot landing on the center of the force plate without any interference to their gait were collected. For each trial, gait events were detected using vertical ground reaction force data to determine the initial foot contact and toe-off.

# Outcome Measures

The spatiotemporal parameters (gait speed, cadence, step length, and step width) were calculated using Plug-in Gait (Vicon Motion Systems, Oxford, UK). A standard lower extremity musculoskeletal model was created using SIMM 7.0 (SIMM; Software for Interactive Musculoskeletal Modeling MusculoGraphics, Santa Rosa, CA) based on the three-dimensional data. The model included the pelvis, sacrum, femur, tibia, fibula, patella, talus, and calcaneus and metatarsal bones, along with 36 muscles of the lower extremity. A segment of the pelvis and both thighs, shanks, and feet were created from these bones. Each segment was joined by the hip joints, knee joints, ankle joints, and subtalar joints. The knee joint noted in this study had 6 degrees of freedom (flexion/extension, adduction/ abduction, internal rotation/ external rotation) and two translation motions (anterior/posterior, medial/ lateral).

Using this model, the following items during the stance phase of gait were calculated: maximum knee flexion/extension, maximum varus/valgus, maximum internal rotation/external rotation angle, and KAM at the first peak. The amounts of change in the rotation angle and tibial translation (anterior-posterior) were calculated from the initial contact to loading response in the stance phase. In this study, a leg was counted as one sample in order to investigate the kinetics and kinematics of a leg.

# Statistical Analysis

The normality of each variable's distribution was determined by a histogram and the Shapiro–Wilk normality test. Participant's demographics, the spatio-temporal parameters, knee joint angles, and tibial translation were compared among the three groups, the R-RHK, uniCR, and bilCR groups, by using analysis of variance (ANOVA) and the post hoc Tukey test. KAM was compared between the groups by using analysis of covariance (ANCOVAs) controlling for gait speed. All statistical analyses were performed using SPSS 23.0 J (IBM Corp., Armonk, NY, USA). The significance level was set at 5%.

# Results

The age, height, weight, and body mass index were not significantly different among the three groups. Among the spatiotemporal parameters, gait speed was significantly slower in the R-RHK group than in the uniCR and bilCR groups ($p < 0.01$) (R-RHK: 0.8 ± 0.06 m/s, uniCR: 1.0 ± 0.04 m/s, bilCR: 1.1 ± 0.2 m/s), and step length was significantly narrower in the R-RHK group than in the uniCR and bilCR groups ($p = 0,01$) (R-RHK: 43.3 ± 6.4 cm, uniCR: 54.5 ± 3.7 cm, bilCR: 52.0 ± 6.0 cm) (Table. 2). The knee joint angles were not significantly different among the groups (Table. 3, Figs. 1–3). KAM controlled for gait speed was not significantly different among the groups (Fig. 4). From initial contact to loading response, the tibial translation in the R-RHK, uniCR, and bilCR groups was 1.5 ± 0.5, 1.5 ± 2.2, and 1.1 ± 1.4 mm, respectively, and the amount of rotation in those groups was 0.4°±1.5°, 1.2°±1.7°, and 0.5°±2.0°, respectively. Tibial translation and the amount of rotation were not significantly different among the groups (Table. 4).

# Discussion

The present study sought to examine kinetics and kinematics during gait for patients who were undergone revision TKA with RHK, and we hypothesized that R-RHK was smaller than the knee joint angle and larger than the KAM as compared to uniCR and bilCR. In this study, the knee joint angles, KAM, and tibial anterior translation were not different among the R-RHK, uniCR, and bilCR groups during gait and the early stance phase, which supports our hypothesis. These findings suggest that the biomechanical data of the R-RHK group were not different compared to those of the uniCR and bilCR groups.

Gait speed in the R-RHK group was significantly lower than that in the uniCR and bilCR groups. The gait speed of patients who received primary TKA in past studies was 0.8–1.1 m/s [9, 18, 19]. A decrease in gait speed is mentioned as an abnormal gait condition after TKA [20]. The results of gait speed and step length in our study suggest that R-RHK may be associated with lower gait ability compared to uniCR and bilCR.

There was no difference in the knee joint angle and moment when comparing the R-RHK group to the uniCR and bilCR groups. The maximum/minimum flexion angles of the knee joint during gait in the R-RHK group were not significantly different from those in previous studies [18, 20] of primary TKA patients. KAM was 0.2–0.6 Nm/kg in previous reports [21–23]. The KAM values of all three groups in this study were comparable to those of previous studies [21–23]. No significant differences were found among the R-RHK, uniCR, and bilCR groups, since the orthopedists controlled for the femoro-tibial angle in patients who underwent revision TKA and those who underwent primary TKA. The Western Ontario and McMaster Universities Osteoarthritis Index function score was reported to plateau at 6 months after TKA [24]. In the patients in whom revision TKA was performed because of aseptic loosening, the Knee Society Scoring

System function score and clinical score were relatively good [10]. The kinetics and kinematics data of this study could be the basis for the improvement in those scores.

