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Quadriceps Strength Can Improve Twelve Months After Opening Wedge High Tibial Osteotomy and Opening Wedge Distal Tibial Tubercle Osteotomy, Particularly After Opening Wedge High Tibial Osteotomy

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Abstract

Background: Knee osteoarthritis (KOA) is a globally prevalent condition leading to joint pain and disabilities. Surgical interventions such as opening-wedge high tibial osteotomy (OWHTO) and opening-wedge distal tuberosity osteotomy (OWDTO) aim to alleviate symptoms and delay disease progression. Quadriceps strength, crucial for knee function, may decline postoperatively, affecting patient outcomes. However, little is known about quadriceps strength variation after OWHTO and OWDTO. This study investigated changes in quadriceps strength before and after OWHTO and OWDTO.

Methods: This retrospective study included patients who underwent OWHTO or OWDTO between 2016 and 2022. Quadriceps strength and demographic and surgical data were collected preoperatively and at 6 and 12 months postoperatively. Statistical analyses were performed to compare changes in quadriceps strength over time.

Results: Of 120 knees, 52 (OWHTO, 27; OWDTO, 25) were included in this study. Quadriceps strength increased over 12 months post-OWHTO, significantly improving at 12 months compared to the preoperative and 6-month values. In OWDTO, the strength improved but not significantly.

Conclusions: Quadriceps strength improved following OWHTO and OWDTO, with OWHTO showing significant enhancements. Future studies should investigate the relationship between quadriceps strength and functional outcomes and guide rehabilitation strategies for improved postoperative recovery.

Keywords: Opening wedge high tibial osteotomy; Opening wedge distal tibial tubercle; Quadriceps strength; Knee osteoarthritis

1. Introduction

Opening-wedge high tibial osteotomy (OWHTO) is a surgical technique widely used to treat Knee osteoarthritis (KOA). This procedure reduces the pressure borne on the cartilage and subchondral bones by correcting the mechanical axis through proximal tibial osteotomy [1]. However, OWHTO changes the tibial tuberosity position to distal and previous studies revealed progression of patellofemoral cartilage injuries and OA associated with decrease in patellar height after OWHTO [2,3]. Meanwhile, opening-wedge distal tuberosity osteotomy (OWDTO) is a surgical technique to correct coronal alignment without affecting the position of the tibial tuberosity by use of descending osteotomy [4,5]. OWHTO and OWDTO can decrease joint pain and delay the progression of knee deterioration [6,7]. In addition, some studies have reported positive postoperative outcomes, including the return to sports and work [8,9], range of motion [10], and subjective joint function [11,12]. Therefore, OWHTO and OWDTO are suitable for young, physically demanding patients with KOA.

Quadriceps strength decreases after surgery because of preoperative joint pain [13], tourniquet use during surgery [14], and the postoperative non-weight-bearing phase [15]. Quadriceps weakness is a risk factor for KOA [16], and lower quadriceps strength is associated with an increased risk of symptoms and functional deterioration [17]. Therefore, regaining postoperative quadriceps strength following OWHTO and OWDTO may be important for young and active patients. However, it is unknown how quadriceps strength changes after OWHTO and OWDTO. In addition, changes in quadriceps muscle strength may differ between OWHTO and OWDTO since the extensor mechanism can be affected differently due to the difference in tibial tuberosity position after surgery.

Therefore, this study primarily aimed to investigate changes in quadriceps strength before and after OWHTO and OWDTO respectively, and secondarily aimed to investigate the difference between OWHTO and OWDTO. Our hypothesis was that quadriceps strength would improve comparably after OWHTO and OWDTO.

2. Materials and methods

2.1 Patient selection

This retrospective study included patients who underwent OWHTO between 2016 to 2022 and OWDTO between 2019 to 2022 and underwent measurements preoperatively and at 6 and 12 months postoperatively. The surgical indications for both OWHTO and OWDTO included varus knee accompanied by medial compartmental OA or associated cartilage injuries and medial meniscal tears. OWDTO was indicated for patients with patellofemoral OA or who were predicted to require more than 10 mm-opening in the preoperative planning. Patients with missing demographic or measurement data were also excluded. This study was approved by the ethics committee of our hospital (No. 170176), and the opt-out method was applied.

2.2 Patient characteristics and radiograph evaluations

Demographic and surgical data were obtained from the patient interviews and medical records. Demographic data included age at the time of surgery, sex, height, weight, and body mass index (BMI). Alignment was measured from the radiographic data of the patient's medical records, including the % mechanical axis (%MA), medial proximal tibial angle (MPTA), and femorotibial angle (FTA). Information on range of motion (ROM), medial or lateral meniscus surgery, femoral cartilage procedures, amount of medial opening gap, and postoperative complication was also collected from medical records. International Knee Documentation Committee (IKDC) was asked as subjective knee function using a self-reported questionnaire. The bony correction angle (ΔMPTA) was determined as changes in MPTA before and after surgery.

