

Association of knee flexion angle after posterior-stabilized total knee arthroplasty with postoperative tibial external position relative to the femur and the extent of tibial internal rotation from knee extension to flexion

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- 1 Association of knee flexion angle after posterior-stabilized total knee arthroplasty with
- 2 postoperative tibial external position relative to the femur and the extent of tibial internal
- 3 rotation from knee extension to flexion

4 **Abstract**

5 **Background**

6 This study evaluated the relationship between preoperative and postoperative knee kinematics,
7 moreover, investigated tibial rotational position and the extent of tibial internal rotation from knee
8 extension to flexion as factors to obtain significant knee flexion after total knee arthroplasty (TKA).

9 **Methods**

10 Fifty-four patients (60 knees total; 15 males, 16 knees; 39 females, 44 knees) who underwent
11 posterior-stabilized TKA using a navigation system were included. Intraoperative knee kinematics
12 involving tibial rotational position relative to the femur and the extent of tibial internal rotation were
13 examined at 2 time points; 1) after landmarks registration (pre-TKA), and 2) after skin closure
14 (post-TKA). The relationship between the knee flexion angle at 1 year postoperatively and
15 intraoperative tibial rotational position, or the extent of tibial rotation among several knee flexion
16 angles calculated with a navigation system were investigated.

17 **Results**

18 The postoperative knee flexion angle was positively associated with the preoperative flexion angle
19 and intraoperative knee kinematics at post-TKA involving tibial external position relative to the
20 femur at knee extension and the extent of tibial internal rotation from extension to 90° of flexion or
21 to maximum flexion. There was a positive relationship between the extent of tibial internal rotation

22 at pre-TKA and that at post-TKA.

23 **Conclusions**

24 The intraoperative kinematics of the extent of tibial internal rotation at post-TKA was influenced by

25 that at pre-TKA. The greater external position of the tibia relative to the femur at knee extension and

26 the greater extent of tibial internal rotation at post-TKA might lead to good knee flexion angle.

27

28 **Keywords:** total knee arthroplasty; tibial internal rotation; knee kinematics; knee flexion angle

29 **1 Introduction**

30 Total knee arthroplasty (TKA) is an established surgical procedure used to treat osteoarthritis of the
31 knee. Although positive results in terms of pain relief have been achieved after TKA, patient
32 satisfaction scores after TKA have been lower than those after total hip arthroplasty [1, 2, 3]. The
33 range of motion of the knee is an important factor that affects the postoperative clinical results of
34 TKA, and the postoperative range of motion of the knee is strongly influenced by the preoperative
35 range of motion [4, 5, 6, 7]. However, patient-reported outcomes after TKA may also be related to
36 preoperative patient demographics [2]. Furthermore, it has been shown that internal rotation of the
37 tibia from extension to flexion of the knee contributes to a better range of motion after TKA, and
38 that tibial external rotation reduces the flexion angle [8, 9, 10, 11]. However, in normal knees,
39 dynamic kinematics include the medial pivot motion, which is defined as femoral external rotation
40 relative to the tibia (equivalent to tibial internal rotation relative to the femur) from extension to 120°
41 of flexion of the knee and femoral bicondylar rollback motion from 120° to maximum flexion [12,
42 13, 14, 15, 16, 17]. Patient-reported outcomes after TKA might be associated with abnormalities of
43 knee kinematics compared to conditions before osteoarthritis [18, 19, 20]. Therefore, to evaluate
44 TKA kinematics, several studies analyzed intraoperative kinematics using a TKA navigation system
45 [8, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30]. When the medial pivot motion of the knee was reproduced
46 after TKA, good range of motion of the knee and high patient satisfaction scores were reported [8,

47 25, 26]. Therefore, the TKA surgical technique used to obtain the medial pivot motion is important.

48 It was hypothesized that the internal rotation of the tibia has favorable effects on the postoperative
49 range of motion of the knee. Thus, the aim of the present study was to investigate the relationship
50 between the range of motion of the knee after TKA and the intraoperative rotational position of the
51 tibia relative to the femur, and to calculate the extent of tibial internal rotation required to obtain a
52 better range of motion.

53

54 **2 Materials and Methods**

55 The study was performed retrospectively and was approved by the ethics committee of the
56 Hamamatsu University School of Medicine. From 2014 to 2017, consecutive patients who
57 underwent primary TKA for severe varus osteoarthritis of the knee, which corresponded to grade 2
58 or more according to the Kellgren-Lawrence classification, were included in the study. Patients with
59 valgus osteoarthritis, inflammatory arthritis such as infection and rheumatoid arthritis, and patients
60 who underwent revision surgery were excluded. Patients who were performed patellar replacement
61 were also excluded. The study population included 54 patients (60 knees) with an average age of
62 74.9 years (range, 52–91 years) who underwent follow-up for a minimum of 1 year.