In our study, the amount of tibial rotation was approximately 1º in the R-RHK group from the initial contact to the loading response in the stance phase. The tibia internally rotates 4º-8º from the initial contact to the loading response in the stance phase [25–27]. The Nex Gen RHK prosthesis allows for tibial rotation [8]; however, our result showed lesser rotation than those reports. The Nex Gen RHK prosthesis has a mechanism to guide the control pivot designed by a hinge and mobile bearing; thus, this motion is considered to be a result of muscles and alignment.

The Nex Gen RHK prosthesis was developed to be able to decrease tibial translation. Tibial translation in the R-RHK group was 1.5 mm, which was smaller than those of previous reports [2, 28, 29], although it was not significantly different compared to the control groups in the current study. The reason for the result of the present study is that the femoral condyle radius and bearing have a high one-to-one conformity, which enables anterior stability. In the uniCR and bilCR groups, most subjects underwent CR type TKA with the anterior-stabilized (AS) bearing, which may have guided tibial rotation and translation in those groups. The AS bearing design motion may be the reason why there was no significant difference in tibial rotation and translation among the three groups.

There are many studies on gait analysis in patients with TKA. However, we could not find a published gait analysis in patients with revision RHK TKA; thus, ours is the first report. The gait biomechanics in our study were similar between patients who underwent revision TKA and those who underwent primary TKA.

# Limitations

Our study has some limitations. First, the patients in this study underwent revision TKA because of aseptic loosening; thus, our results may not be applicable to patients who have undergone revision surgery because of other factors. Satisfaction, pain reduction, and functional improvement were better, and complication rates were lower after revision TKA for aseptic loosening than those after revision TKA for other causes of failure [11]. Therefore, patients who have undergone revision surgery for reasons other than aseptic loosening may have lower gait ability than patients who have undergone revision surgery due to aseptic loosening. Second, it is unclear whether the results of this study are equally applicable to men. KOA has previously also been found to be more common in women than in men [30]. It will be necessary to analyze the kinetics and kinematics in male patients in the future. Lastly, because this study included cross-sectional data after revision TKA, the causal relationship leading to revision remains unclear.

## Conclusions

The present study’s results suggest that the gait of patients undergoing revision surgery using an RHK prosthesis for aseptic loosening TKA may have the same characteristic kinetics and kinematics as that of patients undergoing primary TKA using another type of prosthesis. These findings can be used to guide patients in gait training in the clinical setting after revision TKA. In the future, the gait of patients who have undergone revision surgery because of other factors will be analyzed.

# Declarations


### Acknowledgments

We would like to thank the members of our institution for their assistance and thank Editage (www.editage.jp) for English language editing.


**Ethics approval**: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The Institutional Review Board at our institution approved the study design (approval number: 18031).

**Consent to participate**: All participants provided signed informed consent before participating in the study.

**Consent for publication**: None

**Availability of data and material**:Nnone

**Code availability**: None

### Authors' contributions

All authors made significant contributions to the conception and design, acquisition of data, or analysis and interpretation of data. All the authors made significant contributions to drafting the manuscript or revising it critically for intellectual content. TO participated in the conception and design, analysis, and interpretation of data, and writing the manuscript. TY, SM, TT, RS, and JK participated in the design, acquisition and interpretation of data, and revision of the manuscript. TT participated in the acquisition of data, performed the statistical analysis, and helped revise the manuscript. TT, RS, and JK participated in acquisition of data, interpretation of data, and revision of the manuscript. TY and KS participated in the conception and design, analysis, and interpretation of data, and drafting the manuscript as a researcher in the field of physiotherapy and orthopedics. All the authors have read and approved the final version of the manuscript.


### Funding

This study received research support from Zimmer Biomet, LLC.


### Conflicts of interest

Author TY has received research support from Zimmer Biomet, LLC. Other authors declare that they have no conflict of interest.