2.3 Surgical technique

Four surgeons performed all the surgeries. Before osteotomy, all patients underwent arthroscopy. For meniscal tears, resection or repair was performed depending on the severity of the meniscal degeneration. Typically, for complex degenerative meniscal tears, the flap is resected. Then, the remaining horizontal or radial tears are repaired using an all-inside device (JUGGERSTRICH. Zimmer Biomet Inc. Warsaw, IN, USA). Drilling or abrasion chondroplasty was performed on International Cartilage Repair Society (ICRS) grade II, III and IV cartilage injuries, respectively. Mosaic plasty (OATS system; Arthrex, Naples, FL, USA) was performed for osteonecrosis of the medial femoral condyle. OWHTO and OWDTO were performed as described in previous studies [18].

The pes anserinus, including the hamstring tendons, was detached from the insertion site, and the superficial medial collateral ligament was released to expose the osteotomy site. Biplane cuts were performed in both OWHTO and OWDTO. In OWHTO, a separate ascending cut was performed, whereas a separate descending cut of the tibial tubercle was made distally in the frontal plane with a 5–8 mm thickness. The transverse osteotomy site was opened using a spreader until the intended alignment was achieved. The distance between most of the posteromedial cortices was measured using a caliper. Depending on the size of the gap, two wedge-shaped, β-tricalcium phosphate blocks

(Osferion60, Olympus Terumo Biomaterials Corp., Tokyo, Japan) were placed into the gap. The detached hamstring tendons were reattached to the medial tibial tuberosity to cover the osteotomy gap. A medial locking compression plate (TriS, Olympus Terumo Biomaterials Corp., Tokyo, Japan) was used to fix the tibia. In OWDTO, the distal part of the tibial tubercle was fixed to the distal fragment of the tibia using a 6.5-mm cannulated screw (Hollyx Co., Ltd., Shizuoka, Japan).

2.4 Quadriceps strength

The maximum isokinetic muscle strength of the quadriceps was measured using the Easy Tech Plus (Inter Reha, Inc., Tokyo, Japan). Before the muscle strength test, patients were warmed for 5 min at low resistance using a stationary cycling ergometer. Testing was initiated with the uninvolved leg. Each patient performed two practice contractions followed by five 60°/s maximal effort contractions, and the peak extension torque was recorded. The test was repeated on the involved leg. For standardization, the maximum muscle strength was divided by body weight to calculate the quadriceps strength-to-body weight ratio (QS/BW). Patients were asked if they felt knee pain during the test using an 11-point numeric rating scale (NRS) ranging from 0 (no pain) to 10 (worst possible pain).

2.5 Rehabilitation

Postoperatively, supervised rehabilitation by a physical therapist was immediately started to improve knee function, including active and passive range of motion and relaxation of the stiff muscles. After OWHTO, one-third of partial weight-bearing was started on the third postoperative day, and full weight-bearing was allowed 3 weeks postoperatively. After OWDTO, the schedule for weight-bearing was delayed by 1 week after OWHTO; one-third of partial weight-bearing was initiated 7 days postoperatively, and full weight-bearing was allowed at 4 weeks postoperatively. Straight leg raise and leg extension exercise start immediately after surgery. Squatting started from 3 ad 4 weeks postoperatively for OWHTO and OWDTO, respectively. Patients were discharged 3 weeks postoperatively to home or rehabilitation hospitals. Rehabilitation continued at outpatient clinic in other the hospitals until 6 months after surgery. Jogging is permitted 6 months postoperatively if sufficient bone union was confirmed.

2.6 Statistical analysis

To compare the differences in patient demographics and measurement data between the OWHTO and OWDTO groups, we used an unpaired t-test or Mann–Whitney U test for continuous variables, as appropriate, and the chi-square test for categorical variables. To investigate the changes in QS/BW from pre- to postoperative for OWHTO and OWDTO, a repeated-measures one-way analysis of variance (ANOVA) was performed, and a post hoc analysis was performed using the Bonferroni method. Friedman test was performed to compare changes in pain during quadriceps strength measurements from pre- to postoperative, and multiple comparisons were made using the Bonferroni's method. An a priori sample size analysis determined 20 knees to detect a significant difference in a repeated-measures one-way ANOVA for OWHTO and OWDTO with following condition: effect size of $f = 0.3$, type1 error of $\alpha = 0.05$, power of $1 - \beta = 0.80$, number of groups = 1, number of measurements = 3, correlation among repeated measures = 0.5, nonsphericity correction $\varepsilon = 1$). The statistical significance level was set at 5%, and the free software R ver. 4.2.2 was used for the analysis [19].