63

64 ***2.1 Surgical procedures for TKA***

65 All TKA procedures were performed using a computed tomography (CT)-free navigation system
66 (Stryker Knee Navigation System version 4.0; Stryker Leibinger, Freiburg, Germany). The medial
67 parapatellar approach (45 knees) or the mid-vastus approach (15 knees) was used to expose the knee
68 joint. Minimal release of the medial collateral ligament and soft tissue was performed for osteotomy.
69 The measured resection technique was used for femoral and tibial osteotomy. The anterior cruciate
70 ligament and posterior cruciate ligament were sacrificed, and posterior-stabilized (PS) implants
71 (Triathlon; Stryker Kalamazoo, MI, USA) were used for TKA. The navigation system included
72 several anatomical landmarks. The femoral rotational axis was defined using the surgical
73 epicondylar axis, which was based on the sulcus behind the femoral medial condyle and the tip of
74 the femoral lateral condyle. The anteroposterior axis of the tibia was defined as the line that ran from
75 the medial border of the tibial tubercle to the middle of the tibial insertion of the posterior cruciate
76 ligament to confirm the rotational position when making a keel hole [31]. Following these steps, the
77 navigation system was used for all cases during osteotomy of the femur (distal, anterior, posterior,
78 and chamfers) and tibial plateau. The femoral and tibial components were aimed to exact vertical
79 relative to mechanical axis in coronal plane. In sagittal plane, the femoral and tibial components
80 were aimed to 0 to 5° of flexion. The CT-free navigation system was used during cementing to
81 confirm the rotational position of the tibial component [32]. The patellar replacement was not
82 performed in this series despite the osteoarthritis grade of the patellofemoral joint.

83

84 **2.2 Intraoperative measurements of tibial rotation**

85 Intraoperative kinematics, including rotational position of the tibia and the extent of tibial internal
86 rotation relative to the femoral anteroposterior axis, were examined. Intraoperative measurements of
87 knee kinematics were performed at two time points using the navigation system: 1) when registration
88 was completed before osteotomy (pre-TKA) and 2) when the skin incision was closed after femoral
89 and tibial components were cemented (post-TKA). The patella had reposition and only the medial
90 retinaculum was sutured at pre-TKA measurement. The condition of anterior cruciate ligament was
91 differed among each patient and the posterior cruciate ligament was remained in all patients at
92 pre-TKA measurement. The surgeon held the patient's thighs and flexed the knee from the extension
93 position while the patient's heel was placed on the palm of the assistant and held slightly to avoid
94 tibial rotation, which was in accordance with the method used by Wada [33]. The navigation system
95 automatically recorded the angle of tibial rotation at maximum extension (mean $-10.5 \pm 6.8^\circ$), 30° ,
96 60° , 90° , and maximum flexion (mean $132.5 \pm 10.8^\circ$) during passive knee motion. In this study,
97 internal rotation of the tibia relative to the femur was represented as a positive value, and external
98 rotation of the tibia was represented as a negative value. Two surgeons performed the TKAs
99 procedures in this series. Kinematic measurements were performed one time for each patient by one
100 of the two surgeons. Finally, the extent of tibial internal rotation between each angle of knee flexion

101 was calculated at pre-TKA and post-TKA.

102

103 ***2.3 Postoperative procedure and evaluation***

104 Patients were hospitalized the day before surgery. On the first day after surgery, the suction drain

105 was removed, and patients were allowed to start range of motion rehabilitation and ambulation.

106 Exercises were performed for approximately 3 weeks during hospitalization. After discharge, all

107 patients were followed-up monthly during outpatient visits. The range of motion of the knee was

108 examined using a goniometer for 1 year postoperatively, although the knee flexion angle measured

109 with a goniometer which shows bone axis reference was differed from intraoperative kinematics

110 measured with a navigation system which shows mechanical axis reference. The new Knee Society

111 score (KSS) [34, 35] was also evaluated at 1 year after surgery.

112

113 **3 Theory/calculation**

114 The correlation between the angle of knee extension or flexion at 1 year after surgery and each

115 intraoperative kinematics parameter, including the intraoperative rotational position of the tibia

116 relative to the femur and the extent of tibial internal rotation, was calculated with Pearson's

117 correlation coefficient test. In addition, the multiple regression analysis was performed as a

118 dependent variable was knee flexion angle at 1 year after TKA. The relationship between the KSS at

119 1 year after surgery and each intraoperative parameter was also calculated with Pearson's correlation
120 coefficient test. Comparison between intraoperative knee kinematics at pre-TKA and that at
121 post-TKA was calculated with the paired t-test. The correlations between the extent of intraoperative
122 tibial rotation from knee extension to flexion at pre-TKA and that at post-TKA were also calculated
123 using Pearson's correlation coefficient test.

124 Each intraoperative parameter was compared between the group with a knee flexion angle of 120° or
125 less at 1 year after surgery and the group with a knee flexion angle more than 120° using the
126 parametric t-test. Furthermore, receiver-operating characteristic (ROC) curves for the knee flexion
127 angles between the groups were calculated using the extent of intraoperative tibial internal rotation at
128 post-TKA. The cutoff value was determined by the Youden index, which maximizes the overall rate
129 of correct classification (sum of sensitivity and specificity). SPSS version 21 (IBM Corporation,
130 Armonk, NY) was used for all statistical analyses; $p = 0.05$ was considered statistically significant.