## References


1. Goodfellow JB, O'Connor JJ. Retention of the anterior cruciate in arthroplasty of the knee. J Bone Joint Surg Br. 1988;70:333.
2. Andriacchi TP, Galante JO, Fermier RW. The influence of total knee replacement design on walking and stair climbing. J Bone Joint Surg Am. 1982;64:1328–35.
3. Song SJ, Park CH, Bae DK. What to know for selecting cruciate-retaining or posterior-stabilized total knee arthroplasty. Clin Orthop Surg. 2019;11:142–50.
4. Lachiewicz PF, Falatyn SP. Clinical and radiographic results of the total condylar III and constrained condylar total knee arthroplasty. J Arthroplasty. 1996;11:916–22.
5. Hwang SC, Kong JY, Nam DC, Kim DH, Park HB, Jeong ST, et al. Revision total knee arthroplasty with a cemented posterior-stabilized or constrained condylar prosthesis: a minimum 2-year follow-up analysis. Clin Orthop Surg. 2010;2:112–20.
6. Australian Orthopaedic Association. Hip and knee arthroplasty. 2015. https://aoanjrr.sahmri.com/documents/10180/217745/Hip%20and%20Knee%20Arthroplasty. Accessed 30 Oct 2019.
7. McAuley JP, Engh GA. Constraint in total knee arthroplasty: when and what? J Arthroplasty. 2003;18:51–4.
8. Neumann DR, Hofstaedter T, Dorn U. Follow-up of a modular rotating hinge knee system in salvage revision total knee arthroplasty. J Arthroplasty. 2012;27:814–9.
9. Bolanos AA, Colizza WA, McCann PD, Gotlin RS, Wootten ME, Kahn BA, et al. A comparison of isokinetic strength testing and gait analysis in patients with posterior cruciate-retaining and substituting knee arthroplasties. J Arthroplasty. 1998;13:906–15.
10. Abdelaal MS, Restrepo C, Sharkey PF. Global perspectives on arthroplasty of hip and knee joints. Orthop Clin North Am. 2020;51:169–76.
11. van Kempen RW, Schimmel JJ, van Hellemondt GG, Vandenneucker H, Wymenga AB. Reason for revision TKA predicts clinical outcome: prospective evaluation of 150 consecutive patients with 2-years follow-up. Clin Orthop Relat Res. 2013;471:2296–302.
12. Mandalia V, Eyres K, Schranz P, Toms AD. Evaluation of patients with a painful total knee replacement. J Bone Joint Surg Br. 2008;90:265–71.
13. Parratte S, Pagnano MW. Instability after total knee arthroplasty. J Bone Joint Surg Am. 2008;90:184–94.
14. Patil N, Lee K, Huddleston JI, Harris AH, Goodman SB. Aseptic versus septic revision total knee arthroplasty: patient satisfaction, outcome and quality of life improvement. Knee. 2010;17:200–3.

15. Toms AD, Mandalia V, Haigh R, Hopwood B. The management of patients with painful total knee replacement. J Bone Joint Surg Br. 2009;91:143–50.
16. Sadoghi P, Liebensteiner M, Agreiter M, Leithner A, Böhler N, Labek G. Revision surgery after total joint arthroplasty: a complication-based analysis using worldwide arthroplasty registers. J Arthroplasty. 2013;28:1329–32.
17. Hilding MB, Lanshammar H, Ryd L. Knee joint loading and tibial component loosening. RSA and gait analysis in 45 osteoarthritic patients before and after TKA. J Bone Joint Surg Br. 1996;78:66–73.
18. Saari T, Tranberg R, Zügner R, Uvehammer J, Kärrholm J. Changed gait pattern in patients with total knee arthroplasty but minimal influence of tibial insert design: gait analysis during level walking in 39 TKR patients and 18 healthy controls. Acta Orthop. 2005;76:253–60.
19. Mandeville D, Osternig LR, Chou LS. The effect of total knee replacement surgery on gait stability. Gait Posture. 2008;27:103–9.
20. McClelland JA, Webster KE, Feller JA. Gait analysis of patients following total knee replacement: a systematic review. Knee. 2007;14:253–63.
21. Urwin SG, Kader DF, Caplan N, St Clair Gibson A, Stewart S. Gait analysis of fixed bearing and mobile bearing total knee prostheses during walking: do mobile bearings offer functional advantages? Knee. 2014;21:391–5.
22. Thomsen MG, Husted H, Bencke J, Curtis D, Holm G, Troelsen A. Do we need a gender-specific total knee replacement? A randomised controlled trial comparing a high-flex and a gender-specific posterior design. J Bone Joint Surg Br. 2012;94:787–92.
23. Metcalfe A, Stewart C, Postans N, Barlow D, Dodds A, Holt C, et al. Abnormal loading of the major joints in knee osteoarthritis and the response to knee replacement. Gait Posture. 2013;37:32–6.
24. Fortin PR, Penrod JR, Clarke AE, St-Pierre Y, Joseph L, Belisle P, et al. Timing of total joint replacement affects clinical outcomes among patients with osteoarthritis of the hip or knee. Arthritis Rheum. 2002;46:3327–30.
25. Nagano Y, Naito K, Saho Y, Torii S, Ogata T, Nakazawa K, et al. Association between in vivo knee kinematics during gait and the severity of knee osteoarthritis. Knee. 2012;19:628–32.
26. Levens AS, Inman VT, Blosser JA. Transverse rotation of the segments of the lower extremity in locomotion. J Bone Joint Surg Am. 1948;30A:859–72.
27. Fukaya T, Mutsuzaki H, Ida H, Wadano Y. Two different protocols for knee joint motion analyses in the stance phase of gait: correlation of the rigid marker set and the point cluster technique. Rehabil Res Pract. 2012;2012:586348.
28. Smith CR, Brandon SCE, Thelen DG. Can altered neuromuscular coordination restore soft tissue loading patterns in anterior cruciate ligament and menisci deficient knees during walking? J Biomech. 2019;82:124–33.
29. Lin Z, Huang W, Ma L, Chen L, Huang Z, Zeng X, et al. Kinematic features in patients with lateral discoid meniscus injury during walking. Sci Rep. 2018;8:5053.