3. Results

Figure 1 showed a flowchart of patient exclusion/inclusion (Fig. 1). Thirty-one of the 74 patients who underwent OWHTO but did not perform the muscle strength test preoperatively were excluded. Sixteen patients were excluded from the 43 patients due to data deficit including muscle strength test. Similarly, 8 of the 47 patients who underwent OWDTO but did not perform the muscle strength test preoperatively were excluded. A total of 14 of 39 patients with data deficit were excluded. Finally, 27 knees in 25 patients in OWHTO group and 25 knees in 25 patients in OWDTO group were included in this study.

Table 1 shows the characteristics of patients and the measurement data for each group. There were no significant differences in patient demographics and measurement data between the OWHTO and OWDTO groups. The number of patients with postoperative complications was 6 in OWHTO group (5 with stable hinge fractures, 2 with DVT, and 1 with minor infectious sign) and 9 in OWDTO group (6 with stable hinge fractures, 3 with DVT, and 1 with minor infectious sign). Rehabilitation was not changed in patients with hinge fractures whereas it was stopped for one week in the patients with minor infection.

Figure 2 shows the changes in QS/BW during OWHTO. The mean ± standard deviation of QS/BW was 0.82 ± 0.39 preoperatively, 0.85 ± 0.28 at 6 months postoperatively, and 1.11 ± 0.38 at 12 months postoperatively. QS/BW tended to increase from preoperatively to 12 months postoperatively, with a significant increase at 12 months postoperatively compared to that preoperatively ($p<0.01$) and 6 months postoperatively ($p=0.025$). Figure 3 shows the changes in the QS/BW in OWDTO. The mean ± standard deviation of QS/BW was 0.85 ± 0.44 preoperatively, 0.93 ± 0.39 at 6 months postoperatively, and 1.12 ± 0.44 at 12 months postoperatively. QS/BW tended to increase from preoperatively to 12 months postoperatively; however, there were no significant differences at any point.

In OWHTO, there was a significant difference in pain during quadriceps strength test among the measurement timings ($p < 0.01$), and pain scales at 12 months postoperatively was significantly lower that at preoperatively ($p = 0.026$) (Figure 4). A similar trend was observed in OWDTO while statistically significant difference was not detected among the measurement timings ($p = 0.35$) (Figure 5).

4. Discussion

This study investigated the changes in quadriceps strength before and after OWHTO and OWDTO and showed that QS/BW increased from preoperatively to 12 months postoperatively, with a significant increase at 12 months postoperatively compared with that preoperatively and at 6 months after OWHTO. Meanwhile, the change is QSBW did not reach statistically significance after OWDTO. Therefore, our hypothesis was partially denied.

None of the studies investigated the relationship between OWHTO and quadriceps strength before and postoperative. However, with dome-shaped HTO [20], there was a significant improvement in the isokinetic muscle strength of the quadriceps at 12 months postoperatively compared to the preoperative strength [21]. This study supported previous studies and added a new finding that QS/BW was significantly improved at 12 months postoperatively compared to at 6 months after OWHTO.

This study showed a significant improvement in QS/BW at 12 months postoperatively compared to preoperatively and 6 months after OWHTO. In addition, pain during the measurement was significantly reduced at 12 months postoperatively compared to preoperatively. Therefore, reduced pain by OWHTO may have contributed to the improvement of QS/BW. Measures of physical activity, such as the Tegner Activity Scale, the University of California, Los Angeles (UCLA) activity scale, and the sport and recreation subscale of the Knee Injury and Osteoarthritis Outcome Score (KOOS), have been shown to improve after OWHTO surgery compared to preoperative levels [22,23]. The patients included in this study may also have improved their physical activity post-surgery and have thus improved their quadriceps strength. However, this study did not examine patients' physical-activity levels. Therefore, in future studies, it is necessary to investigate the relationship between physical activity and quadriceps strength change after OWHTO.

