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Effect of 3-week preoperative rehabilitation on pain and daily physical activities in patients with severe osteoarthritis undergoing total knee arthroplasty

Chigusa Ohno[1], Takahiro Ogawa[2,3], Takaya Taniguchi[4], Tokio Kinoshita[2], Yasuhisa Fujita[2], Yukihide Nishimura[5], Hiroshi Yamada[4] and Fumihiro Tajima[2]

Abstract

Background: We hypothesized that 3 weeks of preoperative rehabilitation could improve postoperative pain in patients undergoing total knee arthroplasty (TKA). Aim: This study aimed to evaluate the effects of 3 weeks of preoperative rehabilitation on postoperative pain after TKA.
Methods: This prospective cohort study included 29 subjects (41 knees) divided into two groups: the preoperative rehabilitation group included 14 subjects (20 knees) and the control group included 15 subjects (21 knees). All subjects were scheduled for unilateral or bilateral TKA. The preoperative rehabilitation group completed a 90-min rehabilitation program 3 days per week for 3 weeks before their TKA. The rehabilitation included body weight exercise, resistance exercise, and cycle ergometer exercise. The control group did not undergo any rehabilitation prior to TKA. We assessed the patients using Western Ontario and McMaster Universities' Osteoarthritis Index (WOMAC) and recorded their physical activity of walking, standing, sitting, and lying down at study entry and/or before TKA and 1 month after TKA.
Results: The WOMAC total and WOMAC pain scores were significantly lower after 3-weeks of rehabilitation, but before TKA and 1 month after surgery were significantly lower in the preoperative rehabilitation group than in the control group. The time spent walking, standing, sitting, and lying down for 12 h did not change after TKA in the preoperative rehabilitation group. In contrast, in the control group, the time spent in walking and standing positions decreased and the time in the sitting position increased after TKA ($p < 0.05$). Conclusion: We found that 3-week preoperative training reduced knee pain and helped maintain physical activity after surgery in patients with severe osteoarthritis who underwent TKA.

Keywords

Osteoarthritis, physical activity, preoperative rehabilitation, Western Ontario and McMaster universities osteoarthritis index pain, total knee arthroplasty

[1]Department of Rehabilitation Medicine, Gifu Municipal Hospital, Gifu, Japan
[2]Department of Rehabilitation Medicine, Wakayama Medical University, Wakayama, Japan
[3]Chuzan Hospital Clinical Education and Research Center, Okinawa, Japan
[4]Department of Orthopedic Surgery, Wakayama Medical University, Wakayama, Japan
[5]Department of Rehabilitation Medicine, Iwate Medical University, Morioka, Japan

Corresponding author:
Takahiro Ogawa, Department of Rehabilitation Medicine, Wakayama medical university, Chuzan Hospital Clinical Education and Research Center, 811-1 Kimiidera, Wakayama-shi, Wakayama 641-8509, Japan.
Email: ogawa0417takahiro@yahoo.co.jp

Introduction

Osteoarthritis (OA) is both the most common joint disease worldwide[1] and a major cause of knee pain and disability.[2–4] Knee replacement surgery is highly successful in relieving knee pain and improving knee function in people with advanced arthritis of the joint.[5] However, some patients with OA experience postoperative pain after knee replacement surgery[6,7] which can decrease their activity after surgery and lead to deep vein thrombosis (DVT) and pulmonary embolism (PE).[8] Weakness of the knee extensor muscle is a common finding in patients with OA and is associated with knee pain as well as reduced functional performance and daily activity.[9–11] Several studies have reported the benefits of 4–8 weeks of preoperative rehabilitation before total knee arthroplasty (TKA) including improved knee muscle strength and reduced pre-operative knee pain.[12–16] In addition, postoperative pain was reduced by high-intensity strength training for 8 weeks before TKA.[15] Additionally, a previous study reported that a 3-week resistance training program significantly increased lower body strength in healthy people.[17] Therefore, we hypothesized that 3 weeks of preoperative rehabilitation would improve postoperative pain in patients after TKA. If postoperative pain after TKA was reduced by 3 weeks of preoperative rehabilitation, this rehabilitation regimen could be useful for patients with knee OA because patients would be better able to maintain their activities after TKA and decrease the risk of DVT and PE. To the best of our knowledge, no studies have reported the effects of a 3-week preoperative rehabilitation program before TKA. Therefore, the purpose of this study was to evaluate the effect of 3 weeks of preoperative rehabilitation before TKA on postoperative pain.