131

132 **4 Results**

133 The demographic data of patients are shown in Table 1. Age, body height, body weight, and body
134 mass index were not significantly correlated with the preoperative or postoperative range of motion
135 of the knee or any intraoperative parameters.

136 The extension angle of the knee at 1 year after TKA was significantly correlated with the

137 preoperative extension angle with Pearson's correlation coefficient test (correlation coefficient,
138 0.541; $p<0.001$). Intraoperative kinematics including the intraoperative rotational position of the
139 tibia relative to the femur and the intraoperative extent of tibial internal rotation from knee extension
140 to flexion at pre-TKA and at post-TKA were not associated with the extension angle of the knee at 1
141 year after surgery.

142 The flexion angle of the knee at 1 year after TKA was significantly associated with the preoperative
143 flexion angle (correlation coefficient, 0.592; $p<0.001$), rotational position of the tibia at maximum
144 knee extension (correlation coefficient, 0.249; $p=0.048$), the extent of intraoperative tibial internal
145 rotation from knee extension to 90° of flexion (correlation coefficient, 0.332; $p=0.012$), and the
146 intraoperative extent of tibial internal rotation from knee extension to maximum flexion (correlation
147 coefficient, 0.325; $p=0.014$) with Pearson's correlation coefficient test. However, the knee flexion
148 angle at 1 year after TKA was associated with only preoperative knee flexion angle with the multiple
149 regression analysis (correlation coefficient, 0.570; $p<0.001$). The flexion angle of the knee at 1 year
150 after surgery was not associated with intraoperative kinematics at pre-TKA.

151 KSS scores at 1 year after surgery for patient symptoms, satisfaction, and expectations were not
152 associated with any intraoperative parameters or preoperative KSS scores. The KSS score for patient
153 activity was significantly associated with the preoperative KSS score for patient activity (correlation
154 coefficient, 0.472; $p=0.006$) and the postoperative flexion angle of the knee (correlation coefficient,

155 0.398; $p=0.022$).

156 When intraoperative rotational position of the tibia and the extent of tibial internal rotation at
157 pre-TKA were compared with those at post-TKA, there were significant differences in the tibial
158 rotational position at maximum extension and the extent of tibial internal rotation from maximum
159 extension to 30°, the extent of tibial internal rotation from 30° to 60°, the extent of tibial internal
160 rotation from maximum extension to 90°, and the extent of tibial rotation from maximum extension
161 to maximum flexion (Table 2). Generally, the extent of intraoperative tibial internal rotation
162 decreased at post-TKA compared that at pre-TKA.

163 There was a significant relationship between the extent of tibial internal rotation from maximum
164 extension to 90° flexion at pre-TKA and that at post-TKA (correlation coefficient, 0.473; $p<0.001$)
165 (Fig. 1A). Furthermore, the extent of tibial internal rotation from maximum extension to maximum
166 flexion at pre-TKA was significantly correlated with that at post-TKA (correlation coefficient, 0.592;
167 $p<0.001$) (Fig. 1B). It should be noted that 87.5% of cases had negative values for the extent of tibial
168 internal rotation from maximum extension to 90° flexion at post-TKA if the values of the extent of
169 tibial internal rotation were negative at pre-TKA, and the negative values of the extent of tibial
170 internal rotation meant the external tibial rotation (Fig. 1A). Furthermore, 83.3% of cases had
171 negative values for the extent of tibial internal rotation from maximum extension to maximum
172 flexion at post-TKA if the values of the extent of tibial internal rotation were negative at pre-TKA

173 (Fig. 1B).

174 When patients who had a knee flexion angle of 120° or less at 1 year after surgery and patients who
175 had a knee flexion angle more than 120° were compared with respect to intraoperative kinematics at
176 post-TKA, there were not significant differences in the demographic data. There were significant
177 differences in the preoperative knee flexion angle ($p<0.001$), intraoperative rotational position of the
178 tibia at maximum extension of the knee ($p=0.011$), the intraoperative extent of tibial internal rotation
179 from knee extension to 90° flexion ($p=0.007$), and that from knee extension to maximum flexion
180 ($p=0.017$) between the groups (Table 3).

181 A cutoff value of the extent of intraoperative tibial internal rotation at post-TKA from maximum
182 extension to 90° flexion was calculated using the ROC curve to determine whether the postoperative
183 knee flexion angle exceeded 120° at 1 year after TKA. When a cutoff value of the extent of tibial
184 internal rotation from maximum extension to 90° flexion was 1.25°, the sensitivity was 80.0% and
185 the specificity was 86.4% (Fig. 2A). Furthermore, a cutoff value of the extent of tibial internal
186 rotation at post-TKA from maximum extension to maximum flexion was calculated. When a cutoff
187 value of the extent of tibial internal rotation from maximum extension to maximum flexion was
188 5.25°, the sensitivity was 66.7% and the specificity was 86.4% (Fig. 2B).