In this study, QS/BW increased from the preoperative phase to 12 months postoperatively, but there was no significant change in the OWDTO group. The pain during the quadriceps strength measurement also tended to decrease at 12 months postoperatively but a statistically significant difference was not found. It is possible that some patients were unable to exert muscle output sufficiently due to pain during the quadriceps strength measurement. The tuberosity remains attached to the proximal part of the tibia in OWDTO [24]. The contraction of the quadriceps exerts a force in the direction that causes the proximal bone fragments to separate from the distal part. To avoid delayed bone union, we started weight-bearing 1 week after OWHTO and began quadriceps muscle training cautiously, such as squats, depending on the status of the bone union. Although, timing and progression of the bone union was not evaluated in this study, we also tended to advise patients who received OWDTO to avoid increasing activity level particularly within 3 months. Therefore, this trend might have affected the quadriceps strength recovery in some patients, resulting in the non-significant improvement at postoperatively 12 months. In addition, OWDTO was performed on patients with patellofemoral cartilage injuries or who requires larger opening. This difference in surgical indication may also have affected the quadriceps strength changes. However, OWDTO might maintain patella height and mitigate postoperative patellar femoral OA progression [4,5,25]. Therefore, changes in muscle strength after OWDTO need to be evaluated in longer term to examine the effect of OWDTO on quadriceps muscle strength. Further, given that the larger standard deviation for QS/BW at 6 and 12 moths in OWDTO than those in OWHTO, variability in quadriceps strength recovery among patients who received OWDTO could be a reason why statistical difference was not detected after OWDTO. Therefore, it is necessary to include larger number of patients to draw a definitive conclusion.

Regarding rehabilitation strategy, enhancement of active control of quadriceps and pain control appear to be important in similar to other knee surgeries in the early phase. Open kinetic chain training of knee extension can be performed without restriction immediately after surgery and electrical nerve stimulation can be used to enhance control of quadriceps contraction. To reduce pain during training, physiotherapy such as hot packs and transcutaneous electrical nerve stimulation can be used. Meanwhile, aggressive rehabilitation associated with knee torsional motion in weight bearing needs to be restricted to avoid excessive stress on the osteotomy site. As mentioned above, in

OWDTO, the traction force of the patellar tendon generates opening force vector on the descending osteotomy site unlike OWHTO where the compressive force on the ascending osteotomy site can be expected. Therefore, especially in OWDTO, to avoid excessive stress separating the proximal bone fragment from the distal part, close kinetic chain such as squatting should be initiated, while closely monitoring the state of bone union and the presence or absence of pain. Since quadriceps strength tended to improve 6 months after surgery and sufficient bone union can be expected after 6 months, it may be also important to advise patients to continue muscle strength training 6 months after surgery. However, further research is necessary to develop optimal rehabilitation strategy for OWHTO and OWDTO.

No study has yet examined the relationship between the return to sports and quadriceps strength after OWHTO or OWDTO. After anterior cruciate ligament (ACL) reconstruction, a staged return to sports can proceed according to the quadriceps strength [26,27]. In addition, QS/BW is an important indicator for safe yoga initiation at 3 months after ACL reconstruction, with a reported cutoff value of 1.45 Nm/kg [28]. In the present study, the average QS/BW values were 1.11 and 1.12 at 12 months postoperatively in the OWHTO and OWDTO groups, respectively. Although simple comparisons cannot be made owing to differences in age and level of sports competition between the patients who receive ACL reconstruction and those received osteotomy, the values were still lower than the cut-off value even at 12 months postoperatively. However, this study did not investigate the detail of sports activity including timing of initiation of jogging and participation in sports, and type of sports. Therefore, it was unclear whether the QS/BW values were sufficient for good sports movements in the patients who revived OWHTO and OWDTO. In the future, it will be necessary to investigate the relationship between QS/BW and the ability to perform sports such as yoga or running after OWHTO and OWDTO and to create a QS/BW-based rehabilitation protocol for the return to sports.

The limitations of this study included an insufficient sample size, the failure to account for changes in muscle strength due to changes in alignment, cases of mixed simultaneous ACL reconstruction, the failure to consider additional meniscus and cartilage surgery. In addition, details regarding postoperative rehabilitation, such as timing of the start of squatting or jogging, were lacked since postoperative rehabilitation was conducted in other hospitals and outpatient clinics. Furthermore, patient number, age, and male/female ratio were not equal between OWHTO and OWDTO groups. Therefore, the results may be different if the number of patients, age, and male/female ratio were adjusted with larger number of patients.

5. Conclusions

The present study showed that QS/BW improved over the 12 months after OWHTO and OWDTO. It was suggested that OWHTO may significantly improve strength. It is necessary to investigate the relationship between QS/BW and sports movements and to create rehabilitation protocols based on QS/BW.

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Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that may have influenced the work reported in this study.