30. Muraki S, Oka H, Akune T, Mabuchi A, En-yo Y, Yoshida M, et al. Prevalence of radiographic knee osteoarthritis and its association with knee pain in the elderly of Japanese population-based cohorts: the ROAD study. Osteoarthritis Cartilage. 2009;17:1137–43.

# Tables

Table 1. Subject demographics of each group

| | R-RHK<br>n=6, 6 knees | uniCR<br>n=4, 4 knees | bilCR<br>n=10, 20 knees | | | |
|---|---|---|---|---|---|---|
| | Mean± SD<br>(95% CI) | Mean± SD<br>(95% CI) | Mean± SD<br>(95% CI) | F value | P-value | η2 |
| Age | 73.00±6.83<br>(62.13-83.87) | 67.67±0.58<br>(66.23-69.10) | 71.67±5.13<br>(58.91-84.41) | 0.22 | 0.81 | 0.02 |
| Post surgery TKA (months) | 22.00±17.37<br>(0.42- 43.58) | 9.60±3.28<br>(5.52-13.69) | 10.80±2.68<br>(7.47- 14.13) | 3.67 | 0.05 | 0.24 |
| The number of using AS bearing | - | 3/4 knees | 12/20 knees | - | - | - |
| Height (cm) | 150.88±5.32<br>(144.26-157.50) | 154.20±8.00<br>(144.26-164.14) | 145.92±4.60<br>(140.21-151.63) | 1.22 | 0.31 | 0.11 |
| Weight (kg) | 65.28±9.15<br>(53.92-76.64) | 63.20±7.39<br>(54.03-72.38) | 58.00±10.40<br>(45.09-70.92) | 0.03 | 0.98 | 0.00 |
| BMI (kg/m2) | 28.56±2.47<br>(25.49-31.63) | 26.54±1.72<br>(24.40-28.67) | 27.20±4.54<br>(21.26-32.84) | 0.57 | 0.58 | 0.05 |

TKA, total knee arthroplasty; BMI, body mass index; R-RHK, revision TKA was due to aseptic loosening with the rotator hinge knee type; uniCR, unilateral primary TKA with the cruciate retaining type; bilCR, bilateral primary TKA with the cruciate retaining type; CI, confidence interval

Table 2. Spatio- temporal parameters of each group

| | R-RHK | uniCR | bilCR | | | |
|---|---|---|---|---|---|---|
| | Mean± SD (95% CI) | Mean± SD (95% CI) | Mean± SD (95% CI) | F value | P-value | η2 |
| Gait speed (m/s) | 0.79±0.02 (0.77- 0.82) | 0.99±0.04 (0.94- 1.05) | 1.02±0.14 (0.80- 1.23) | 9.31 | <0.01 | 0.47 |
| Cadence (steps/min) | 114.50±15.54 (89.76- 139.24) | 112.00±2.44 (108.10- 118.90) | 119.75±12.50 (99.86- 139.64) | 1.31 | 0.29 | 0.11 |
| Step length (cm) | 43.50±7.55 (31.49- 55.51) | 54.50±3.70 (48.62- 60.38) | 52.14±5.53 (48.94- 55.34) | 6.69 | 0.01 | 0.39 |
| Step width (cm) | 17.00±3.56 (11.34- 22.66) | 14.67±4.08 (10.38- 18.95) | 14.67±4.37 (10.08- 19.25) | 2.48 | 0.11 | 0.18 |

R-RHK, revision TKA was due to aseptic loosening with the rotator hinge knee type; uniCR, unilateral primary TKA with the cruciate retaining type; bilCR, bilateral primary TKA with the cruciate retaining type; CI, confidence interval

Among the spatiotemporal parameters, gait speed in the R-RHK group was significantly slower and step length in the R-RHK group was significantly longer than those in the uniCR and bilCR groups.