Methods

Study design, setting, and participants. This prospective observational cohort study was conducted at the Department of Rehabilitation Medicine and Orthopedics at Wakayama Medical University Hospital between April 2017 and April 2018. In this time, some patients undergoing TKA at this hospital underwent preoperational rehabilitation for functional improvement on the recommendation of an orthopedic surgeon, irrespective of study participation. Patients were divided into two groups based on preoperative rehabilitation: a group who underwent preoperative rehabilitation and a control group without preoperational rehabilitation. All subjects included in this study were older than 50 years of age, diagnosed with advanced idiopathic knee OA (according to the radiological criteria of the American College of Rheumatology Guidelines) and scheduled for unilateral or bilateral TKA. We excluded patients who had active or recently treated infections, who were unable to walk independently, and who had any medical condition which contraindicated exercise. The study protocol was approved by the institutional review board of Wakayama Medical University Hospital (approval ID: 1874). All subjects provided signed informed consent before the commencement of the study.

Patients in the preoperative rehabilitation group completed a rehabilitation program 3 days per week for 3 weeks before TKA. Each training session was 90-min long. The rehabilitation program was designed to increase lower limb muscle strength (Table 1). Each training session was supervised by a physical therapist and started with body weight exercises, including two sets of 20 repetitions of step-ups and calf raises, and five sets of 10 repetitions of wall squats. After body weight exercises, the subjects performed four sets of 30 seconds double leg stance and four sets of 15 seconds single leg stance on the unstable device. The subjects also underwent resistance exercises, including knee extension and hip abduction. The intensity of the exercise was based on the ability of the subject to execute a maximum of 10 repetitions. The systematic review was shown that seven to nine repetitions per set appear to be the training variables that could have the greatest and most rapid effects on improving maximal voluntary strength in healthy old adults.[18] In addition, we referred to the TKA preoperative rehabilitation protocol that has been shown to be effective. The protocol was a maximum of 10 repetitions.[15] The subjects performed five sets of 10 repetitions of each resistance exercise and a cycle ergometer exercise at 60% heart rate reserve for 20 min. The Karvonen formula ((220 − age − resting heart rate) × % intensity + resting heart rate) was used to determine the heart rate to achieve the desired and prescribed intensity. A cycle ergometer was used in TKA preoperative rehabilitation, but the specific intensity was not stated.[15] Therefore, we used the Karvonen formula, which is often used as a protocol for patient rehabilitation.[19] The training session ended with light static stretching of the hip abductors, hip flexors, hip extensors, knee extensors, knee flexors, and ankle plantar flexors. The control group did not undergo any rehabilitation prior to TKA.

All TKAs were performed using the same surgical technique and were conducted by the same group of experienced orthopedic surgeons at our hospital. In all cases, the posterior cruciate ligament was removed, and surgery was performed using a tourniquet. After TKA surgery, all subjects received the same postoperative rehabilitation protocol at the hospital as part of the

Table 1. Preoperative rehabilitation program applied in this study.

Exercise	Description
Body weight exercises	
Step-ups	2 sets of 20 repetitions
Calf raises	2 sets of 20 repetitions
Wall squats	5 sets of 20 repetitions
Double leg stance	4 sets of 30 seconds
Single leg stance	4 sets of 15 seconds
Resistance exercises	
Knee extension	5 sets of 10 repetitions
Hip abduction	5 sets of 10 repetitions
Cycle ergometer exercise	60% heart rate reserve for 20 min
Light static stretching	Hip abductors, hip flexors, hip extensors, knee extensors, knee flexors, and ankle plantar flexors