189

190 **5 Discussion**

191 The most important finding of the present study was that the extent of tibial internal rotation at
192 post-TKA was positively associated with the range of motion of the knee at 1 year after TKA.
193 Additionally, the extent of tibial internal rotation at post-TKA was positively related to that at
194 pre-TKA, although the extent of tibial internal rotation at post-TKA was significantly decreased
195 compared to that at pre-TKA. It should also be noted that most patients with preoperative tibial
196 external rotation also had postoperative tibial external rotation.

197 Several reports indicated that the preoperative knee range of motion positively affected the
198 postoperative knee range of motion [5, 4, 6, 7]. The present results moderately suggested that
199 preoperative extension and flexion angles of the knee also positively affected postoperative
200 extension and flexion angles, respectively. Although there is no doubt that the range of motion of the
201 knee after TKA is significantly associated with the preoperative range of motion, it was interesting
202 that the results of this study indicated that the external rotation of the tibia at knee extension and the
203 extent of tibial internal rotation positively affected the postoperative flexion angle of the knee. Knee
204 kinematics at pre-TKA involving rotational position of the tibia and the extent of tibial internal
205 rotation was not correlated with knee flexion angle at 1 year after TKA, but knee kinematics at
206 post-TKA was associated with that at pre-TKA. It was considered that knee kinematics at pre-TKA
207 might be affected by preoperative varus deformity of lower extremity or posterior slope of tibial
208 plateau. Furthermore, direction and length of the medial and lateral collateral ligaments, and

209 iliotibial tract might be different from pre-TKA due to the osteophyte removal and deformity
210 correction at post-TKA. However, based on the present results, the knee kinematics at post-TKA was
211 considered to be affected by remained structures after TKA.

212 Previous studies of knee kinematics focused on the postoperative status [36, 37]. However, to our
213 knowledge, several reports have compared the differences in knee kinematics before and after TKA.
214 The tibial rotation in deep knee flexion relative to the femur was approximately 28° in a normal knee
215 [12, 38]. Siston et al. reported that the rotational motion of osteoarthritic knees was significantly
216 reduced after PS TKA [29]. Seon et al. reported that femoral external rotation after cruciate-retaining
217 TKA was significantly decreased compared to that of the preoperative knee, although the extent of
218 femoral external rotation after TKA was significantly positively related to that measured
219 preoperatively [28]. These reports are similar to our results in that tibial internal rotation after TKA
220 was related to that before TKA and decreased after TKA. Dennis et al. reported that the tibial
221 internal rotation was less than 4° after TKA with most types of implants [12], and Cates et al.
222 reported that 2.9° of axial rotation in PS TKA [36]. In the present study, the extent of internal
223 rotation of the tibia around mid-flexion range, such as approximately 30° to 60° of knee flexion, did
224 not affect the postoperative flexion angle of the knee. For patients with postoperative knee flexion of
225 more than 120° , rotational position of the tibia at knee extension had more external rotation, and the
226 extent of tibial internal rotation from extension to 90° and that from extension to maximum flexion

227 were greater. However, results in this study indicated that the extent of tibial internal rotation at
228 pre-TKA was less than that of the normal knee, and the extent of tibial internal rotation at post-TKA
229 was further declined compared to that at pre-TKA, hence the cutoff value due to the evaluation of
230 the ROC curve was relatively low. Therefore, it was suggested that it may be possible to only
231 evaluate by measurement of tibial internal rotation using the navigation system in TKA. Furthermore,
232 these results by evaluation of the navigation system suggested that screw-home movement and
233 medial pivot motion might be critical for the knee flexion angle, even for PS TKA that involves
234 sacrifice of the anterior and posterior cruciate ligaments. Wada et al. performed a cadaver study and
235 reported that tibial internal rotation during knee flexion was improved by increasing the tightness of
236 the medial collateral ligament [39]. For PS TKA involving sacrifice of the anterior and posterior
237 cruciate ligaments, appropriate tension in the medial collateral ligament may be important for tibial
238 internal rotation and medial pivot motion. However, postoperative tibial internal rotation is
239 significantly affected by preoperative tibial rotation, and most patients with preoperative tibial
240 external rotation also had postoperative tibial external rotation. Only PS TKA was used for all cases
241 of tibial internal rotation, which limited the observable outcomes. Therefore, medial pivot,
242 bicruciate-retaining, and bicruciate-stabilized implants should be studied, especially in patients with
243 tibial external rotation at pre-TKA.