Table 3. Kinetics and kinematics data during gait

| | R-RHK | uniCR | bilCR | | | |
|---|---|---|---|---|---|---|
| | Mean± SD (95% CI) | Mean± SD (95% CI) | Mean± SD (95% CI) | F value | P-value | η2 |
| maximum flexion angle (deg) | 40.24±7.07 (31.47-49.01) | 41.21±9.20 (29.78-52.63) | 35.42±7.13 (26.57-44.28) | 0.24 | 0.79 | 0.01 |
| minimum flexion angle (deg) | 9.30±8.91 (-1.76-20.36) | 9.61±4.73 (3.73-15.50) | 5.20±5.74 (-1.93-12.33) | 0.92 | 0.41 | 0.05 |
| maximum varus angle (deg) | 1.65±2.14 (-1.76-5.06) | -0.64±2.75 (-5.01-3.72) | 1.50±1.81 (-1.39-4.39) | 0.55 | 0.58 | 0.03 |
| maximum inner rotation angle (deg) | -2.11±15.13 (-26.20-21.98) | -8.98±4.75 (-16.54--1.41) | -5.86±7.18 (-17.28-5.57) | 1.17 | 0.32 | 0.06 |
| maximum external rotation angle (deg) | 10.99±8.57 (-2.67-24.60) | 15.37±5.09 (7.26-23.47) | 11.78±5.80 (2.54-21.01) | 1.41 | 0.26 | 0.07 |
| amount of rotation angle (deg) | 5.60±3.30 (0.35-10.86) | 6.40±2.88 (1.81-10.98) | 5.92±2.47 (1.99- 9.85) | 0.26 | 0.77 | 0.01 |
| KAM(Nm/kg)* | 0.55±0.34 (0.18- 0.57) | 0.37±0.16 (0.18-0.57) | 0.35±0.11 (0.22- 0.48) | 0.74 | 0.71 | 0.07 |

R-RHK, revision TKA was due to aseptic loosening with the rotator hinge knee type; uniCR, unilateral primary TKA with the cruciate retaining type; bilCR, bilateral primary TKA with the cruciate retaining type; CI, confidence interval; KAM, maximum knee adduction moment during stance phase

The knee joint angles were compared among the three groups, the R-RHK , the uniCR, and the bilCR groups by using analysis of variance (ANOVA) and the post-hoc Tukey test.

*KAM was compared inter groups by analysis of covariance (ANCOVAs) controlling for gait speed.