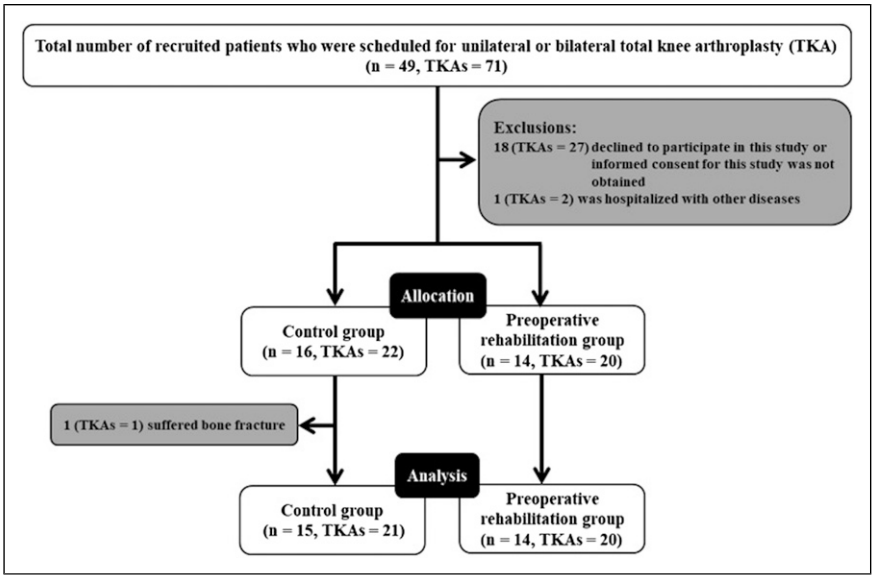

Figure 1. Flow diagram of the progress through the study.

usual clinical care. The postoperative rehabilitation protocol was constructed according to the postoperative rehabilitation protocol shown in previous preoperative rehabilitation studies[15,20] and the study described in TKA postoperative rehabilitation.[21] The subjects started the rehabilitation program within 24–48 hours after surgery. The subjects were mobilized out of the bed during the first rehabilitation. Mobilization (meaning all out-of-bed activities) was conducted and supervised by a physical therapist. Rehabilitation usually involved resistance exercise, stretching exercises, exercises of daily living, aerobic training, and gait training. This postoperative rehabilitation program was performed daily (Monday to Saturday) twice per day during the hospital stay (3–4 weeks), and each session lasted 1 h. Of the 49 subjects screened (71 knees), 29 subjects (41 knees) were included in the study (insert Figure 1). 20 subjects were excluded: 18 because they declined to participate in this study or informed consent for this study was not obtained. Some of them declined because the measurements such as physical activity were complicated. One subject was hospitalized with other diseases, and one subject withdrew from the study after an accident with bone fracture. Finally, the preoperative rehabilitation group included 14 subjects (20 knees), and the control group included 15 subjects (21 knees).

Outcome measures. The timing of the three data assessment tests was as follows: before the first preoperative rehabilitation session, 3 weeks before TKA

(limited to the preoperative rehabilitation group). The second test was performed just before TKA (after completing the 3 weeks of training for the preoperative rehabilitation group). Finally, the third test was performed 1 month after TKA. Each of these assessment tests consisted of assessing the physical activity described below, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), isometric strength (knee extension), and passive knee range of motion assessment (flexion and extension). Each measured parameter was evaluated by a team of skilled physical therapists.

Physical activity. Physical activity during daily living was quantified non-invasively using a triaxial accelerometer (KSN-200; KISSEI COMTEC, Nagano, Japan). This device includes five sensors (each with a diameter of 27 mm × a thickness of 9.1 mm). The sensors measure the angles and acceleration of body segments in two orthogonal directions. The activity monitor classifies activity according to time spent walking, standing, sitting, and lying down. One sensor was placed at the midline approximately 2 cm distal to the sternal notch, another on the anterior surface of each lower thigh at the mid-tibia level, and one was placed on the anterior surface of each thigh at the mid-femur level. The sensors were secured to the skin with hypoallergenic adhesive tape. The subjects were instructed to wear the monitor for 12 hours while awake, except when they had to take a shower or bath. They were allowed to exercise and were encouraged to conduct their daily routine activities. The recorded data were uploaded to a personal computer after each test.

Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). The WOMAC was administered during interviews. WOMAC is a commonly used measure of related quality of life (QOL) in patients with OA. It is a 24-item, self-administered questionnaire divided into subscales for pain (5 items), joint stiffness (2 items), and physical function (17 items).[22] It is rated on a 5-point Likert scale (0–4), with higher scores indicating lower symptoms or disability levels. The instrument is scored by summing each subscale and computing the total score.