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Author contributions

Ryo GOTO: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing – Original Draft, Funding acquisition. **Takehiko MATSUSHITA:** Data Curation, Writing – Review & Editing, Supervision, Project administration. **Yuya UEDA:** Investigation, Data Curation, Writing – Review & Editing. **Yohei SHIBATA:** Investigation, Data Curation, Writing – Review & Editing. **Daisuke MIURA:** Investigation, Data Curation, Writing – Review & Editing. **Kumiko ONO:** Investigation, Data Curation, Writing – Review & Editing. **Akihiro KIDA:** Investigation, Data Curation, Writing – Review & Editing. **Kyohei NISHIDA:** Data Curation, Writing – Review & Editing. **Kanto NAGAI:** Data Curation, Writing – Review & Editing. **Noriyuki KANZAKI:** Writing – Review & Editing. **Yuichi HOSHINO:** Data Curation, Writing – Review & Editing. **Yoshitada SAKAI:** Project administration, Supervision, Writing – review & editing. **Ryosuke KURODA:** Project administration, Supervision, Writing – review & editing.

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Table 1. Characteristic and measurement data of the study participants

	OWHTO	OWDTO	p
N	27	25	
Sex (Male)	12 (44.4)	16 (64.0)	0.18
Age (years)	55.1 ± 10.2	58.4 ± 8.2	0.20
Height (cm)	164.7 ± 10.6	165.3 ± 9.0	0.84
Weight (kg)	72.7 ± 13.1	70.6 ± 10.9	0.52
BMI (kg/m^2)	26.7 ± 3.2	25.8 ± 3.3	0.32
Medial Meniscus surgery *			0.26
meniscectomy	9 (33.3)	8 (32.0)	
repair	10 (37.0)	5 (20.0)	
degeneration	0 (0.0)	5 (20.0)	
centralization	1 (3.7)	1 (4.0)	
rasping	1 (3.7)	0 (0.0)	
leave alone	3 (11.1)	3 (12.0)	
no	2 (7.4)	3 (12.0)	
Lateral Meniscus surgery *			0.23
meniscectomy	0 (0.0)	2 (8.0)	
degeneration	0 (0.0)	1 (4.0)	
no	26 (96.3)	22 (88.0)	
Cartilage surgery **			0.59
abrasion	9 (33.3)	11 (44.0)	
drilling	4 (14.8)	2 (8.0)	
drilling/abrasion	0 (0.0)	1 (4.0)	
microfracture	0 (0.0)	1 (4.0)	
mosaicplasty	0 (0.0)	1 (4.0)	
mosaicplasty/abrasion	1 (3.7)	0 (0.0)	
no	12 (44.4)	8 (32.0)	
Postoperative complication	6 (22.2)	9 (36.0)	0.43
The patellar ICRS grade			< 0.05
0	8 (29.6)	1 (4.0)	
1	13 (48.1)	19 (76.0)	
2	6 (22.2)	4 (16.0)	
3	0 (0.0)	1 (4.0)	
4	0	0	
The trochlear ICRS grade			0.31
0	7 (25.9)	2 (8.0)	
1	6 (22.2)	5 (20.0)	
2	4 (14.8)	9 (36.0)	
3	9 (33.3)	8 (32.0)	
4	1 (3.7)	1 (4.0)	

Tibial opening size (mm)	9.5 ± 2.3	10.8 ± 2.0	0.03
Corrective angle (ΔMPTA) (°)	5.4 ± 2.8	6.3 ± 2.3	0.05

Note: Data are presented as mean ± SD, n (%). P-values show the results of the unpaired t-test for continuous variables and the chi-square test for categorical variables between OWHTO and OWDTO. OWHTO: Opening Wedge High Tibial Osteotomy; OWDTO: Opening Wedge Distal Tuberosity Osteotomy; BMI: Body Mass Index; ICRS: International Cartilage Research Society. The missing data are as follows. (*: n =1; **: n = 2)

Table 2. Objective and Subjective Knee function and radiographic parameters

	OWHTO	OWDTO	p
ROM (extension) (°)			
Preoperative	-1.1 ± 2.1	-4.8 ± 4.0	<0.01
12 months postoperatively	-0.9 ± 2.0	-1.6 ± 2.8	0.32
ROM (flexion) (°)			
Preoperative	138.2 ± 7.0	131.8 ± 9.3	0.01
12 months postoperatively	137.8 ± 4.9	137.0 ± 9.4	0.71
IKDC _ symptom			
Preoperative *	14.0 ± 7.8	14.6 ± 6.3	0.76
12 months postoperatively	22.2 ± 6.2	22.4 ± 6.2	0.94
IKDC _ sports			
Preoperative *	20.1 ± 8.7	19.7 ± 6.0	0.84
12 months postoperatively	27.4 ± 6.6	28.8 ± 5.6	0.42
IKDC _ function			
Preoperative *	4.6 ± 2.4	3.8 ± 2.2	0.21
12 months postoperatively	7.6 ± 2.2	7.9 ± 1.6	0.60
FTA (°)			
Preoperative	178.1 ± 3.1	178.6 ± 2.3	0.58
12 months postoperatively	171.6 ± 2.9	171.1 ± 2.9	0.53
%MA (°)			
Preoperative	29.3 ± 12.6	25.2 ± 8.2	0.22
12 months postoperatively	59.2 ± 10.3	57.2 ± 9.9	0.51
MPTA (°)			
Preoperative	85.7 ± 3.0	84.8 ± 1.8	0.23
12 months postoperatively	91.0 ± 2.5	91.1 ± 2.0	0.83