Table 4. Kinetics and kinematics data from initial contact to loading response

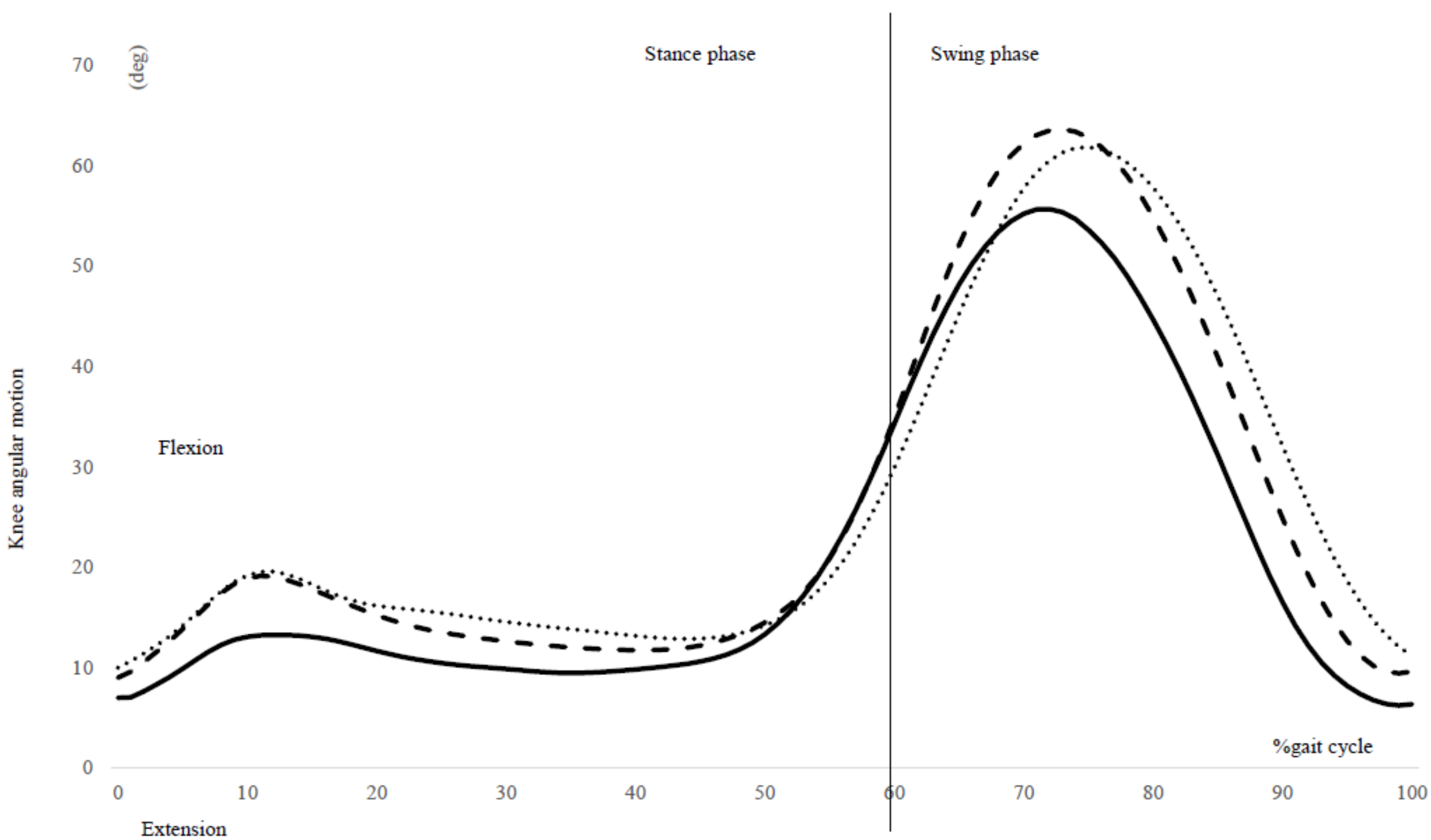
| | R-RHK | uniCR | bilCR | | | |
|---|---|---|---|---|---|---|
| | Mean± SD<br>(95% CI) | Mean± SD<br>(95% CI) | Mean± SD<br>(95% CI) | F value | P-value | η2 |
| tibialis translation (mm) | 1.46±0.52<br>(0.81-2.10) | 1.45±2.20<br>(-1.29-4.18) | 0.99±1.63<br>(-1.02-3.01) | 0.01 | 0.99 | 0.00 |