Isometric strength with a dynamometer. The isometric strength of the knee extensors was measured using a portable handheld dynamometer (μTas F-1; Anima, Tokyo, Japan). To measure the maximal isometric knee extension strength, subjects were seated with 90° hip flexion and knee flexion. The subjects were instructed to remain seated in an upright position and place both hands on their upper legs to avoid compensation. An ankle pad was placed 3 cm proximal to the medial malleolus. The subjects were instructed to contract their quadriceps as forcefully as possible, pushing their legs against the pad. The dynamometer was positioned perpendicular to the tibia and fixed with a belt to the plinth. All subjects repeated isometric maximal voluntary contractions twice. The trial with the higher score was selected for analysis. Peak torque values were normalized to body weight and reported as Nm/kg. Dynamometry is considered the gold standard for muscle strength assessment, and dynamometry tests of knee extensor muscles in knee OA have proven to be a reliable metric.[23,24]

Passive knee range of motion (ROM). Passive knee joint flexion and extension ROM of the affected knee were measured using goniometry. The subjects were placed in a supine position and the fulcrum of the goniometer was placed over the lateral epicondyle with a 30-cm arm pointing toward the major trochanter of the femur and the other toward the lateral malleolus. This is a reliable method that has been found to be valid for subjects with knee ROM restrictions.[25]

Statistical analysis. The WOMAC scores in a previous study had a standard deviation of 11.[26] We calculated a sample size assuming the difference between the means of the two groups was 10. A sample size of 20 knees before TKA in each group was needed to reject the null hypothesis with a statistical power of 80 % and a significance level of $p < 0.05$.

Differences between the groups in age, height, weight, and body mass index (BMI) were tested using the unpaired t-test. The x^2 test was used to examine differences in the side, gender, and Kellgren-Lawrence scale grades. Changes in physical activity, WOMAC, isometric strength of knee extensors, and passive knee ROM between the two groups were evaluated using the Mann–Whitney U test. The Friedman test was used to examine differences in WOMAC, passive knee ROM, and physical activity during each time duration, followed by the Dunn test as a post hoc test. We used the Wilcoxon signed-rank test to determine the differences between before TKA and 1 month after surgery in the control group. Age, height, weight, and BMI were expressed as the mean ± SD (Table 2). The WOMAC, physical measures, and physical activity are expressed as mean ± SD (Tables 3–5). Differences were considered statistically significant at $p < 0.05$. All statistical analyses were conducted using GraphPad Prism 6 software (GraphPad Software Inc., CA).

Results

The demographics of the subjects are summarized in Table 2.

There were no significant differences between the groups. Passive knee ROM flexion and extension were

Table 2. Demographics of the sample population.

	Control (n = 21 TKAs)	Preoperative rehabilitation (n = 20 TKAs)	
Number of patients	15	14	
Age (years)	73.1±6.5	72.6±8.7	$p > 0.05$
Height (cm)	153.7±10.1	153.2±7.2	$p > 0.05$
Weight (kg)	60.2±11.1	60.3±8.8	$p > 0.05$
BMI (kg/m^2)	25.4±3.6	25.6±2.8	$p > 0.05$
Operating site (left/right)	13/8	9/11	$p > 0.05$
Sex (male/female)	6 (40%)/9 (60%)	3 (21%)/11 (79%)	$p > 0.05$
Kellgren-Lawrence scale grades			
III	9	7	$p > 0.05$
IV	12	13	$p > 0.05$

Data are mean±SD.

Table 3. Scores of all physical measures.

Variable	Time of testing	Control (n=21 TKAs)	Preoperative rehabilitation (n=20 TKAs)
ROM flexion (°)	Before preoperative rehabilitation	-	124.9±12.4
	Just before TKA	117.2±16.8	130.4±13.3$^{\#}$†
	1 month after surgery	120.9±6.8	123.6±5.9*
ROM extension (°)	Before preoperative rehabilitation	-	−12.8±4.5
	Just before TKA	−12.8±9.0	−8.1±3.4$^{\#}$†
	1 month after surgery	−5.6±3.9*	−5.8±4.6$^{\#}$
Isometric knee extension (Nm/kg)	Before preoperative rehabilitation	-	0.9±0.4
	Just before TKA	1.0±0.4	1.0±0.4
	1 month after surgery	0.6±0.3*	0.6±0.3*

Data are mean±SD.
*$p < 0.05$, compared with just before TKA in the same group.
$^{\#}p < 0.05$, compared with before preoperative rehabilitation in the same group.
†$p < 0.05$, compared with the control group.