244 There were several limitations to this study. First, intraoperative measurements of the knee

245 kinematics might have been different from the measurements evaluated during outpatient
246 examinations due to general anesthesia, use of an air tourniquet, or non-weight-bearing conditions.
247 However, it was reported that knee kinematics measured intraoperatively were strongly correlated
248 with postoperative kinematics [26,40]. Therefore, it was considered that intraoperative
249 measurements of the knee kinematics in this study were significantly associated with postoperative
250 kinematics. However, the current method that we measured intraoperative kinematics by the surgeon
251 and assistant was slightly differed from Wada's procedures [33], and the reliability assessment of this
252 procedure was not performed. Second, the follow-up time of 1 year was relatively short. Longer
253 follow-up might be required to evaluate patients' satisfaction, expectations, and activity using the
254 KSS score, although it was reported that a follow-up period of 1 year was sufficient for predicting
255 the range of motion of the knee after TKA [41]. Third, the actual rotational position of the implant
256 has not been evaluated by postoperative CT examinations. In particular, abnormal rotational
257 alignment of the femoral and tibial components can affect knee kinematics. Furthermore, several
258 reports showed that rotational alignment of femoral component was improved by using navigation
259 [42,43]. Fourth, the anterior to posterior translation from knee extension to flexion was not evaluated.
260 The anterior or posterior translation might be associated with knee kinematics and range of motion.
261 The present findings confirm that preoperative knee range of motion significantly affects
262 postoperative knee range of motion. Postoperative passive knee kinematics was significantly

263 associated with preoperative knee kinematics with regard to tibial rotation from knee extension to
264 flexion. The extent of tibial internal rotation was so small that it could only be detected by using the
265 navigation system. Therefore, the present results suggested that the extent of tibial internal rotation
266 measured using the navigation system will help to predict the postoperative knee flexion angle after
267 TKA.

268

269 **6 Conclusion**

270 The extent of tibial internal rotation at post-TKA affected the knee flexion angle after surgery,
271 although the detected value was relatively small enough to be measured using navigation system.

272

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276 **Ethical approval:** All procedures performed during studies involving human participants were in
277 accordance with the ethical standards of the institution (Hamamatsu University School of Medicine)
278 and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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391 **Figure captions**

392 **Fig. 1**

393 A: The contribution of the extent of pre-tibial rotation (TR) movement and post-TR movement from
394 maximum extension to 90° flexion. B: The contribution of the extent of pre-TR movement and
395 post-TR movement from maximum extension to maximum flexion. There was a significant
396 relationship between the extent of movement pre-TR from maximum extension to 90° flexion and
397 that post-TR from maximum extension to 90° of flexion (correlation coefficient, 0.473; $p < 0.001$) (A).
398 The pre-TR extent of movement from maximum extension to maximum flexion was significantly
399 correlated with the post-TR extent of movement from maximum extension to maximum flexion
400 (correlation coefficient, 0.592; $p < 0.001$) (B).

401

402 **Fig. 2**

403 A: The receiver-operating characteristic (ROC) curve for the postoperative knee flexion angle of
404 120°, which was calculated for the extent of post-tibial rotation (TR) movement from maximum
405 extension to 90° of flexion using cutoff values.
406 B: The ROC curve for the postoperative knee flexion angle of 120°, which was calculated for the
407 extent of pre-TR movement from maximum extension to maximum flexion using cutoff values.

Table 1

The demographics data of patients

Gender (male / female)	15 (16 knees) / 39 (44 knees)
Age (yr)	74.9 ± 7.9
Body height (cm)	152.0 ± 8.9
Body weight (kg)	62.1 ± 12.9
Body mass index (kg/m ²)	26.7 ± 3.9
Kellgren-Lawrence classification	II: 8 knees, III: 35 knees, IV: 17 knees
Preoperative knee extension angle (°)	-9.1 ± 8.6
Preoperative knee flexion angle (°)	120.7 ± 18.8
Postoperative knee extension angle (°)	-4.8 ± 4.7
Postoperative knee flexion angle (°)	115.6 ± 15.5

Values are presented as numbers, or mean and standard deviation.

Table 2

Comparison of the tibial rotational position at each angle and the extent of tibial internal rotation among each flexion angle of the knee between pre-TKA and post-TKA.

	Pre-TKA	Post-TKA	<i>p</i> value
The tibial rotational position at maximum extension (°)	-3.2 (8.4)	1.1 (7.0)	<0.001*
The tibial rotational position at 30° flexion (°)	0.89 (8.0)	2.3 (7.6)	0.065
The tibial rotational position at 60° flexion (°)	2.8 (9.0)	2.3 (6.8)	0.514
The tibial rotational position at 90° flexion (°)	3.9 (8.8)	3.3 (6.5)	0.443
The tibial rotational position at maximum flexion (°)	5.4 (8.8)	6.2 (7.4)	0.292
The extent of tibial internal rotation from maximum extension to 30° flexion of the knee (°)	4.0 (4.9)	1.2 (3.2)	0.001*
The extent of tibial internal rotation from 30° to 60° flexion of the knee (°)	1.8 (4.4)	0.0 (3.2)	0.014*
The extent of tibial internal rotation from 60° to 90° flexion of the knee (°)	0.73 (3.8)	1.1 (3.3)	0.660
The extent of tibial internal rotation from 90° to maximum flexion of the knee (°)	2.0 (3.8)	2.9 (3.4)	0.080
The extent of tibial internal rotation from maximum extension to 90° flexion of the knee (°)	7.2 (7.4)	2.1 (6.1)	<0.001*
The extent of tibial internal rotation from maximum extension to flexion of the knee (°)	8.9 (8.6)	5.2 (8.0)	0.001*

Values are presented as mean (standard deviation).