Note: Data are presented as mean ± SD. P-values show the results of the unpaired t-test between OWHTO and OWDTO. OWHTO: Opening Wedge High Tibial Osteotomy; OWDTO: Opening Wedge Distal Tuberosity Osteotomy; ROM: range of motion; IKDC: International Knee Documentation Committee; FTA: femorotibial angle; %MA: % mechanical axis; MPTA: medial proximal tibial angle. The missing data are as follows. (*: n =1)

Table 3. The result of the Quadriceps strength test in OWHTO and OWDTO

	OWHTO	OWDTO	p
Quadriceps strength (Nm)			
Preoperative	61.7 ± 36.9	59.9 ± 32.3	0.85
6 months postoperatively	61.7 ± 23.8	64.8 ± 28.9	0.67
12 months postoperatively	81.3 ± 33.4	80.4 ± 37.9	0.93
Quadriceps strength to body weight ratio (Nm/kg)			
Preoperative	0.82 ± 0.39	0.85 ± 0.44	0.83
6 months postoperatively	0.85 ± 0.28	0.93 ± 0.39	0.40
12 months postoperatively	1.11 ± 0.38	1.12 ± 0.44	0.92
Pain (NRS)			
Preoperative	0.0 [0.0, 4.0]	0.0 [0.0, 3.0]	0.95
6 months postoperatively	0.0 [0.0, 0.75]	0.0 [0.0, 3.0]	0.33
12 months postoperatively	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	0.91

Note: Data are presented as mean ± SD, n (%), or median [IQR]. P-values show the results of the unpaired t-test or Mann–Whitney U test between OWHTO and OWDTO. OWHTO: Opening Wedge High Tibial Osteotomy; OWDTO: Opening Wedge Distal Tuberosity Osteotomy; NRS: numeric rating scale.

Figure legends

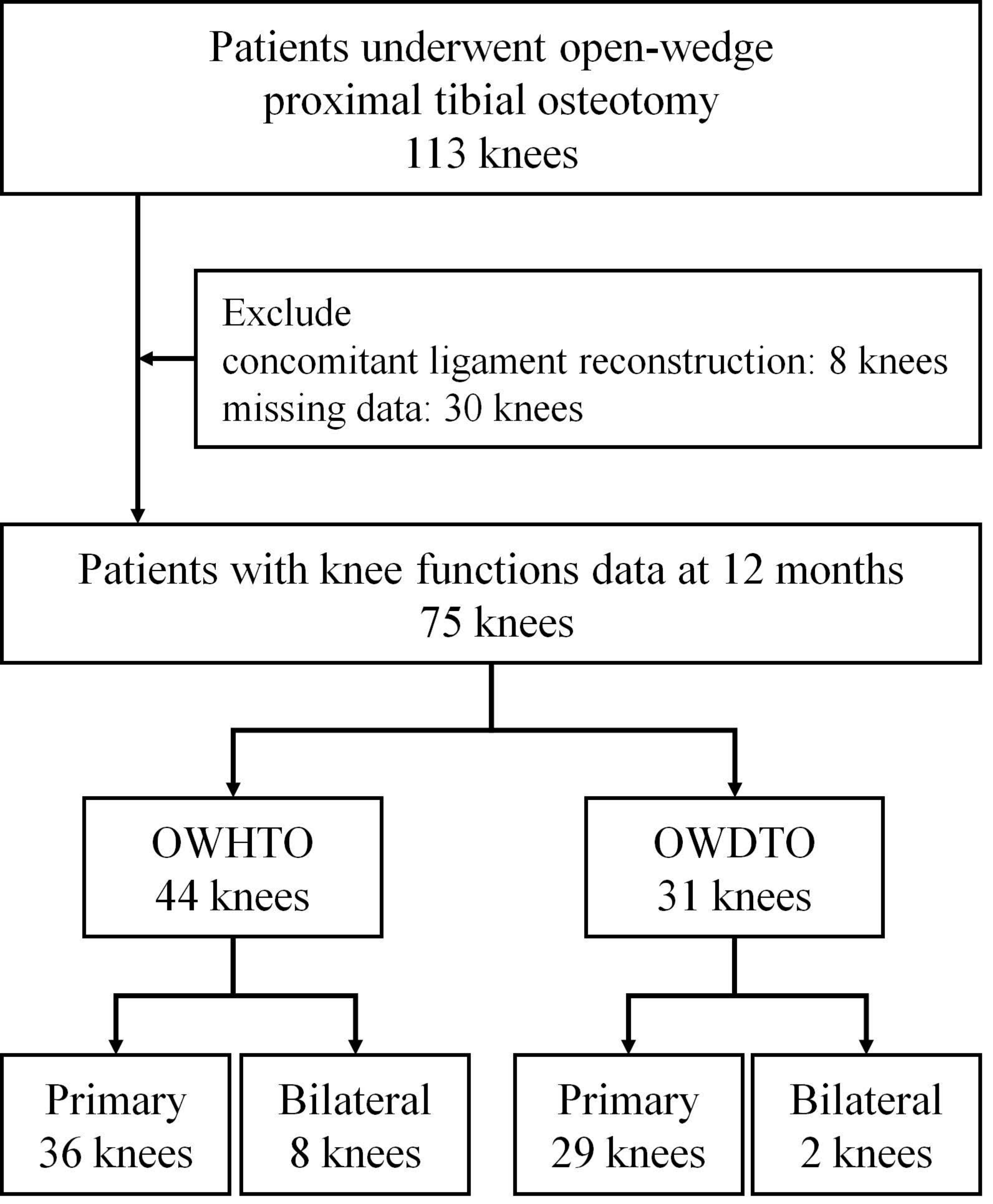
Figure 1. Flow chart of patient exclusion/inclusion.