Table 4. Scores of all questionnaires.

Variable	Time of testing	Control (n=21 TKAs)	Preoperative rehabilitation (n=20 TKAs)
WOMAC total	Before preoperative rehabilitation	-	41.5±13.7
	Just before TKA	47.9±20.2	34.9±11.1$^{\#}$†
	1 month after surgery	31.7±14.0*	23.6±10.2*$^{\#}$†
WOMAC pain	Before preoperative rehabilitation	-	9.3±4.2
	Just before TKA	10.4±3.4	8.0±2.8†
	1 month after surgery	6.9±2.4*	4.8±2.2*$^{\#}$†
WOMAC stiffness	Before preoperative rehabilitation	-	3.6±2.0
	Just before TKA	5.0±1.5	3.2±2.0†
	1 month after surgery	3.1±1.2*	2.6±1.4
WOMAC functional	Before preoperative rehabilitation	-	28.7±11.3
	Just before TKA	32.5±16.3	23.7±9.0
	1 month after surgery	21.8±11.6*	16.2±9.9*$^{\#}$

Data are mean±SD.
*$p < 0.05$, compared with just before TKA in the same group.
$^{\#}p < 0.05$, compared with before preoperative rehabilitation in the same group.
†$p < 0.05$, compared with the control group.

Table 5. Scores of all physical activity.

Variable	Time of testing	Control (n=15 TKAs)	Preoperative rehabilitation (n=14 TKAs)
Walking time (min)	Before preoperative rehabilitation	-	228.7±109.6
	Just before TKA	221.3±114.7	234.1±111.6
	1 month after surgery	144.5±82.0*	204.3±95.9
Standing time (min)	Before preoperative rehabilitation	-	26.5±17.2
	Just before TKA	48.6±47.5	31.0±22.2
	1 month after surgery	27.0±24.7*	30.1±23.7
Sitting time (min)	Before preoperative rehabilitation	-	340.1±117.5
	Just before TKA	338.4±113.9	341.3±154.0
	1 month after surgery	412.4±95.4*	363.5±89.2
Lying time (min)	Before preoperative rehabilitation	-	121.6±104.5
	Just before TKA	97.4±94.0	105.2±115.2
	1 month after surgery	120.4±96.2	114.4±86.3

Data are mean±SD.
*$p < 0.05$, compared with just before TKA in the same group.

significantly different before and after 3-weeks of preoperative rehabilitation and just before TKA in the preoperative rehabilitation group (Table 3).

The passive knee ROM just before TKA was significantly better in the preoperative rehabilitation group compared to the control group. The questionnaire data from the WOMAC are displayed in Table 4. The WOMAC total showed significant improvement between the assessments conducted before preoperative rehabilitation and just before TKA in the preoperative rehabilitation group (Table 4). The WOMAC total and WOMAC pain scores just before TKA and 1 month after surgery were significantly lower in the preoperative rehabilitation group than in the control group (Table 4). The effect sizes of WOMAC pain just before TKA and 1 month after surgery were 0.771 and 0.913, respectively. These results seemed to be large by Cohen's[27] guideline.

Physical activity is displayed in Table 5. The time spent walking, standing, sitting, and lying down for 12 h did not change after TKA in the preoperative rehabilitation group. In contrast, the time the control group spent in walking and standing positions decreased and time in the sitting position increased after TKA ($p < 0.05$) (Table 5). Physical activity was not significantly different between the two groups.

Discussion

The purpose of this study was to evaluate the association between 3 weeks of preoperative rehabilitation before TKA and postoperative pain following TKA. The two major findings of this study were: *1)* WOMAC pain scores before surgery and 1 month after surgery were significantly lower in the preoperative rehabilitation group than in the control group. *2)* The post-TKA activity level did not change in patients in the preoperative rehabilitation group, whereas it decreased in the control group. These findings suggest that preoperative rehabilitation reduces postoperative knee pain and does not attenuate daily activities.