The tibial rotational position was shown that internal rotation of the tibia relative to the femur was indicated as positive value.

The extent of tibial rotation was shown that internal rotation of the tibia between each knee flexion angle was defined as positive value.

*: significant difference between the groups

Table 3

Comparison of the tibial rotational position and the extent of tibial rotation at post-TKA between patients with a postoperative knee flexion angle of $\leq 120^\circ$ and patients with a postoperative knee flexion angle of $>120^\circ$.

	Postoperative knee flexion angle		<i>p</i> value
	$\leq 120^\circ$ (n=23)	$>120^\circ$ (n=37)	
Age (years)	76.7 \pm 8.3	72.7 \pm 7.3	0.082
Gender (male / female)	4 (4 knees) / 18 (20 knees)	11 (12 knees) / 21 (24 knees)	0.128
Preoperative knee extension angle ($^\circ$)	-10.9 \pm 7.9	-5.0 \pm 4.8	0.004*
Preoperative knee flexion angle ($^\circ$)	108.0 \pm 17.9	132.4 \pm 10.3	0.001*
Knee extension angle at 1 year ($^\circ$)	-6.3 \pm 5.1	-3.4 \pm 3.7	0.032*
Knee flexion angle at 1 year ($^\circ$)	102.6 \pm 11.2	127.6 \pm 6.4	<0.001*
Intraoperative maximum extension angle ($^\circ$)	-10.2 \pm 6.4	-12.4 \pm 6.9	0.975
Intraoperative maximum flexion angle ($^\circ$)	128.8 \pm 10.9	137.3 \pm 10.4	0.661
The tibial rotational position at maximum extension ($^\circ$)	3.9 \pm 6.8	-1.2 \pm 6.5	0.011*
The tibial rotational position at 30 $^\circ$ of flexion ($^\circ$)	4.1 \pm 7.9	0.84 \pm 7.1	0.151
The tibial rotational position at 60 $^\circ$ of flexion ($^\circ$)	2.9 \pm 6.7	1.6 \pm 6.8	0.532
The tibial rotational position at 90 $^\circ$ of flexion ($^\circ$)	3.3 \pm 6.5	3.0 \pm 6.8	0.875
The tibial rotational position at maximum flexion ($^\circ$)	5.7 \pm 6.4	6.3 \pm 8.3	0.802
The extent of tibial internal rotation from maximum extension to 30 $^\circ$ of flexion ($^\circ$)	0.18 \pm 3.5	1.6 \pm 2.9	0.058
The extent of tibial internal rotation from 30 $^\circ$ to 60 $^\circ$ of flexion ($^\circ$)	-1.2 \pm 2.5	0.72 \pm 3.4	0.062
The extent of tibial internal rotation from 60 $^\circ$ to 90 $^\circ$ of flexion ($^\circ$)	0.34 \pm 3.3	1.4 \pm 3.6	0.310

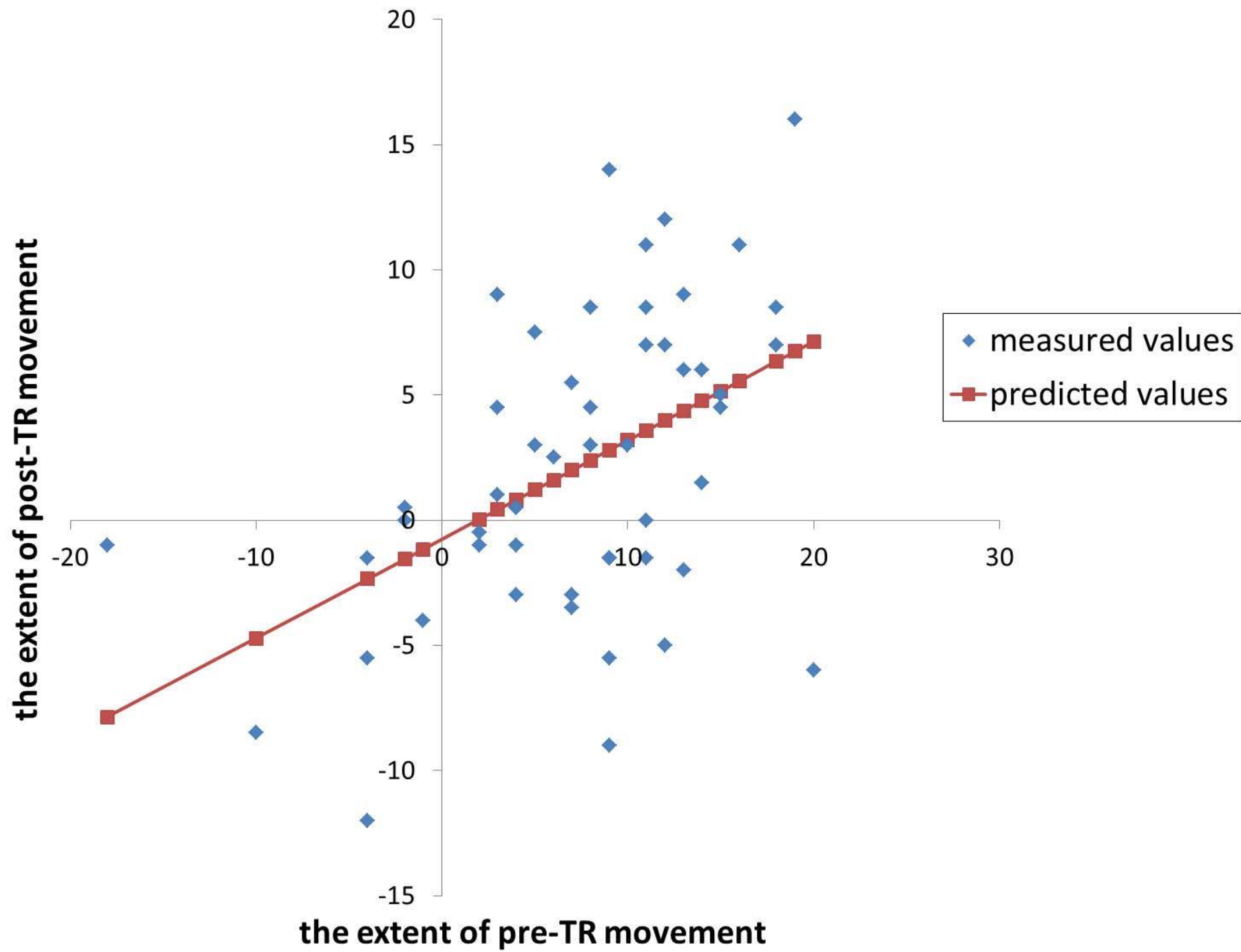
The extent of tibial internal rotation from 90° to maximum flexion (°)	2.5 ± 2.3	3.3 ± 4.7	0.520
The extent of tibial internal rotation from maximum extension to 90° of flexion (°)	-1.2 ± 5.0	3.8 ± 6.5	0.007*
The extent of tibial internal rotation from maximum extension to flexion (°)	1.2 ± 6.6	7.0 ± 8.6	0.017*