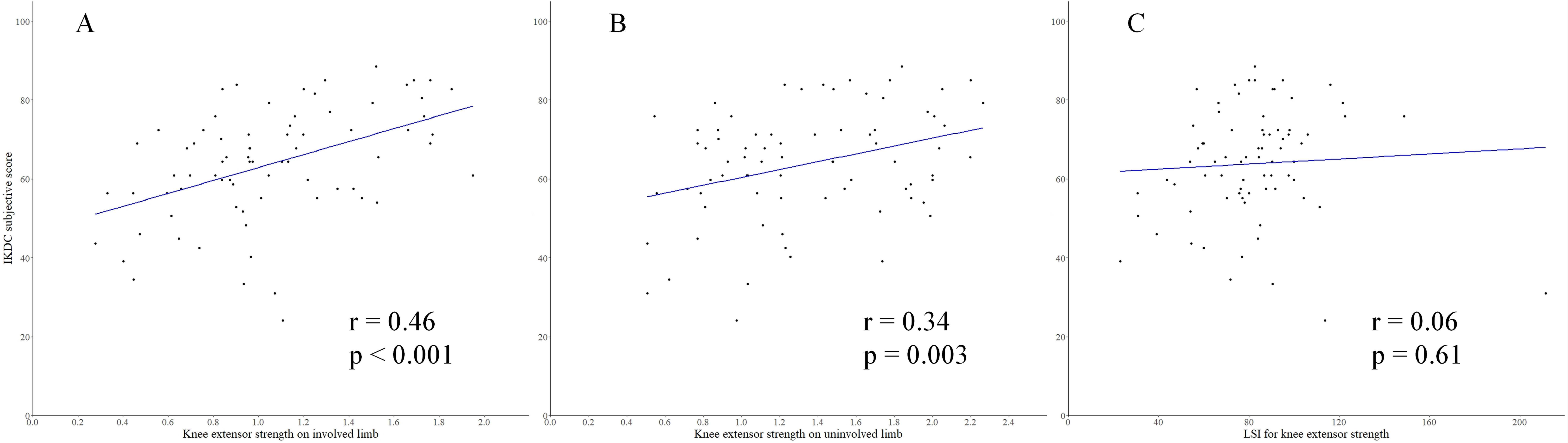
Figure 2. Quadriceps strength to body weight ratio change in the OWHTO group