WOMAC pain scores before surgery and 1 month after surgery were significantly lower in the preoperative rehabilitation group than in the control group. Previous preoperative studies reported no differences in knee pain reduction between groups[20,28–31]; however, our 3-week preoperative rehabilitation regimen induced significant reductions in knee pain. While previous studies have shown that knee pain is related to muscle strength,[5,32] our findings showed no improvement in isometric strength of the knee extensors. Thus, we assume that muscle strength did not directly contribute to the reduction in knee pain. Previous studies have suggested that exercise suppresses inflammatory response.[33,34] Myokine elevation from skeletal muscle after exercise may be related to the attenuation of inflammatory response.[34,35] In this study, the rehabilitation program was designed to train the lower limb. Therefore, this rehabilitation program for knee function might be effective in producing myokines from the muscles of the large lower limbs. Accordingly, it is possible that our 3-week preoperative rehabilitation program played a role in the suppression of the inflammatory response. Furthermore, in the preoperative rehabilitation group, knee pain improved both before and 1 month after surgery. Preoperative rehabilitation for 3-weeks might attenuate the inflammatory response before surgery and reduce knee pain 1 month after surgery due to the effects of preoperative rehabilitation and TKA.

The physical activity of patients undergoing TKA can be improved. However, there are no reports on the

changes in the physical activity of patients who undergo preoperative exercise training. To our knowledge, this is the first study to analyze the amount of physical activity done by patients who underwent preoperative exercise training. In the preoperative rehabilitation group, the time spent walking, standing, sitting, and lying down did not change after TKA. In the control group, after TKA the time spent walking and standing decreased, and that spent sitting increased. In other words, the activity levels decreased after TKA in the control patients, but not in those who received preoperative rehabilitation. Previous studies have shown that knee pain is related to physical activity.[10,11] The study reported the origin of pain is inflammation and the inflammatory response.[36] Previous studies have suggested that exercise suppresses inflammatory response.[33,34] In this study, preoperative rehabilitation exercise may have reduced inflammation, which may have reduced pain. On the other hand, pain scores might be significantly lower in the preoperative rehabilitation group than in the control group due to the lack of effect of suppressing inflammation caused by exercise. Our study suggests that the ability to maintain the same physical activity in the preoperative rehabilitation group may be related to reduced knee pain.

The present study demonstrated that 3 weeks of training effectively improved ROM, WOMAC total, and WOMAC functional scores. Previous studies have described the application of a preoperative training period of 4–8 weeks.[12-16] In our study, the preoperative rehabilitation group completed the rehabilitation program 3 days per week for 3 weeks before surgery demonstrating the effectiveness of this shorter program in improving various functional parameters. Therefore, it may be effective for patients' QOL and knee pain to train mainly on the lower limbs for 3 weeks.

Our preoperative rehabilitation program may be beneficial since exercise-based programs are efficacious in reducing knee pain, increasing functional performance, improving QOL, and maintaining physical activity.[8,37,38] Previous studies have reported that physical activity is related to the incidence of early loosening.[37] Other studies have concluded that low physical activity was associated with lower muscle strength[11] and that physical activity is a significant factor that protects against poor function.[38] Based on these findings, this preoperative rehabilitation regimen can potentially prevent postoperative complications and maintain long-term function.

Study limitations

The present study has some limitations. First, there was no difference in physical activity between the two groups, although there was a significant difference within each group. Further research is required in this regard. Second, physical activity on the recorded days might not always reflect typical days. Patients participating in a research study on physical activity could change their normal behavior, and the obtained measurements might not always reflect their actual activity. However, all subjects were instructed to wear the monitor for 12 h while awake; accordingly, we believe that this method recorded almost all physical activities. Other factors, such as dosing, may be considered for physical activity. Future studies should assess other factors. In addition, we think it is necessary to carry out highly accurate research such as RCT in the future.

Conclusions

The present study examined the effects of 3 weeks of preoperative training on the lower limbs in patients with severe OA. After preoperative training, knee pain in patients with OA was reduced both before surgery and 1 month after surgery. The post-TKA activity level did not change in patients in the preoperative rehabilitation group, but decreased in the control group. Therefore, this rehabilitation program for knee function might be effective in reducing postoperative knee pain and maintaining physical activity.

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ORCID iD

Takahiro Ogawa https://orcid.org/0000-0003-4775-5649

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