| amount of tibial rotation angle (deg) | 0.98±1.50<br>(-1.39-3.36) | 1.69±2.51<br>(-2.31-5.69) | 0.67±0.48<br>(-0.1- 1.40) | 1.26 | 0.30 | 0.07 |

R-RHK, revision TKA was due to aseptic loosening with the rotator hinge knee type; uniCR, unilateral primary TKA with the cruciate retaining type; bilCR, bilateral primary TKA with the cruciate retaining type; CI, confidence interval

Tibial translation; The plus means anterior.

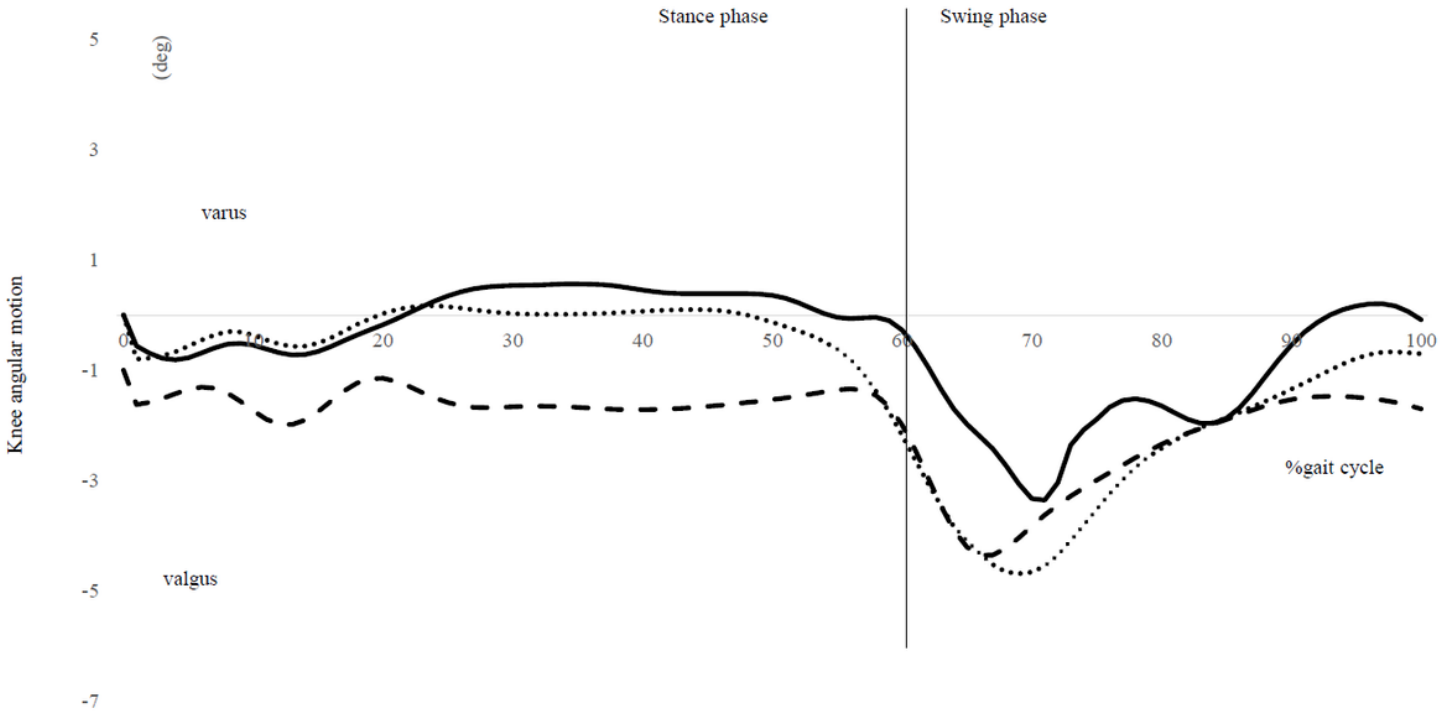
Rotation; The plus means internal rotation