Figure 3. Quadriceps strength to body weight ratio change in the OWDTO group

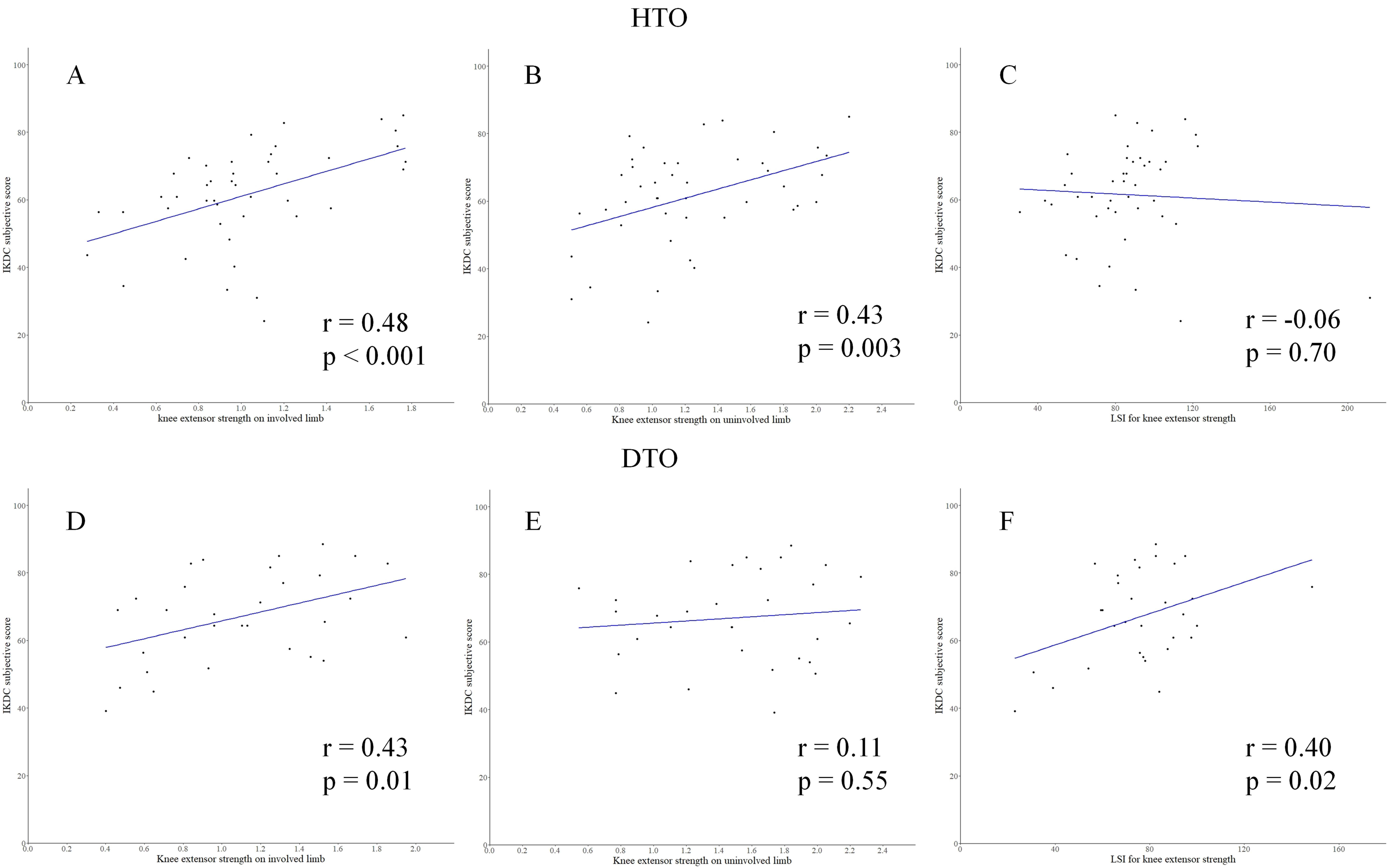
Figure 4. Pain scale during quadriceps strength measurement in OWHTO group

Figure 5. Pain scale during quadriceps strength measurement in OWDTO group


Patients underwent open-wedge proximal tibial osteotomy
113 knees
Exclude
concomitant ligament reconstruction: 8 knees
missing data: 30 knees
Patients with knee functions data at 12 months
75 knees
OWHTO
44 knees
OWDTO
31 knees
Primary
36 knees
Bilateral
8 knees
Primary
29 knees
Bilateral
2 knees



A
B
C
IKDC subjective score
r = 0.46
p < 0.001
r = 0.34
p = 0.003
r = 0.06
p = 0.61
Knee extensor strength on involved limb
Knee extensor strength on uninvolved limb
LSI for knee extensor strength



HTO
A
r = 0.48
p < 0.001
IKDC subjective score
knee extensor strength on involved limb
B
r = 0.43
p = 0.003
IKDC subjective score
Knee extensor strength on uninvolved limb
C
r = -0.06
p = 0.70
IKDC subjective score
LSI for knee extensor strength
DTO
D
r = 0.43
p = 0.01
IKDC subjective score
Knee extensor strength on involved limb
E
r = 0.11
p = 0.55
IKDC subjective score
Knee extensor strength on uninvolved limb
F
r = 0.40
p = 0.02
IKDC subjective score
LSI for knee extensor strength