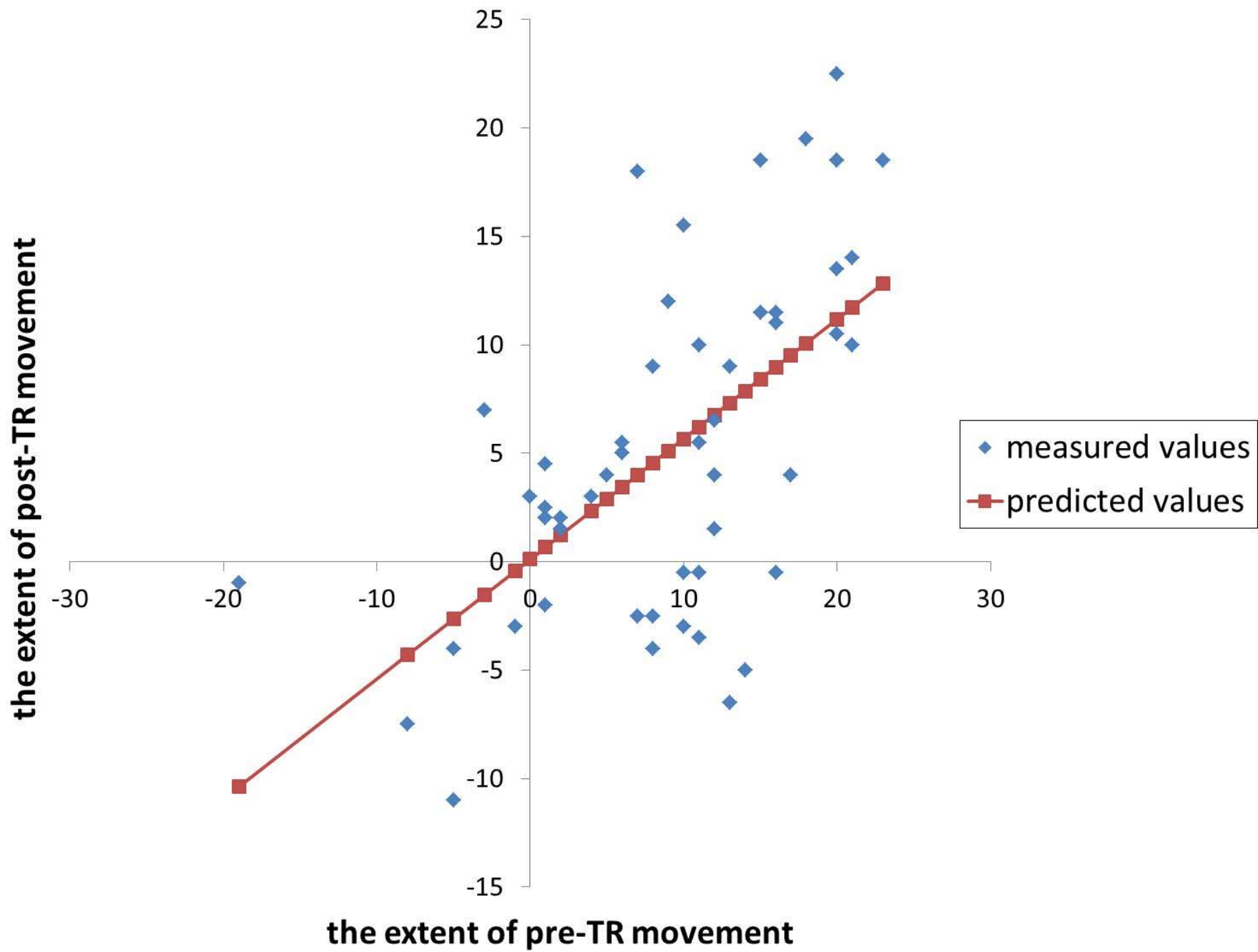
Values are presented as numbers, or mean and standard deviation.