# Figures



## Figure 1

Knee angular motion (sagittal plane) The continuous, dash, and dot lines represent R-RHK, uniCR, and biICR, respectively Abbreviations: R-RHK, revision total knee arthroplasty with a rotating hinge knee type prosthesis; uniCR, unilateral primary total knee arthroplasty with a cruciate-retaining prosthesis; biICR, bilateral primary total knee arthroplasty with a cruciate-retaining prosthesis




## Figure 2

Knee angular motion (frontal plane) The continuous, dash, and dot lines represent R-RHK, uniCR, and biICR, respectively Abbreviations: R-RHK, revision total knee arthroplasty with a rotating hinge knee type prosthesis; uniCR, unilateral primary total knee arthroplasty with a cruciate-retaining prosthesis; biICR, bilateral primary total knee arthroplasty with a cruciate-retaining prosthesis

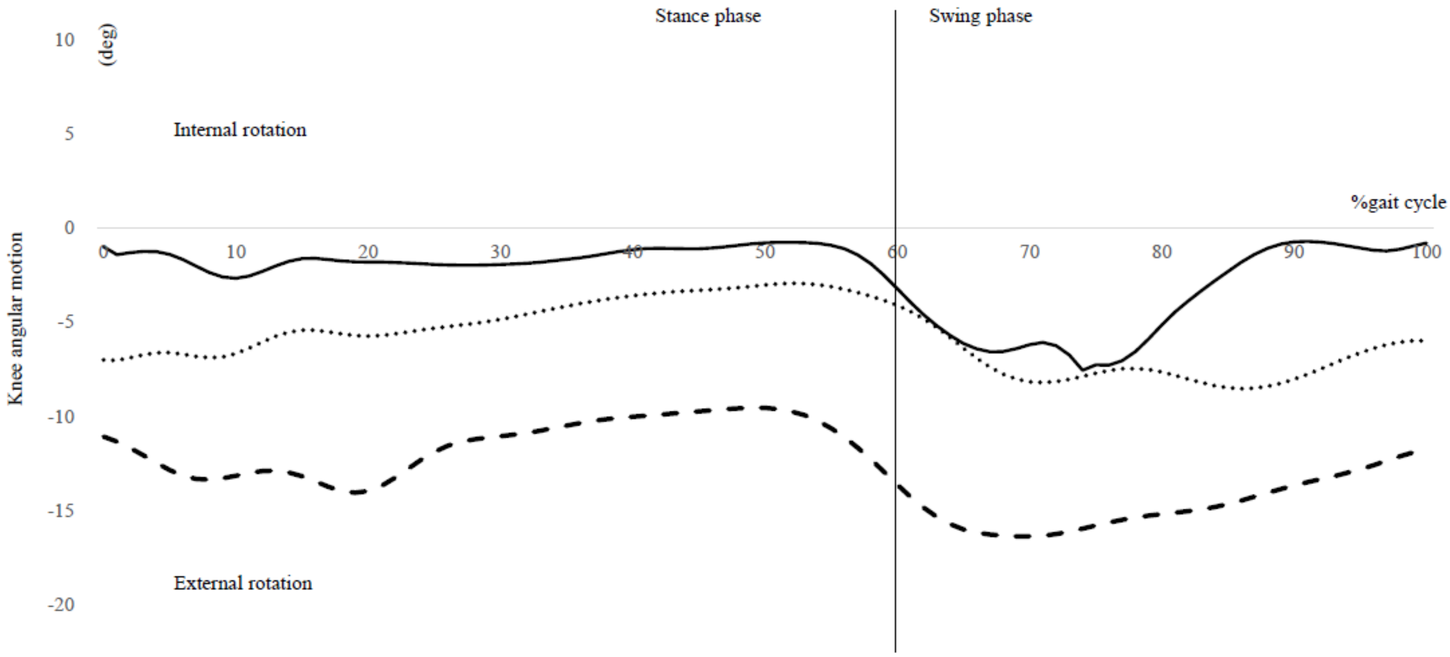



**Figure 3**

Knee angular motion (horizontal plane) The continuous, dash, and dot lines represent R-RHK, uniCR, and bilCR, respectively.

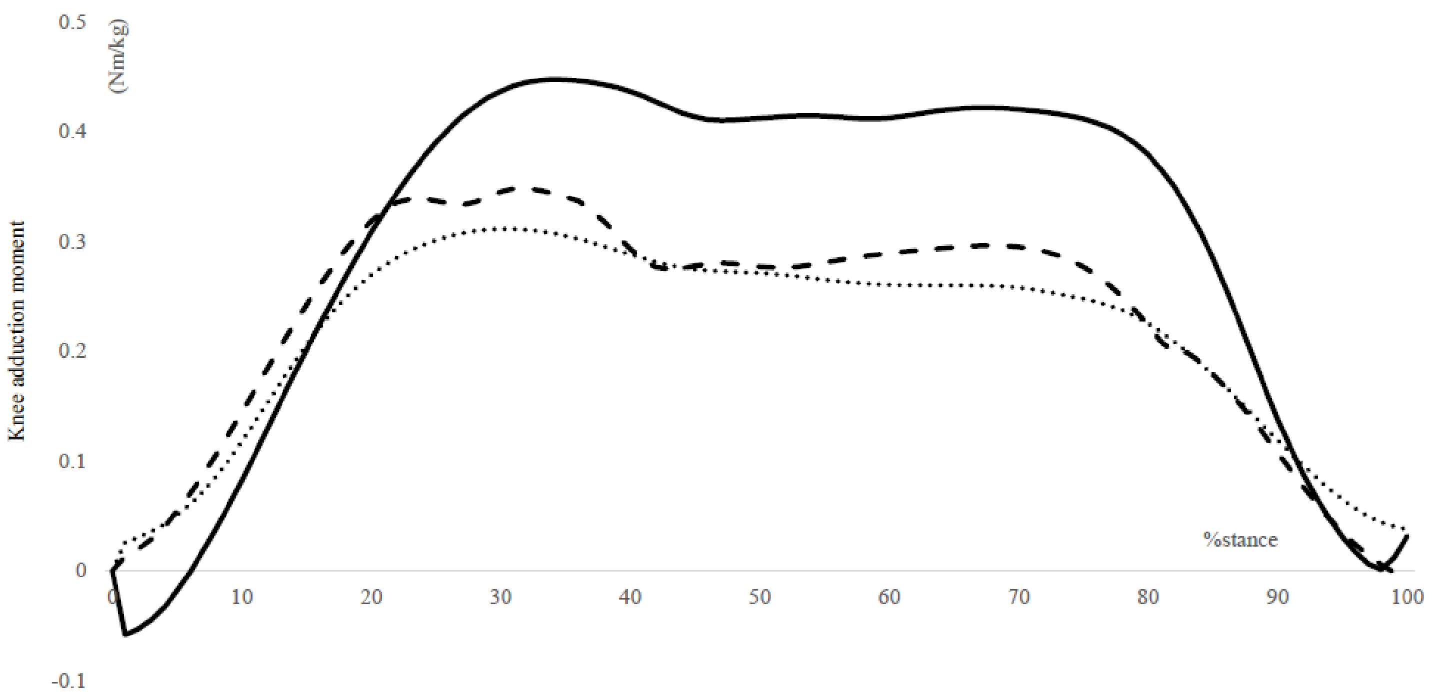



**Figure 4**

Knee adduction moment The continuous, dash, and dot lines show R-RHK, uniCR, and bilCR, respectively Abbreviations: R-RHK, revision total knee arthroplasty with a rotating hinge knee type prosthesis; uniCR, unilateral primary total knee arthroplasty with a cruciate-retaining prosthesis; bilCR, bilateral primary total knee arthroplasty with a cruciate-retaining prosthesis

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- STROBEStatementChecklist.docx