The tibial rotational position was shown that internal rotation of the tibia relative to the femur was indicated as positive value.

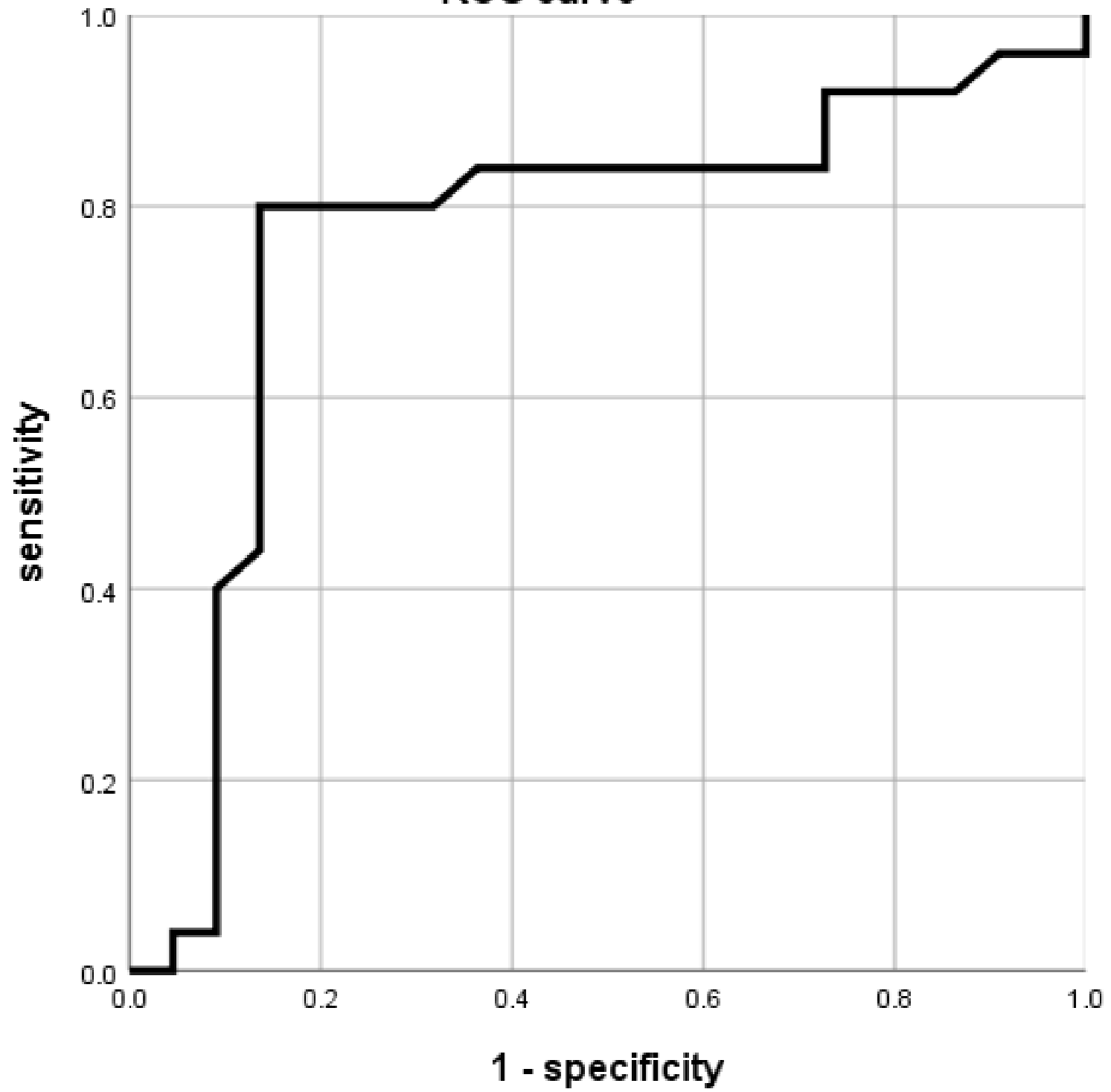
The extent of tibial rotation was shown that internal rotation of the tibia between each knee flexion angle was defined as positive value.

*: significant difference between the groups





ROC curve



ROC curve

